Lignocellulosic conversion to ethanol: the environmental life cycle impacts

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Contents

- Sustainable biofuel
- Life cycle assessment
- Current work
- Conclusions
Programme LACE:
Lignocellulosic Conversion To Ethanol

Theme A: Life Cycle Analysis

Strand 1
Optimising Deconstruction

Optimising Sugar Release

Optimising Fermentation

Strand 2

Theme B: Farm Systems

Theme C: Social and Ethical Dimensions
Sustainable biofuel
Sustainable biofuel

- Energy analysis;
- Environmental life-cycle assessment (LCA), assessed in terms of various pollutant emissions;
- Integrated appraisal of biofuel chain
Life cycle assessment

LCA is an environmental management tool to determine the environmental impact of a product or system over its whole life – from production, through use and to recycling, reuse or disposal (from “the cradle to the grave”).
**Life cycle assessment**

**METHODOLOGY**

- In an LCA study, the energy and materials used, and pollutants or wastes released into the environment as a consequence of a product or activity are quantified over the whole life-cycle, ‘from cradle-to-grave’.

**STANDARDS**

- ISO 14040 series – Environmental Life Cycle Assessment
- PAS 2050 – Life Cycle GHG Emissions of Goods & Services

**DATABASES**

- Ecoinvent
- Bath - Inventory of *(Embodied)* Carbon and Energy [ICE]
LCA Stages

- Goal Scoping
- Inventory
- Impact Assessment
  - Classification
  - Characterisation
  - (Normalisation)
  - (Valuation)
- Improvement Assessment – Interpretation
The Biofuel Life-Cycle

Crop harvesting    >    Processing    >    End Use

Fossil fuels are used in the harvesting and processing of the crop, and in transporting between stages.
Lignocelluloses to ethanol

- Infrastructure
  - Building
  - Machinery

- Auxiliary Equipment

- Fuel and electricity

- Emissions

- Field preparation
  - Soil cultivation
  - Mulching
  - Transplanting
  - Training
  - Fertiliser application
  - Pesticide application
  - Harvest

- Production treatment
  - Grading
  - Packing

- Wheat
  - Straw for incorporation

- Seed
  - Fertiliser
  - Irrigation
  - Pesticides

- Transport

- Bioenergy
  - Fuel
  - Electricity
  - Chemicals
  - Water
  - Enzyme
  - Yeast

- Anaerobic Digestion
  - Biogas
    - Upgrading
    - BioCH4

- Hydrolysis
  - C6 sugars
    - Fermentation
    - Bioethanol
  - C5 sugars
    - Combustion
    - Electricity & heat
    - Lignin
      - Pyrolysis
      - Pyrolytic liquid
      - Separation
      - Chemicals

- Storage of straw

- Waste

- Emissions
Ethanol conversion process

1. Feedstock handling
   - Feedstock
   - Shredded Stover
   - Recycle Water
   - Nutrients

2. Pretreatment and Conditioning
   - Lime
   - Steam
   - Acid
   - Hydrolyze

3. Saccharification and Co-Fermentation
   - Enzyme
   - Nutrients
   - Vent
   - Bath
   - Excess Cond.

4. Distillation dehydration Solids separation
   - Steam
   - Still solids
   - Evap. Syrup
   - BCh Product
   - Recycle Cond.

5. Wastewater Treatment
   - Excess Cond.
   - Wastewater
   - Boiler Blowdown
   - Anaerobic CH4

6. Storage
   - Boiler Blowdown
   - Recycle Cond.
   - Evap. Syrup

7. Burner/Boiler Turbogenerator
   - Steam
   - Electricity

8. Utilities
   - Electricity
Material flow

Feedstock handling

Shredded corn stover with 30% moisture content
128676 Kg/h

Pre-hydrolysis

Glucose oligmers, 716 Kg/h
Xylose oligmers, 646 Kg/h
Xylan, 439 Kg/h
Ethanol, 47 Kg/h

Hydrolysis & fermentation

Glucose, 2432 Kg/h
Xylose, 18087 Kg/h
Cellulose, 28432 Kg/h
Cellubiose, 312 Kg/h

Ethanol, 24825 Kg/h + 668 Kg/h

Ethanol recovery

5.21 Kg corn stover for 1 Kg ethanol

Product yield: 22.6% dry basis

Wastewater treatment

Wastewater, 96697 Kg/h

Treated water, 95805 kg/h

Ethanol, 24686 Kg/h

Ethanol, 24825 Kg/h
## Characterisation results

<table>
<thead>
<tr>
<th>Impact category</th>
<th>Unit</th>
<th>Total</th>
<th>Feedstock handling</th>
<th>Prehydrolysis</th>
<th>Hydrolysis &amp; fermentation</th>
<th>Ethanol recovery</th>
<th>Wastewater treatment</th>
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<tr>
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</tbody>
</table>
Characterisation results
Conclusions

- An LCA analysis of ethanol conversion process was carried out taking account of feedstock handling, pre-hydrolysis, hydrolysis and fermentation, bioethanol recovery, and wastewater treatment.

- Among the ethanol conversion processes, the pre-hydrolysis step contributes significantly to the environmental burdens.

- The use of sulphuric acid and process steam, as well as electricity, are identified as the main sources for the environmental burdens that contribute to climate change and ozone depletion.
Thank You for Your Kind Attention

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Impact assessment method
ReCipe

LCI result

Raw mat.
Land use
CO2
VOS
P
SO2
NOx
CFC
Cd
PAH
DDT

Ozone depletion
Hum tox
Radiation
P. C. Ozone Form.
Particulate Form.
Climate Change
Terr. Ecotox
Terr. Acidif.
Agr. Land Occ.
Urban Land Occ.
Nat. Land Transf.
Marine Ecotox.
Marine Eutr.
Fresh water Eutr.
Fresh W. Ecotox
Fossil fuel Cons.
Minerals Cons.
Water Cons.

Decr. Ozone P.
Hazard. W. Dose
Absorbed Dose
Ozone Conc.
PM10 Conc.
Infra-red Forcing
Hazard W. Conc.
Base Saturation
Occupied Area
Transformed area
Hazard W. Conc.
Algae Growth
Algae Growth
Hazard W. Conc
Energy Content
Decrease Conc.
Water use

Damage
Damage
Damage
Damage
Damage
Damage
Damage
Damage
Damage
Damage
Damage
Damage
Damage
Damage
Damage
Damage
Damage

Human health
DxLY
Ecosystems
Species, yr
Resources
Surplus cost

Environmental
Mechanism, Part 1
Midpoint
Environmental
Mechanism, Part 2
Endpoint