Work Package 2: Upstream Environmental Assessment

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(USC)
Gantt Chart WP2

Year 1
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2.1 Literature Review Environmental Indicators
2.2 System Boundaries for upstream environmental assessment of bio-based products
2.3 Selection of environmental indicators and impact categories
2.4 Life Cycle Inventory for feedstock production and upstream processing
2.5 Major environmental impacts associated with feedstock production and upstream processing

Deliverable D2.1
Deliverable D2.2
Deliverable D2.3
Deliverable D2.4

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WP2: Upstream Environmental Assessment

Main outcomes
Literature review of environmental indicators considered in bio-based products studies

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<td>2016/USA</td>
<td>1 kg dry ethanol</td>
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<td>Tao et al., 2011</td>
<td>Corn stover</td>
<td>Isobutanol, fufural, acetic acid, lignin</td>
<td>Cradle to gate</td>
<td>2015/USA</td>
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<td>On-site investigation</td>
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<td>Hong et al., 2014</td>
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<td>Ethylene</td>
<td>Cradle to grave</td>
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<td>1 ton ethylene</td>
<td>Guanget Anju</td>
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<tr>
<td>Negroni &amp; Gennari, 2014</td>
<td>Algae (Chlorella vulgaris)</td>
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<td>1 kg of biodiesel (dry weight)</td>
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<td>Nitrogen fertilizer</td>
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<td>2009/Spain</td>
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<td>2015/USA</td>
<td>1 lb capacity for packaging of straw</td>
<td>Ecoinvent SimPro &amp; Literature</td>
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<td>Righi et al., 2016</td>
<td>Microbial biomass</td>
<td>PHA</td>
<td>Gate to gate</td>
<td>2015/USA</td>
<td>1 kg of PHB ready for bioplastic product manufactu</td>
<td>Laboratory data &amp; databases</td>
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<tr>
<td>Lunte et al., 2017</td>
<td>Carbohydrate feedstock</td>
<td>PLA (in comparison w/ PET)</td>
<td>Cradle to gate</td>
<td>2017/USA</td>
<td>1000 kg of transport pallet (5 years lifetime)</td>
<td>Laboratory testing &amp; Ecoinvent</td>
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<td>Hamann et al., 2017</td>
<td>Wastewater organic material</td>
<td>PHA</td>
<td>Cradle to gate</td>
<td>2014/Sweden</td>
<td>1 kg of PHA for use</td>
<td>National reports, literature, lab scale</td>
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<td>Corn &amp; sugar cane</td>
<td>PLA, TPI, Bio-PE, Bio-PET</td>
<td>Cradle to gate</td>
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<td>Dufresne et al., 2016</td>
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<td>Cradle to gate</td>
<td>2016/South Africa</td>
<td>1 ton LA at factory gate</td>
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<td>2015/USA, China, Brazil, China</td>
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<td>Jiang et al., 2014</td>
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<td>2014/China</td>
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</tr>
<tr>
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<td>Laboratory scale</td>
</tr>
<tr>
<td>Moussa et al., 2018</td>
<td>Lignin oil &amp; flax fiber</td>
<td>Printed circuit board</td>
<td>Cradle to gate</td>
<td>2016/Europe</td>
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<td>Real production data, Louisiana (USA) facility &amp; LCA software</td>
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<tr>
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<td>Oils (flax &amp; canola)</td>
<td>Biooil</td>
<td>Cradle to gate</td>
<td>2015/Sweden</td>
<td>1 kg of bioliquid biomass at the factory gate</td>
<td>Ecoinvent 2.1 database</td>
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<tr>
<td>Benetti et al., 2019</td>
<td>Oilseed crops (flax &amp; canola)</td>
<td>Biooil</td>
<td>Cradle to gate</td>
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</tr>
<tr>
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<td>Hemp seed</td>
<td>Insulation products for buildings</td>
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<td>2017/France</td>
<td>1 m of insulation board</td>
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</tr>
<tr>
<td>Soratana et al., 2017</td>
<td>Guayule/hevea</td>
<td>Natural rubber</td>
<td>Cradle to gate</td>
<td>2017/USA</td>
<td>1 kg of rubber</td>
<td>Literature, patents, government, corporation reports, databases</td>
</tr>
<tr>
<td>Brocchin project, 2017</td>
<td>Lignocellulosic feedstock</td>
<td>TPS, Bio-PE, Bio-PET</td>
<td>Cradle to gate</td>
<td>2017/USA</td>
<td>1 ton of dry biomass using the field</td>
<td>Ecoinvent Database, pilot plants, literature</td>
</tr>
<tr>
<td>Martinez et al., 2013</td>
<td>Wheat</td>
<td>Bioethanol</td>
<td>Cradle to gate</td>
<td>2013/UK</td>
<td>1 kg/1MJ</td>
<td>Modelling</td>
</tr>
<tr>
<td>Martinez et al., 2016</td>
<td>Wheat straw</td>
<td>Biogas</td>
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<td>1 kg of biogas</td>
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<tr>
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<td>Hard wood</td>
<td>Biochar, furfural, acetic acid, lignin</td>
<td>Cradle to gate</td>
<td>2015/USA</td>
<td>1 kg of biogas</td>
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</tr>
<tr>
<td>Staw, 2017</td>
<td>Macquarie &amp; cattle manure</td>
<td>Biogas</td>
<td>Cradle to gate</td>
<td>2017/United Arab Emirates</td>
<td>1 G Biogas/year</td>
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<tr>
<td>Gao et al., 2016</td>
<td>Woody biomass residues</td>
<td>Syngas electricity</td>
<td>Cradle to gate</td>
<td>2016/US</td>
<td>1 GWh of energy</td>
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<td>Isola et al., 2017</td>
<td>Maize grain (fructose)</td>
<td>Photodegradable FDCA</td>
<td>Cradle to gate</td>
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<td>Site [maize], laboratory scale (HMF)</td>
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<td>Bioethanol</td>
<td>Cradle to gate</td>
<td>2011/Brazil</td>
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</tr>
<tr>
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<td>Cradle to gate</td>
<td>2011/USA</td>
<td>1 kg of propanoic acid</td>
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</tr>
<tr>
<td>Chang et al., 2017</td>
<td>Softwood</td>
<td>Bioethanol</td>
<td>Cradle to gate</td>
<td>2017/Canada</td>
<td>1 kg of biodiesel ready for use</td>
<td>Experimental &amp; field survey data, Ecoinvent database</td>
</tr>
<tr>
<td>Aadjeir et al., 2017</td>
<td>Cassava starch</td>
<td>1% 2-MeTHF</td>
<td>Cradle to gate</td>
<td>2017/USA</td>
<td>1 kg of biodiesel</td>
<td>AspenPlus process simulations &amp; literature</td>
</tr>
<tr>
<td>Adam &amp; Dunn, 2016</td>
<td>Corn stover</td>
<td>Polymer grade lactic acid (PLLA) &amp; ethyl lactate</td>
<td>Cradle to gate</td>
<td>2016/USA</td>
<td>1 kg corn stover</td>
<td>AspenPlus process simulations &amp; literature</td>
</tr>
</tbody>
</table>
Task 2.1 Literature review of environmental indicators considered in bio-based products studies

**Product Families**

- Oils (non-polymerized)
- Sugars and starch (non-polymerized)
- Fibres
- Platforms by fermentation routes
- Platforms by other routes
- Plastic polymers (non-fibre)
- Fine and bulk chemicals
- Proteins
- Others

Literature review of 83 articles assessing bio-based products

Delivery D2.1

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Task 2.2  System Boundaries for upstream environmental assessment of bio-based products

System Boundaries

Sugar beet cultivation → Sugar beet root → Sugar extraction → Sugar beet pulp → Pretreatment & Enzymatic hydrolysis → Fermentable sugars → Processing

Sugar beet cultivation → Sugar beet root → Sugar extraction → Sugar beet pulp → Pretreatment & Enzymatic hydrolysis → Fermentable sugars → Processing

Maize cultivation → Maize stover → Maize grain → Wet milling → Starch → Enzymatic hydrolysis → Glucose → Processing

Sucrose, lime fertiliser and molasses

Bo-PLA

350 mm × 250 mm of packaging film

1 kg of polymer

Functional units (WP3)

1 ha of mulched agricultural land

PLA + bio-based co-polymer

USC, Quantis, AUA, Unibo, UWM, ChemProf, UoY

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**Task 2.2** System Boundaries for upstream environmental assessment of bio-based products

**Definition of functional unit (FU)**

- ~ 1.5 kg of maize grain
- ~ 2 kg maize stover
- ~ 5 kg beet pulp

**Functional units (WP2)**

- 1 kg of fermentable sugars
- 7.5 g of fermentable sugars
- 220 kg of fermentable sugars
- 1 PLA packaging film (300 mm x 250 mm) – 5.58 g of PLA
- 1 ha of Agricultural mulch film
- 2.7 kg of fermentable sugars

**Functional units (WP3)**

- 1 kg of PBS

**M6-M9**

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Task 2.3 Selection of **strategic environmental indicators** and **impact categories** for LCA of bio-based products

- Bio-based materials studies (D2.1)
- Feedstock studies (USC)
- PEFCR Guidance v6.3
- Complementary sources

Deliverable D2.2

[Poster for Deliverable D2.2: Selection of environmental indicators and impact categories for the life cycle assessment of bio-based products]

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### 11 impact categories

1. **Acidification** (mol H\(^+\)-eq)
   - PEFCR Guidance 6.3
   - Accumulated Exceedance

2. **Particulate matter** (Disease Incidence)
   - PEFCR Guidance 6.3
   - UNEP recommended model

3. **Global warming potential (incl. BIO)** (kg CO\(_2\)-eq)
   - IPCC GWP100 and GWP\(_{bio}\) for biogenic carbon

4. **Affected Biodiversity** (m\(^2\) year*PAS)
   - Inventory data + weighting factor for biodiversity
   - 2005 Millennium Ecosystem Assessment

5. **Terrestrial Eutrophication** (mol N\(-eq\))
   - PEFCR Guidance 6.3
   - Accumulated Exceedance

6. **Freshwater Eutrophication** (kg P\(-eq\))
   - PEFCR Guidance 6.3
   - EUTREND model as implemented in ReCiPe 2008

7. **Human toxicity, Cancer (CTUh)**
   - PEFCR Guidance 6.3
   - USEtox model18

8. **Land use, soil quality index** [Dimensionless (Pt)]
   - PEFCR Guidance 6.3
   - LANCA indicators

9. **Soil erosion** (kg soil loss)
   - RUSLE 2 + Borrelli (2017)
   - Revised Universal Soil Loss Equation, using C factor specific to crops

10. **Fossil resources Depletion** (MJ)
    - PEFCR Guidance 6.3
    - Abiotic resource depletion – fossil fuels (ADP fossil): CML

11. **Water scarcity** (m\(^3\) water deprived-eq)
    - PEFCR Guidance 6.3
    - Available WAter REmaining (AWARE)
Task 2.4  LCI for feedstock production and upstream processing

12 agricultural scenarios in 6 countries

- 3 scenarios\(^a\) (FR, UK and DE)
- 5 scenarios:\(^a\)
  - US, with stover removal
  - US, with no stover removal
  - IT, high yield, with stover removal
  - IT, low yield, with stover removal
  - BE, with stover removal
- 4 scenarios\(^a\) from the above maize grain farms, with stover removal

5 pre-processing scenarios

- 2 scenarios\(^a\) of sugar beet processing
- 2 scenarios\(^a\) of maize grain processing

Second stage pre-processing scenario

- 1 scenario\(^b\) of sugar beet pulp processing
- 1 scenario\(^b\) of maize stover processing

6 beet pulp fermentable sugars scenarios

20 scenarios

Economic allocation

10 maize grain fermentable sugars scenarios

4 maize stover fermentable sugars scenarios

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Fig. 1: Environmental hotspot analysis of sugar beet production FU: 1 kg of sugar beet (DE scenario)

Fig. 2: Environmental hotspot analysis of maize production FU: 1 kg of maize grain (US scenario)

Acronym: CC – Climate change; PM – Particulate matter; HT – Human toxicity; AC – Acidification; FE – Freshwater eutrophication; TE – Terrestrial eutrophication; WD – Water depletion and FD – Fossil depletion; Sc - Scenario

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Task 2.5  
Life Cycle Impact for feedstock production and upstream processing

Agriculture + pre-processing

Fig. 3a) Contribution analysis of fermentable sugar production
FU: 7.5 g of fermentable sugars

Acronym: CC – Climate change; PM – Particulate matter; HT – Human toxicity; AC – Acidification; FE – Freshwater eutrophication; TE – Terrestrial eutrophication; WD – Water depletion and FD – Fossil depletion; Sc - Scenario

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Task 2.5  Life Cycle Impact for feedstock production and upstream processing

Agriculture + pre-processing

- Sc8 – Grain and stover removal in IT/Process 2
- Sc9 – Grain and stover removal in BE/Process 1
- Sc10 – Grain and stover removal in BE/Process 2
- Sc11 – Stover in the US
- Sc12 – Stover in IT
- Sc13 – Stover in IT2
- Sc14 – Stover in BE

Fig. 3b) Contribution analysis of fermentable sugar production
FU: 7.5 g of fermentable sugars

Acronym: CC – Climate change; PM – Particulate matter; HT – Human toxicity; AC – Acidification; FE – Freshwater eutrophication; TE – Terrestrial eutrophication; WD – Water depletion and FD – Fossil depletion; Sc – Scenario
Task 2.5 Life Cycle Impact for feedstock production and upstream processing

Agriculture + pre-processing

Fig. 3c) Contribution analysis of fermentable sugar production
FU: 7.5 g of fermentable sugars

Sc15 – Sugar beet in UK / Process 1
Sc16 – Sugar beet in UK / Process 2
Sc17 – Sugar beet in FR / Process 1
Sc18 – Sugar beet in FR / Process 2
Sc19 – Sugar beet in DE / Process 1
Sc20 – Sugar beet in DE / Process 2

Acronym: CC – Climate change; PM – Particulate matter; HT – Human toxicity; AC – Acidification; FE – Freshwater eutrophication; TE – Terrestrial eutrophication; WD – Water depletion and FD – Fossil depletion; Sc – Scenario

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### Functional unit (FU) – 7.5 g of fermentable sugars

<table>
<thead>
<tr>
<th>Impact category</th>
<th>Unit</th>
<th>Average</th>
<th>Max</th>
<th>Min</th>
<th>Average</th>
<th>Max</th>
<th>Min</th>
<th>Average</th>
<th>Max</th>
<th>Min</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maize grain</td>
<td></td>
<td></td>
<td></td>
<td>Maize stover</td>
<td></td>
<td></td>
<td>Sugar beet pulp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CC</td>
<td>kg CO₂ eq</td>
<td>4.25·10⁻³</td>
<td>5.92·10⁻³</td>
<td>2.26·10⁻³</td>
<td>4.81·10⁻³</td>
<td>6.70·10⁻³</td>
<td>3.62·10⁻³</td>
<td>2.43·10⁻³</td>
<td>2.57·10⁻³</td>
<td>2.32·10⁻³</td>
</tr>
<tr>
<td>PM</td>
<td>deaths</td>
<td>2.27·10⁻¹⁰</td>
<td>3.43·10⁻¹⁰</td>
<td>7.73·10⁻¹¹</td>
<td>2.55·10⁻¹⁰</td>
<td>3.84·10⁻¹⁰</td>
<td>1.69·10⁻¹⁰</td>
<td>1.40·10⁻¹⁰</td>
<td>1.88·10⁻¹⁰</td>
<td>1.16·10⁻¹⁰</td>
</tr>
<tr>
<td>HT</td>
<td>CTUh</td>
<td>2.39·10⁻¹⁰</td>
<td>5.91·10⁻¹⁰</td>
<td>7.30·10⁻¹¹</td>
<td>1.74·10⁻¹⁰</td>
<td>3.50·10⁻¹⁰</td>
<td>6.43·10⁻¹¹</td>
<td>3.23·10⁻¹¹</td>
<td>3.57·10⁻¹¹</td>
<td>2.57·10⁻¹¹</td>
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<tr>
<td>AC</td>
<td>mol H⁺ eq</td>
<td>5.2·10⁻⁵</td>
<td>7.68·10⁻⁵</td>
<td>1.39·10⁻⁵</td>
<td>4.57·10⁻⁵</td>
<td>7.33·10⁻⁵</td>
<td>2.41·10⁻⁵</td>
<td>1.67·10⁻⁵</td>
<td>1.85·10⁻⁵</td>
<td>1.46·10⁻⁵</td>
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<tr>
<td>FE</td>
<td>kg P eq</td>
<td>8.41·10⁻⁶</td>
<td>1.53·10⁻⁶</td>
<td>3.46·10⁻⁷</td>
<td>1.49·10⁻⁶</td>
<td>1.80·10⁻⁶</td>
<td>1.20·10⁻⁶</td>
<td>8.33·10⁻⁷</td>
<td>8.78·10⁻⁷</td>
<td>8.00·10⁻⁷</td>
</tr>
<tr>
<td>TE</td>
<td>mol N eq</td>
<td>2.84·10⁻⁴</td>
<td>5.80·10⁻⁴</td>
<td>1.21·10⁻⁴</td>
<td>2.08·10⁻⁴</td>
<td>3.49·10⁻⁴</td>
<td>1.03·10⁻⁴</td>
<td>4.04·10⁻⁵</td>
<td>4.62·10⁻⁵</td>
<td>3.63·10⁻⁵</td>
</tr>
<tr>
<td>LU</td>
<td>Pt</td>
<td>0.44</td>
<td>8.28·10⁻¹</td>
<td>4.83·10⁻²</td>
<td>2.58·10⁻¹</td>
<td>4.31·10⁻¹</td>
<td>-6.04·10⁻³</td>
<td>3.14·10⁻¹</td>
<td>5.66·10⁻¹</td>
<td>7.48·10⁻³</td>
</tr>
<tr>
<td>WD</td>
<td>m³ depriv.</td>
<td>4.96·10⁻⁵</td>
<td>1.49·10⁻⁵</td>
<td>2.06·10⁻⁴</td>
<td>3.61·10⁻²</td>
<td>8.36·10⁻²</td>
<td>7.78·10⁻⁵</td>
<td>5.24·10⁻⁵</td>
<td>5.33·10⁻⁵</td>
<td>5.18·10⁻⁵</td>
</tr>
<tr>
<td>FD</td>
<td>MJ</td>
<td>4.62·10⁻³</td>
<td>6.24·10⁻²</td>
<td>2.50·10⁻¹</td>
<td>6.66·10⁻¹</td>
<td>8.29·10⁻¹</td>
<td>5.41·10⁻¹</td>
<td>3.77·10⁻¹</td>
<td>3.94·10⁻¹</td>
<td>3.65·10⁻²</td>
</tr>
<tr>
<td>BIO</td>
<td>PAS·m²·year</td>
<td>20.40</td>
<td>39.63</td>
<td>1.62</td>
<td>15.39</td>
<td>23.90</td>
<td>2.68</td>
<td>3.67</td>
<td>4.61</td>
<td>2.97</td>
</tr>
<tr>
<td>SE</td>
<td>kg soil year</td>
<td>5.36·10⁻³</td>
<td>1.42·10⁻²</td>
<td>6.04·10⁻⁵</td>
<td>3.72·10⁻³</td>
<td>1.27·10⁻²</td>
<td>9.99·10⁻⁵</td>
<td>1.64·10⁻⁴</td>
<td>3.99·10⁻⁴</td>
<td>3.44·10⁻⁵</td>
</tr>
</tbody>
</table>

Compare with other feedstock and/or agricultural systems.

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## Functional unit WP2 (FU) – 7.5 g of fermentable sugars

### Impact category

<table>
<thead>
<tr>
<th>Impact category</th>
<th>WP2 – Upstream processes (Maize grain)</th>
<th>WP2 – Upstream processes (Maize stover)</th>
<th>WP3 – Production and distribution</th>
<th>Intended EoL (Aerobic composting)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic</td>
<td>(4.25 ± 1.62) \cdot 10^{-03}</td>
<td>(4.81 ± 1.47) \cdot 10^{-03}</td>
<td></td>
<td>4.46 \cdot 10^{-03}</td>
</tr>
<tr>
<td>Mass</td>
<td>- 8.07 %</td>
<td>+ 60.25 %</td>
<td></td>
<td>-4.50 \cdot 10^{-03}</td>
</tr>
<tr>
<td>CC kg CO₂ eq</td>
<td>(4.25 ± 1.62) \cdot 10^{-03}</td>
<td>(4.81 ± 1.47) \cdot 10^{-03}</td>
<td></td>
<td>1.75 \cdot 10^{-04}</td>
</tr>
<tr>
<td>Mass</td>
<td>- 8.44 %</td>
<td>+ 63.15 %</td>
<td></td>
<td>6.33 \cdot 10^{-01}</td>
</tr>
<tr>
<td>PM deaths</td>
<td>(2.39 ± 1.89) \cdot 10^{-10}</td>
<td>(1.74 ± 1.32) \cdot 10^{-10}</td>
<td></td>
<td>2.10 \cdot 10^{-07}</td>
</tr>
<tr>
<td>Mass</td>
<td>- 13.20 %</td>
<td>+ 137 %</td>
<td></td>
<td>6.54 \cdot 10^{-12}</td>
</tr>
<tr>
<td>HT CTUh mol H+ eq</td>
<td>(5.20 ± 2.27) \cdot 10^{-05}</td>
<td>(4.57 ± 2.08) \cdot 10^{-05}</td>
<td></td>
<td>1.35 \cdot 10^{-04}</td>
</tr>
<tr>
<td>Mass</td>
<td>- 8.54 %</td>
<td>+ 85 %</td>
<td></td>
<td>1.39 \cdot 10^{-05}</td>
</tr>
<tr>
<td>AC kg P eq</td>
<td>(8.41 ± 4.23) \cdot 10^{-07}</td>
<td>(1.49 ± 0.32) \cdot 10^{-06}</td>
<td></td>
<td>8.33 \cdot 10^{-07}</td>
</tr>
<tr>
<td>Mass</td>
<td>- 9.22 %</td>
<td>+ 42 %</td>
<td></td>
<td>122 %</td>
</tr>
<tr>
<td>FE mol N eq</td>
<td>(2.84 ± 1.58) \cdot 10^{-04}</td>
<td>(2.08 ± 1.12) \cdot 10^{-04}</td>
<td></td>
<td>8.94 \cdot 10^{-04}</td>
</tr>
<tr>
<td>Mass</td>
<td>- 12.22 %</td>
<td>+ 129 %</td>
<td></td>
<td>6.47 \cdot 10^{-07}</td>
</tr>
<tr>
<td>TE m³ depriv.</td>
<td>(4.96 ± 6.52) \cdot 10^{-02}</td>
<td>(3.61 ± 4.26) \cdot 10^{-02}</td>
<td></td>
<td>5.23 \cdot 10^{-06}</td>
</tr>
<tr>
<td>Mass</td>
<td>- 18.60 %</td>
<td>+ 179 %</td>
<td></td>
<td>5.46 \cdot 10^{-07}</td>
</tr>
<tr>
<td>WD MJ</td>
<td>(4.62 ± 1.55) \cdot 10^{-02}</td>
<td>(6.66 ± 1.37) \cdot 10^{-02}</td>
<td></td>
<td>6.20 \cdot 10^{-04}</td>
</tr>
<tr>
<td>Mass</td>
<td>- 7.19 %</td>
<td>+ 42 %</td>
<td></td>
<td>6.57 \cdot 10^{-05}</td>
</tr>
<tr>
<td>FD FDU</td>
<td>(8.41 ± 4.23) \cdot 10^{-07}</td>
<td>(1.49 ± 0.32) \cdot 10^{-06}</td>
<td></td>
<td>2.34 \cdot 10^{-02}</td>
</tr>
<tr>
<td>Mass</td>
<td>- 9.22 %</td>
<td>+ 42 %</td>
<td></td>
<td>9.80 \cdot 10^{-06}</td>
</tr>
</tbody>
</table>
MAIN CONSIDERATIONS

1. Most of the LCA studies related to upstream activities (agriculture + pre-processing) focus on feed/food production. There are few LCA studies that use fermentable sugars as a functional unit. Most of them emphasize their attention on the end-product, such as biofuels and bio-products. Modelling upstream activities of bio-products is relevant since they are bottlenecks for biorefineries.

2. Understanding the social, environmental and techno-economic aspects of agricultural activities and pre-processing of the production of bioproducts is very important as these upstream activities embody a very distinct and independent stage in the bio-products supply chain. Agriculture, for example, is highly determined by geographic and climatic conditions.

3. In general, when economic allocation is performed, the average values from the 20 scenarios for the production of 1 kg of fermentable sugars emit about 0.50 kg of CO₂ and 6 MJ of energy.

4. However, standard variation values are very high due to the different agricultural systems considered in this study.

www.STAR-ProBio.eu Funded by the EU H2020 Programme
In this upstream LCA, the outcomes showed that the use of fermentable sugars from beet pulp has less impact than maize grain and stover, consequently reducing the global impacts of the three STAR-ProBio case studies.

The sensitivity analysis comparing economic and mass allocation indicates that the figures for maize grain do not vary considerably with the changes in the parameter values, when compared with maize stover or beet pulp. Both showed an extremely high sensitivity in the results.

This report is an attempt to present the environmental impacts of upstream processes for the Star-ProBio case studies. A variety of gaps will be explored in the future, such as the use of other types and innovative raw materials, for instance, micro and macro algae and cellulose from forestry operations.

Additionally, new pre-treatment technologies, especially for processing lignocellulosic crops and new ways of integrating supply chains between the upstream and downstream processes of bio-based products, are expected to emerge in the future.
Work Package 2: Upstream Environmental Assessment

6th Meeting of the General Assembly
28-29 April 2020

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