Biobased Processes: Systematically Evaluating Chances and Challenges

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Possible biobased synthesis pathways

Biomass →

gasification, pyrolysis:
C1- (C2-, C3-) building blocks

extract major components:
starch, sugar, vegetable oil
remains: energy use

separate „all“ components:
cellulose, lignin, use of whole plant, biorefinery

Products
interaction of some major drivers

- World population: 7,000,000,000
- Energy: 21,000 kWh/(cap a)
- Materials: ca. 0.9 kg/(cap d)
- Food: 2.8 kg/(cap d)
- Fossil resources: 5.6 kg/(cap d)
- Land area (agricultural): 7,000 m²/cap
land-area use: +1.5°C, high pop. variant

in 2100:
CO₂ 464 ppm
ΔT 1.50 °C

calculation of exergy

exergy of a material stream

\[ E_i = \sum_{i=1}^{N} (E_{i,\text{chem}} + E_{i,\text{phys}}) + \Delta E_{\text{mix}} \]

chemical exergy of a material stream

\[ E_{i,\text{chem}} = \delta G_i + \sum_{i=1}^{j} \nu_{i,j} E_{i,\text{chem}}^0 \]

physical exergy of a material stream

\[ E_{i,\text{phys}} = \frac{T_R}{T_U} \int C_i(T) dT + V_i \int F (P_R - P_U) + \frac{T_R}{T_U} \int \frac{1}{T} C_i(T) dT \]

+ exergy losses in processes and equipment
chemical exergy of various materials

- Hydrogen
- Methane, natural gas
- Crude oil
- Plant oil
- Coal
- Amylose
- Glucose
- Ethanol
- Methanol
- Glycerol
- Lactic acid
- Carbon monoxide
- Polystyrene
- Polyethylene
- Polypropylene
- Polyvinyl chloride
- Polycarbonate
- Polyethylene terephthalate
- Polyethylene terephthalate
- Lactic acid
- Polylactic acid
- Methanol
- Coal
- Crude oil
- Plant oil
- Glucose fermentation
- Net reaction
- Fossil feedstock
- Biomass
- Intermediates
- Products
- Chemical exergy in MJ/kg
COH composition

- COH composition
- fossil raw materials
- bio-based feedstock
- conventional polymers
- bio-based polymers

synthesis pathways to PET

- chemical energy in MJ/kg
- hydrogen
- crude oil
- ethanol
- ethylene
- ethylene oxide
- 1,2-ethanediol
- PET

- CO
- H₂O, O₂
- H₂O
process: ethylene $\rightarrow$ ethylene oxid

results of exergy analysis

$\Delta > 0.3$ MJ/kg
comparision of the processes

exergy demand for different routes
land-area use 2050 for different routes

![Bar chart showing land area use for different routes. The chart includes routes like glucose → fatty acid, crude oil, fatty acid → glucose, fatty acid → fatty acid, and fatty acid → crude oil.](chart)

process ideas

- **plant-based material** → **paraxylene** → **terephthalic acid**
- **plant-based material** → **ethanol** → **ethylene glycol**
- **bottle forming** → **bio-PET**
evaluation of selected options

- exergetically favorable
- no diluted aqueous solution
- no complex mixture
- liquid or gas as feedstock

- gasification, pyrolysis of entire biomass
- methanation of entire biomass
- starch and sugar to oxygen-rich products
- plant oil to conventional products
- separate cellulose and lignin

evaluation:
- not tested
- good
- acceptable
- infeasible

exergy is general energy measure
mix of feedstock and technologies
results (integration limited):
- extraction/separation of direct valuables
- glucose → products with more oxygen
- plant oil → products with less oxygen
- rest to methanation
- energy demand for processes will increase
- land area required for biobased feedstock:
  200 to 800 m²/capita (food ≈ 7000 m²/capita)
integration:
- agriculture - production - consumer needs
references

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