System analysis of green biorefinery

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The main challenges related to green biorefinery system analysis from an environmental point of view

- Many interacting and complex value chains
- Many by-products some with multiple application options
- Many (relevant) environmental impacts
- Few and fragmented (inventory) data
- Temporal and site specific dependent system performance (i.e. results presented here are valid for DK)
Life Cycle Assessment – A suited environmental assessment methodology

LCA has several advantages:

- Designed for value chain assessment
- Many existing data
- Covers many (18+) environmental impact categories (i.e. not only global warming)
- Well described/documente and ISO standardized
- Can handle by-products (in two different ways)
- Can handled product substitution (i.e. crediting of impacts)

Source: ISO 14040:2006 modified by MORB

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Life Cycle Assessment – Long story short

1. Model the system
2. Quantify exchanges
3. Quantify exchanges
4. Repeat until satisfactory

Impact assessment

Environmental profile of scenarios

- Global warming
- Acidification
- Photochemical ozone formation
- Nutrient enrichment
- Human toxicity
- Ecotoxicity
- Land use
- Volume waste
- Hazardous waste

Analysed system (life cycle)

Product system modelling

1. Model the system
2. Quantify exchanges
3. Quantify exchanges
4. Repeat until satisfactory
The “universal” LCA algorithm for bio-refining

Green Biomass $\rightarrow$ [Diagram]

$E_{I_{tot}} = E_{I_{agr}} + E_{I_{GBR}} - E_{I_{conv}}$

Source: Corona et al. (2018)
# Comparing systems/feedstocks

<table>
<thead>
<tr>
<th>Agricultural Stage</th>
<th>Biorefinery</th>
<th>Avoided Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>Coagulation</td>
<td>Protein Concentrate</td>
</tr>
<tr>
<td>Clovergrass</td>
<td>Separation</td>
<td>Soybean Meal</td>
</tr>
<tr>
<td>Festuclum</td>
<td>Protein Drying</td>
<td>Electricity</td>
</tr>
<tr>
<td>Ryegrass</td>
<td>Juice</td>
<td>Electrolyte Fuel</td>
</tr>
</tbody>
</table>

Source: Corona et al. (2018)

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Decision support – feedstock selection

Source: Corona et al. (2018)
Decision support – feedstock selection

Global Warming Potential

Eutrophication Potential

Potential Freshwater Ecotoxicity

Non-Renewable Energy Use

Source: Corona et al. (2018)
Decission support - GBR hotspot analysis (ryegrass)

Hotspot Analysis GBR [NRE]

Source: Corona et al. (2018)
Scenario analysis (ryegrass)

Scenario Analysis [NRE]

- Baseline
- Biogas
- Woodchips
- 2035
- 2050

Source: Corona et al. (2018)
Combined PFS and LCA applied for TEA
Combined PFS and LCA applied for TEA

Techno-environmental assessment (TEA) of green biorefining based on alfalfa as feedstock:

- The basic concept of the assessment was to quantify the environmental performance of the technical combinations:
  - 1 or 2 step pressing combined with
  - Thermal or biological precipitation techniques combined with
  - Separation in either 1 or 2 steps combined with
  - 3 different utilizations of the solid fraction (feed, fermentation or composite)
- Default (inventory) data provided were too inaccurate/generalized to be applied for a detailed assessment and generation of more specific precise data was conducted using Process Flowsheet Simulation (PFS)
The application of TEA based on LCA for deeper analysis of specific scenarios, allows for:

- Environmental comparison of various treatment techniques and utilization options
- Environmental contribution analysis of specific scenarios, allowing for comparison of optimization options for the scenarios
- Identification of influencing parameters/factors

Source: Corona et al. (2018)
Summary - System analysis of green biorefinery

Basic application of LCA for e.g. hotspot analysis allows for:
• Environmental comparison of various feedstocks
• Identification of environmental hotspots in selected value chains

Deeper analysis of green biorefining value chains is in general hindered by lack of precise data on refining processes/technologies. The lack of data can be compensated for via PFS.

TEA based on LCA allows for:
• Comparison of various refining techniques/ sequence and utilization of the residual resources
• Detailed contribution analysis across multiple impact categories
• Identification of impact influencing factors/parameters
• Prospective decision support taking future systems changes into account
Environmental screening of potential biomass for green biorefinery conversion

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ABSTRACT
Green Biorefinery (GBR) is a new biorefinery technology for the conversion of fresh biomass to value added products. In the present study, we combined a Process Flow Sheet Simulation (PFS) and Life Cycle Assessment (LCA) of a small scale decentralized GBR to screen environmental impact profiles for potential biomass feedstocks for GBR conversion. Furthermore, we carried out hotspot and sensitivity analysis to identify where the largest impacts arise in the biorefining stage in order to provide recommendations and focus points for GBR technology development. The GBR considered in this study produces a protein-rich feed for monogastric animals and an energy-rich feed from the protein pulp and lignins from the GBR residues. The included biomass feedstocks are: alfalfa, greenhouse-grown rape, corn stover, and switchgrass. These biomass were selected to accommodate variations in central biomass characteristics like: crop yield, rate of fertilization application, chemical biomass composition, and related potential environmental implications. Among the studied crops, alfalfa provides the best overall environmental performance due to its high yield and low agricultural input demands. Results of the hotspot analysis further identified the cogeneration and the drying as the processes that induce most of the environmental impacts in the biorefining stage. Conversion of green biomass for the production of feed and energy could provide environmental benefits compared to the production of conventional feed. However, the GBR technology still needs for optimization in order to further reduce the environmental impacts, across all impact categories, by decreasing energy consumption and increasing conversion efficiency.