Integrated Life Cycle Sustainability Assessment of 2nd generation bio-refineries produced fumaric acid for downstream production of bio-plastics

Michael Bruns
Marten Stock
Andreas Genest (a.genest@ifu.com)
AvniR 2016, October 8th, Lille
Agenda

• Project: BioREFINE-2G

• Life Cycle Sustainability Assessment (LCSA)
  • Life Cycle Assessment (LCA)
  • Life Cycle Costing (LCC)
  • Social Life Cycle Assessment (SLCA)

• Conclusions
• Outlook: Further Steps
Project Aims

- To produce at least one dicarboxylic acid in 2nd generation biorefineries
- To develop downstream processing methods to **purify** diacids from the fermentation broth at purities required for polymerization
- To develop methods for **polymerization** of the selected diacids to bio-based polymers
- To **demonstrate and verify** the fermentation process of diacid production in a several thousand liter-scale demo plant
- To **evaluate the impact of biopolymers produced through the BioREFINE-2G project through Life Cycle Sustainability Assessment (LCSA)**
LCSA – Why and How?

Figure: UNEP/SETAC Life Cycle Initiative (2011)

Figure: UNEP/SETAC Life Cycle Initiative (2009)
Setup of LCA Model

Figure: ifu (2016)
Environmental Impact – GWP 100
LCA Results

Figure: Scenarios on production of fumaric acid.. LCIA method ReCiPe Midpoint (H) w/o LT .ifu (2016)

<table>
<thead>
<tr>
<th></th>
<th>conv. 2 %</th>
<th>10 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>medium</td>
<td>Scenario 1</td>
<td>Scenario 4</td>
</tr>
<tr>
<td>old</td>
<td>Scenario 2</td>
<td>Scenario 3</td>
</tr>
<tr>
<td>new</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
LCA Summary

• Process development ongoing → high uncertainty
• Comparison process
• Ongoing work with Project Partners and adjustment of process

• Experience I: Process steps do not fit together
• Experience II: Detailed process analysis revealed optimization potentials
## Eco-Efficiency Portfolio

<table>
<thead>
<tr>
<th></th>
<th>Fumaric acid</th>
<th>Succinic acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>GWP (kg CO2 eq/kg)</td>
<td>20.309</td>
<td>2.929</td>
</tr>
<tr>
<td>production cost per unit [€/kg]</td>
<td>6.16</td>
<td>1.638</td>
</tr>
<tr>
<td>market price [€/kg]</td>
<td>12.5</td>
<td>7.5</td>
</tr>
<tr>
<td>marginal return [€/kg]</td>
<td>6.35</td>
<td>5.86</td>
</tr>
</tbody>
</table>

### Graph

**Graph:**
- **X-axis:** Production costs / kg
- **Y-axis:** kg CO2-eq/kg
- **Legend:**
  - Blue circle: Succinic acid
  - Orange circle: Fumaric acid

37% due to Input Material „debarked wood“
<table>
<thead>
<tr>
<th>Stakeholder categories</th>
<th>Impact categories</th>
<th>Subcategories</th>
<th>Inv. indicators</th>
<th>Inventory data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workers</td>
<td>Human rights</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local community</td>
<td>Working conditions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Society</td>
<td>Health and safety</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consumers</td>
<td>Cultural heritage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value chain actors</td>
<td>Governance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Socio-economic repercussions</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
S-LCA

- Data
  - Questionnaire
  - Literature research
  - Database

- Database: Social Hotspot Database
  - Values for UNEP Subcategories
  - Product Category
  - Country of Origin

- Approaches vary
Figure: ifu (2016). Screenshot SLCA, Consumer, Norway

Green – no evidence
Yellow – low risk
Orange – medium risk
Red – High risk
Grey – no data
S-LCA – Closer Look

Figure: ifu (2016). Screenshot SLCA, Consumer, Norway

Green – no evidence
Yellow – low risk
Orange – medium risk
Red – High risk
Grey – no data
Figure: ifu (2016). Screenshot SLCA, Local Community, Brasil

**Green** – no evidence

**Yellow** – low risk

**Orange** – medium risk

**Red** – High risk

**Grey** – no data
Figure: ifu (2016). Screenshot SLCA, Workers, Brasil

- Green – no evidence
- Yellow – low risk
- Orange – medium risk
- Red – High risk
- Grey – no data
S-LCA Summary

• Integration of S-LCA into original LCA model possible

• Visualization of results can point out hotspots

• We chose not to continue towards quantitative indicators

• Within bioREFINE-2G: no established supply chain
Conclusions

• LCSA: three dimensions in one model is possible

• Different system boundaries are applied for LCA, LCC, S-LCA

• LCSA has been a catalyst for ongoing discussions and thus led to improved communication within the project. The final project outcomes will benefit from this process.
Outlook

• Further Refinement of all models

• Regionalized impact Assessment

• Anticipated highlight: Data Collection at BioRefinery

• Project Consortium looking for opportunity for further collaboration

• Project Consortium has grown confident in asking life-cycle-related questions
Thank you very much for listening! Do you have questions?

Andreas Genest (a.genest@ifu.com)
www.ifu.com

www.biorefine2g.eu/
LCA Results log

- Scenario 0
- Scenario 1
- Scenario 2
- Scenario 3
- Scenario 4

- agricultural land occupation
- water depletion
- urban land occupation
- terrestrial acidification, TAP100
- photochemical oxidant formation
- particulate matter formation
- ozone depletion
- climate change, GWP100
- fossil depletion
- freshwater eutrophication
- ionising radiation
- natural land transformation
- terrestrial acidification, TAP100
- urban land occupation
- photochemical oxidant formation
- particulate matter formation
- ozone depletion
- climate change, GWP100
- fossil depletion
- freshwater eutrophication
- ionising radiation
- natural land transformation