Results 2 - MCDA
Assessment tools for sustainability monitoring of bioeconomy networks

Jakob Hildebrandt, M.Sc. in International Material Flow Management
1. Motivation (I): Cross-sectoral cooperation with in a bioeconomy region

Source. Bioeconomy e.V. bioeconomy.de
1. Motivation (II): Integration of energy and material flows along value chains

TG 1: Production and material utilization of non-food biomass (wood production, logistics and manufacturing; innovative timber construction)

TG 2: Production of base chemicals from non-food biomass

Material flows: Wood, Residues

Flows: Ethylene, Hydrogen, Aromats, ....

Residue streams

Energy

Energetic optimization of processes

TG 3: Polymers, materials and products from biomass

Flows: e.g. Biophenol derivates, wood fibre

Energy

Residue streams

TG 4: Energetic utilization and optimization in the context of the overall cascading value chain

TG 5: Management of the BioEconomy

TG 6: Education for the BioEconomy

Parameters, methods, optimization

Source: Cluster BioEconomy
1. Motivation (III): Levering sustainability potentials of bio-based products before entering the market

**Product group 1: Engineered wood products**

Products:
- Laminated veneer lumber
- Glulam timber
- Cross-laminated timber
- Wood fibre boards

**Product group 2: Wood-based platform chemicals and polymers**

Products:
- Lignin-based Foams
- Lignin-based Resins
- Cellulose-based Olephines
- Other bio-based polymers (e.g. PLA)

**Product group 3: Wood-based composites**

Products:
- Composite materials (structural elements)
- Wood-Plastic-Composites (non-structural elements)
1. Background (III)

Accompanying Research

Marketing & Innovation

Material Flow Management
- Process modelling and evaluation
- Life Cycle Assessment (LCA)
- Social LCA and Life Cycle Costing
- Sustainability monitoring

Surroundings
- Producer
- Process/Equipment

Governance
- Management strategies for cluster development
- Framework for innovation
- Governance analysis
- Scenario analysis
- Monitoring of cluster acceptance
- Potential analysis for innovation and start-ups

Quality management
Supply Chain Management
Market potential and positioning analysis

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2. Goal and Scope (I):

**Goal:**
- Development of a monitoring system for portfolio management with selected key performance indicators
- Establishment of a sustainability index for value-added networks within a bioeconomy region
- Identification of trade-offs between decision alternatives

**Operationalization:**
- Collecting Life Cycle inventory data for socio-economic and environmental assessment of selected production chains
- Early identification of chances & risks (Hotspots) for development towards sustainable production and consumption

\[ \text{∑ Sustainability-Index} \]
SUMINISTRO – Sustainability monitoring Index for assessing regional bio-based industry networks

### Main features

<table>
<thead>
<tr>
<th>Implementation planning</th>
<th>Utility Functions:</th>
<th>Weighting of Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined monitoring (Ex-Post) and ex-ante evaluation</td>
<td>Combined indicator calibration through pair-wise comparisons or utility functions</td>
<td>Participative goal definition and indicator weighing</td>
</tr>
<tr>
<td>Resource constraints can be monitored, considered and managed over time</td>
<td>Integration of benchmarks for Sustainability assessment</td>
<td>Constant adjustment and integration of newly cooperating or conflicting stakeholder groups possible</td>
</tr>
</tbody>
</table>

Software: [D-SIGHT®](#)
3. Materials and Methods (II): Case study system of the Spitzencluster Region (TRL 3 – 9)

Upstream processes: Forest management, Harvesting & Pretreatment

<table>
<thead>
<tr>
<th>Logistics</th>
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<tr>
<td>Buche Volllaum-Ernte</td>
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</table>

Production processes: wood processing, engineered timber production, biorefineries

Energetic utilization of residues

Biorefinery processes

Composite materials

Production of LVL, X-Lam & Glulam

Energetic utilization of residues

Downstream processes: Use phase, Waste treatment, recycling and cascade use

Material recycling / Energetic recovery

Cascade Use

Upscaling of R&D-processes and established production systems
3. Materials and Methods (III): Representative product basket case (TRL 7 - 9)

Input:
630,000 t abs.dry/a

Output:
- Hydrolysis Lignin: 181,500 t/a
- Expanded PLA: 97,000 t/a
- Organosolv Lignin: 62,000 t/a
- Biomethane: 40,000 t/a
- Bark: 80,000 t/a
- Lignin Sandwich: 4,000 t/a
- Cross-laminated timber: 22,500 t/a
- By-products: 7,500 t/a
- Saw logs
- Pulp/fibre wood
- Beech wood

[Diagram showing the flow of materials from input to output]
# Economic benchmarks

<table>
<thead>
<tr>
<th>Economic benchmarks</th>
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<tbody>
<tr>
<td>Eurostat</td>
</tr>
<tr>
<td>UNECE</td>
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<tr>
<td>FAOSTAT</td>
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</tbody>
</table>

# Forestry potentials & sustainability

<table>
<thead>
<tr>
<th>Forestry potentials &amp; sustainability</th>
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<tbody>
<tr>
<td>BUNDESWALDINVENTUR</td>
</tr>
<tr>
<td>Forest Europe growing life</td>
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</tbody>
</table>

# Techn.-econ. data

<table>
<thead>
<tr>
<th>Techn.-econ. data</th>
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<tbody>
<tr>
<td>Kuratorium für Waldverwaltung und Forsttechnik e.V.</td>
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# Socio-econ. data

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<tbody>
<tr>
<td>BG RCI</td>
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<tr>
<td>UNTERNEHMENS-REGISTER</td>
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# Spec. process inventories

<table>
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<tr>
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<tbody>
<tr>
<td>Pollmeier</td>
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<tr>
<td>Fraunhofer</td>
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<td>Fraunhofer</td>
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# Env. product benchmarks

<table>
<thead>
<tr>
<th>Env. product benchmarks</th>
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<tbody>
<tr>
<td>AMERICAN WOOD COUNCIL</td>
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# Env. benchmarks of production sites

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<th>Env. benchmarks of production sites</th>
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<tr>
<td>E-PRTR</td>
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# Techn. process benchmarks

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<tbody>
<tr>
<td>thinkstep GaBi</td>
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<tr>
<td>THÜREN</td>
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<tr>
<td>Ecoflow</td>
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3. Materials and Methods (IV): Data sources along value chains and aggregation levels

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3. Materials and Methods (V): Extracting Life Cycle Impacts from a LCA-Modell of the product basket

Individual product chains vs. Product basket

Life Cycle Impacts

**RESULTS OF THE LCA - ENVIRONMENTAL IMPACT:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>A1-A3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global warming potential</td>
<td>kg CO2-eq</td>
<td>0.024/2.27</td>
</tr>
<tr>
<td>Depletion potential of the stratospheric ozone layer</td>
<td>kg CFC-11-eq</td>
<td>0.014/0.0</td>
</tr>
<tr>
<td>Acidification potential of land and water</td>
<td>kg SO2-eq</td>
<td>0.06/0.04</td>
</tr>
<tr>
<td>Eutrophication potential</td>
<td>kg (PO4)3- - Eq</td>
<td>0.00/0.00</td>
</tr>
<tr>
<td>Neurotoxic potential</td>
<td>kg 1,2,3- Eq</td>
<td>0.00/0.00</td>
</tr>
<tr>
<td>Abiotic depletion potential for non-fossil resources</td>
<td>kg 10 6-eq</td>
<td>0.00/0.00</td>
</tr>
<tr>
<td>Abiotic depletion potential for fossil resources</td>
<td>kg 10 6-eq</td>
<td>0.00/0.00</td>
</tr>
</tbody>
</table>

**RESULTS OF THE LCA - RESOURCE USE:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>A1-A3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renewable primary energy as energy carrier</td>
<td>[MJO]</td>
<td>1.8</td>
</tr>
<tr>
<td>Non-renewable primary energy as energy carrier</td>
<td>[MJO]</td>
<td>37.6</td>
</tr>
<tr>
<td>Use of net fresh water</td>
<td>[m³]</td>
<td>1.66</td>
</tr>
</tbody>
</table>

**RESULTS OF THE LCA - OUTPUT FLOWS AND WASTE CATEGORIES:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>A1-A3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazardous waste disposed</td>
<td>[kg]</td>
<td>0.000000547</td>
</tr>
<tr>
<td>Non-hazardous waste disposed</td>
<td>[kg]</td>
<td>3.780</td>
</tr>
<tr>
<td>Radioactive waste disposed</td>
<td>[kg]</td>
<td>0.00017</td>
</tr>
</tbody>
</table>

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4. Results (I): Varying weighted average of aggregated life cycle impacts

- Cross-laminated Timber Product
- Wood-Fibre Insulation Boards
- Biomethane produced in LC biorefinery
- Natural fibre reinforced composite materials
- PLA products

\[ \varnothing \text{ GWP} = 0.7 \, \text{t CO}_2\text{-equiv.}/\text{t} \]
4. Results (II): Comparative LCA of the regional product basket

Relative advantage of the regional bio-based basket in comparison of CML 2013 Impacts

- MAETP
- ADP fossil
- GWP 100 a
- HTTP
- FAETP
- AP
- POCP
- TETP
- EP
- ODP, catalytic
- ADP elements

ADP elements: Abiotic depletion of elements [kg Sb-equiv.]
EP: Eutrophication potential [kg Phosphat-equiv.]
TETP: Terrestrial ecotoxicity potential [kg DCB-equiv.]
POCP: Photochemical ozone creation potential [kg Ethen-equiv.]
AP: Acidification potential [kg SO2-equiv.]
HTTP: Human toxicity potential [kg DCB-eqiv.]
GWP 100 a: Global warming potential [kg CO2-equiv.]
ADP fossil: Abiotic depletion of fossils [MJ]
MAETP: Marine aquatic ecotoxicity potential [kg DCB-equiv.]
FAETP: Freshwater aquatic ecotoxicity potential [kg DCB-equiv.]
4. Results (III): Comparing cumulated resource use over time, decoupling and limits to growth

- **Use of Natural Gas**
  - Substituting Natural Gas with biogenic heat

- **Saw logs and veneer logs**
4. Results (IV): Benchmarking and definition of utility functions

Individual chains

Min.

Max.

Aggregated networks

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4. Results (V): Keeping indicators and product baskets on track of the radar

- Keeping indicators and product baskets on track of the radar
- 680 kg CO\textsubscript{2}-equiv./t
- 68 % of Biomass-input
- > 40 % Energetic recovery
- > 55 % self-sufficient heat supply
- high demand resins and natural gas
- less 5 % of input
- unclear benefit of Hydrolysis Lignin

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5. Conclusions (I): Capabilities of the monitoring tool

- Single production systems can be evaluated as well as aggregated multi-product systems.
- Resource flows can be traced and allocated to projects over time.
- Specifying an “ideal” path towards more sustainable regional resource conversion and tracking progress in achieving it.
- Aggregation of sustainability metrics for biorefinery concepts and sLCA was realized and embedded into assessment scenarios.
5. Conclusions (II): Areas of applications and potential users of the tool

- **R&D pipeline mgmt.**
  - Time and resource constraints can be set and performance indicators be adjusted

- **Benchmarking**
  - Comparing products from partners vs. global competitors as well optimized scenarios for cooperation

- **Reporting**
  - Communicating progress in sustainable use and conversion of regional biomass resources

- **Regional councils**
  - Exposing options for sustainable growth and cooperation within bioeconomy regions

- **Network managers**
  - Bringing the success stories of innovation and cooperation onto a single dashboard

- **Plant managers**
  - Coordinating efforts for horizontal and vertical integrations of their supply chains with other plant managers
Jakob Hildebrandt

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Department of Bioenergy

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