Implementing Strategies of Biorefineries in the BioEconomy

The Approach of Life Cycle Sustainability Assessment of Biorefineries
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Most Sustainable Use of Wood?

- Power
- Heat
- Paper
- Transportation
- Chemicals
- Products

Most sustainable option?
“There is no scientific evidence that the material use of biomass provides greater sustainability benefits than the energetic use, or vice versa.

BUT there is evidence that the combined energetic and material use ("biorefining") of biomass has the potential for large sustainability benefits.”
Biorefinery is the sustainable processing of biomass into a spectrum of marketable products.

**Bioenergy**
- liquid/gaseous transport biofuels
- electricity
- heat
- solid fuels

**Bioproducts**
- bulk chemicals
- fine chemicals
- animal feed
- food
- pulp & paper
- materials
- fertilizer
- gases
- ....

Based on different conversion processes:
- Bio-chemical
- Thermo-chemical
- Physical-chemical
- Others

**Biomass Resources**
- oil
- starch
- sugar
- lignocellulose
- ....
Sustainability in the Life Cycle based on Whole Value Chain

Resources & raw materials

Environment

Economy

Society

Products & services

THE INNOVATION COMPANY
The Methods of Sustainability Assessment

Life Cycle Sustainability Assessment (LCSA)

- **Environment**
  - LCA – Life Cycle Assessment
- **Economy**
  - LCC – Life Cycle Costing
- **Society**
  - sLCA – Social Life Cycle Assessment
  - SIA – Social Impact Assessment

*Environmental, economic and social assessment of sustainability based on scientific indicators*
What are the „Conventional Systems“ for Comparison?

**Biorefinery System**
- Biomass Feedstock
  - Transport Conversion Distribution
  - Bioenergy & biomaterials

**Conventional Systems**

**Bioenergy and Fossil System**
- Biomass Feedstock
  - Transport Conversion Distribution
  - Bioenergy & biomaterials

**Fossil System**
- Fossil Ressource
  - Transport Conversion Distribution
  - Energy & materials

**Product services**
1) Biorefinery classification scheme with description most relevant technical characteristics

2) Assessment of the technologies and processes using "Technology Readiness Level (TRL)" and "Biorefinery Complexity Index (BCI)."

3) Calculation of most relevant economic data using the approach of Life Cycle Costing (LCC).

4) Application of Life Cycle Assessment (LCA) to assess the most relevant environmental aspects.

5) Screening of relevant social issues in a Social Life Cycle Assessment (sLCA).

6) Life Cycle Sustainability Assessment (LCSA) assessing environmental, economic and social issues.

7) Integration of biorefineries in existing industrial infrastructure.

"BioRefinery Fact Sheet" to provide facts & figures to pave the way to BioEconomy.
Initial Selection of Sustainability Indicators in LCSA

Environment
- GHG emissions (t CO$_2$-eq/a)
- Primary energy demand (GJ/a) (biomass, renewable, fossil, others)
- Area demand (ha/a)

Economy
- Production costs (€/a)
- Revenues from products (€/a)
- Value added (€/a)
- Employment (persons/a)
- Trade balance (€/a)

Society
- Workers
- Consumers
- Local community
- Society
- Value chain actors (excl. consumers)
What are the **facts & figures** of different biorefineries?

Look here, you find **facts & figures** in our Biorefinery Fact Sheet.
Overview - Biorefinery Fact Sheet (1.0)

Part A: Biorefinery Plant

Part B: Value Chain

Assessment

Annex:

Methodology of sustainability assessment and data with references

NEW Version (2.0)

additional page with

✓ 4 macro-economic indicators
✓ „hot spots“ for 4 social indicators

made by „Biorefinery Fact Sheet Calculator“ of JOANNEUM RESEARCH
Part A: Biorefinery Plant - Classification Scheme

2-platform (oil, hydrogen) biorefinery using algae for HVO-Biofuel, PUFA and fertilizer

CO₂ conditioning ➔ Cultivation ➔ Drying & extraction ➔ Pretreatment ➔ Oil ➔ Fractionation ➔ Hydrotreatment ➔ Hydrogen ➔ Hydrogen production ➔ Nutrient recovery

PUFA ➔ HVO-Biofuel ➔ Fertilizer

Other resources ➔ Conversion ➔ Electricity and heat (internal use only)
2-platform (oil, hydrogen) biorefinery using algae for HVO-biofuel, PUFA and fertilizer

Biorefinery Complexity Index is indicator for TRL of each features and integrated system
Part A: Biorefinery Plant - Share of Costs & Revenues

2-platform (oil, hydrogen) biorefinery using algae for HVO-Biofuel, PUFA and fertilizer

**Costs**
- aux. energy, 0.8%
- aux. materials, 2.8%
- maintenance, 22.7%
- insurance, 7.6%
- personal, 2.0%
- capital, 64.2%

**Revenues**
- fertilizer from algae, 1%
- PUFA, 14%
- HVO-Hydrated vegetable oil, 86%

**Framework:**
- Algae yield: 70 t/(ha*a)
- HVO: 100 kt/a

**Investment Revenue:**
- PUFA: 10,000 €/t
- HVO: 1,250 €/t
- 1,000 Mio €
2-platform (oil, hydrogen) biorefinery using algae for HVO-Biofuel, PUFA and fertilizer

2,000 jobs

- direct jobs: 17%
- indirect jobs: 83%

Based on socio-economic input/output model

NEW Version (2.0)
- additional page
- 4 macro-economic indicators
- "hot spots" for 4 social indicators
A 2-platform (oil, hydrogen) biorefinery using algae for HVO-biofuel, PUFA and fertilizer

**Conventional Reference System**

- **Extraction**
  - Diesel
  - Set aside

- **Refinery**
  - Fertilizer
  - PUFA

- **Transport**
  - Fish Farming
  - PUFA

- **Fertilizer Production**
  - Fish Farming

- **Fossil Resource**

**Land for aquaculture**

- **Cultivation Algae**
  - Biorefinery
    - HVO-Biofuel
    - PUFA
    - Fertilizer

- **Distribution**
  - Recycling/energy generation*)
  - Use

*) Recycling/energy generation
**Part B: Value Chain Assessment - Overview**

*2-platform (oil, hydrogen) biorefinery using algae for HVO-Biofuel, PUFA and fertilizer*

<table>
<thead>
<tr>
<th>Whole value chain</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Greenhouse gas emissions</strong></td>
<td><strong>range</strong></td>
</tr>
<tr>
<td>biorefinery</td>
<td>41 (39 to 48) [kt CO$_2$-eq/a]</td>
</tr>
<tr>
<td>reference system</td>
<td>454 (420 to 520) [kt CO$_2$-eq/a]</td>
</tr>
<tr>
<td>saving</td>
<td>-91% (-85% to -95%) [%]</td>
</tr>
<tr>
<td><strong>Cumulated energy demand</strong></td>
<td><strong>fossil</strong></td>
</tr>
<tr>
<td>biorefinery</td>
<td>0.5 (0.47 to 0.59) [PJ/a]</td>
</tr>
<tr>
<td>reference system</td>
<td>6.0 (5.6 to 6.9) [PJ/a]</td>
</tr>
<tr>
<td>saving</td>
<td>-91% (-85% to -95%) [%]</td>
</tr>
<tr>
<td>total</td>
<td>13.8 (13 to 16) [PJ/a]</td>
</tr>
<tr>
<td>change</td>
<td>119% (110% to 136%) [%]</td>
</tr>
<tr>
<td><strong>Area demand for aquaculture</strong></td>
<td><strong>feedstock</strong></td>
</tr>
<tr>
<td></td>
<td>7,900 (7300 to 9000) [ha/a]</td>
</tr>
<tr>
<td><strong>Costs</strong></td>
<td><strong>annual costs</strong></td>
</tr>
<tr>
<td></td>
<td>132 (120 to 150) [Mio €/a]</td>
</tr>
<tr>
<td>specific costs</td>
<td>871 (810 to 1000) [€/t]</td>
</tr>
<tr>
<td><strong>Revenues</strong></td>
<td><strong>annual revenues</strong></td>
</tr>
<tr>
<td></td>
<td>146 (140 to 170) [Mio €/a]</td>
</tr>
<tr>
<td>specific revenues</td>
<td>961 (890 to 1100) [€/t]</td>
</tr>
</tbody>
</table>

Communication in typical ranges & orders of magnitude!
Part B: Value Chain Assessment – Energy & Emissions

2-platform (oil, hydrogen) biorefinery using algae for HVO-Biofuel, PUFA and fertilizer

GHG reduction:
Primary energy 85 – 95%

Total increase: 110 – 136%

Fossil reduction: 85 – 95%
Part B: Value Chain Assessment - Cost & Revenues

2-platform (oil, hydrogen) biorefinery using algae for HVO-Biofuel, PUFA and fertilizer

Costs [Mio. €/a]:
- (120 - 150)
- 132

Revenues:
- (140 - 170)
- 146
Part B: Value Chain Assessment – Macro-economic Indicators (2.0)

2-platform (oil, hydrogen) biorefinery using algae for HVO-Biofuel, PUFA and fertilizer

Value added

Based on socio-economic input/output model

Employment
Part B: Value Chain Assessment – Social indicators (2.0)

2-platform (oil, hydrogen) biorefinery using algae for HVO-Biofuel, PUFA and fertilizer

Process steps with relevant social issues:
- Cultivation algae
- Lipid extraction
- Hydrogen production

“Hot spots”:
- Differences Europe – Outside Europe
- Area demand is a big issue/criteria
27 Biorefinery Fact Sheets are available

- 15 public online on webpage
  - 2 Austrian Cases
    - Biorefinery Pöls AG (Steiermark)
    - Biorefinery BioCRACK (Schwechat)
  - 5 Glossy Biorefinery Fact Sheets

- 5 non public

- 7 in progress (e.g. biogas, pyrolysis, protein, rubber dandelion, algae)

- New case studies: data collection
Conclusions: The Assessment Framework

Assisting stakeholders in finding a position on biorefining in a biobased economy

Biorefinery Fact Sheet gives facts & figures on biorefinery plant in whole value chain assessment

10 sustainability indicators (broadly agreed) for comparison to reference system

Life Cycle based Sustainability Assessment with LCSA - environment (LCA), economy (LCC), society (sLCA/SIA)

Biorefinery Complexity Index (BCI) as indicator for the overall complexity and development status of a biorefinery

Technology: Description and assessment of Technology Readiness Level (TRL) for involved process technologies & features

Classification of biorefineries via 4 features: platforms, products, feedstocks, processes
www.iea-bioenergy.task42-biorefineries.com
www.fuel4me.eu

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