Bio-Ökonomie: Chancen, Risiken und Blick auf das Gesamtsystem

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CO₂ content of the atmosphere

source: http://www.esrl.noaa.gov/gmd/ccgg/trends/
THE major driver

- World population: 7,600,000,000
- Food: 2.8 kg/(cap d)
- Energy: 21,000 kWh/(cap a)
- Materials: ca. 0.9 kg/(cap d)
- Fossil resources: 5.6 kg/(cap d)
- Land area (agricultural): 7,000 m²/cap

Petrochemicals ≈ 4% of fossil resources

- Coal
- Natural gas
- Crude oil
- Petrochemicals
agenda

- world population ⇒ driving force
- energy transition ⇒ time scale
- food vs. fuel & material ⇒ limiting criteria
- feedstock → fuel & material ⇒ available options
- ⇒ chances, challenges
development of UN-WPP predicting for 2050

![Graph showing world population scenarios](image)

- **High variant:** 11.03 billion in 2050
- **Medium variant:**
- **Low variant:**

**World population scenarios**

Source: United Nations, World Population Prospect 2017 Revision
The UN high-population variant has to be considered as realistic a scenario as the medium variant.
annual global growth rates

Future growth scenarios of wind & solar
defining three future scenarios

- max. substitution rate: 3.0%
- growth rate: 30%
- 20%
- 2.0%

wind + solar

on global average!

CO₂ according to three scenarios

- +1.93 °C
- +1.66 °C
- +1.51 °C

renewables scenarios:
- 20% - 2.0%, easiest
- 25% - 2.5%, medium
- 30% - 3.0%, challenging
conclusion

time-scale: turning point in 5 to 10 years
strong effect in 10 to 20 years
volatile prices of fossil feedstock foreseeable
By then, bio-economy should better be well on its way!
Reducing population growth simplifies transition.

world hunger
assumptions for scenario analysis

- continue trends
- slow increase of per capita kcal-supply
- increase agricultural productivity
- intensify animal production
- 10% primary energy bio-based

land-area: challenging, high pop. variant
land-area: challenging, medium pop. variant

land-area: challenging, medium pop., vegetal
workarounds?
productivity of land area GM vs. non-GM

conclusion

To feed the world, change in behavior essential:

- maximum 2 children per family
- exclusively plant-based food

Nevertheless: competition for land area between

- feedstock for biofuels and biomaterials
- food production.

⇒ land-area demand for feedstock
   is essential selection criterion!
calculation of exergy

exergy of a material stream

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

chemical exergy of a material stream

\[ E_{i,\text{chem}} = X_i G_i + \sum_{j} \nu_{i,j} E_{j,\text{chem}} \]

physical exergy of a material stream

\[ E_{i,\text{phys}} = \int_{T_U}^{T_R} C_i(T) dT + V_i^F (P_R - P_U) - \int_{T_U}^{T_R} 4 C_i(T) dT \]

+ exergy losses in processes and equipment

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calculating exergy

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chemical exergy of various materials

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after: Philipp Frenzel, Raffaella Hillerbrand, Andreas Pfennig:
Increase in energy and land use by a bio-based chemical industry.
Chemical Engineering Research and Design 92 (2014) 2006-2015
chemical exergy of various materials

elements in chemical industry by weight

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

chemical exergy

\[ E_{\text{chem}} = -55.35x_O + 46.20 \]

mass fraction oxygen

crude-oil level

plant-oil level

glucose level

options for bio-based chemicals

ranges: maximum national and world average productivity

color: 
- ■ technically realized
- ■ partly pilot-plant
- ■ lab-values or complex

in radius 50km:
- 200 m²/cap >600 000 t/a
- 400 m²/cap >300 000 t/a
- 600 m²/cap >200 000 t/a

conclusion

• solely third generation bio-processes not feasible
• first and second generation compete for same land area as food
• various options available as feedstock: sugar cane, sugar beet, corn, palm oil, miscanthus/reeds
• preferably either sugar chemistry or utilization of CO₂
• cellulose utilization is add-on benefit, but large by-products
• strong interaction: agriculture ↔ food ↔ chemistry ↔ energy

for updated values without crop rotation, please see later publications.
chances, challenges

- biobased chemistry: various options
- bio-economy ≠ only bio-technology
- bio-economy ≠ automatically sustainability
- technology ↔ human behavior
- economics, ecologics, ethics
- big chance: real circular economy
- all happens in ±30 years (or it is too late)
references

P. Frenzel, S. Fayyaz, R. Hillerbrand, A. Pfennig:
Biomass as Feedstock in the Chemical Industry –
An Examination from an Exergetic Point of View

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Increase in energy and land use by a bio-based chemical industry

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Exergetical Evaluation of Biobased Synthesis Pathways
Polymers 6 (2014) 327-345

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https://publications.rwth-aachen.de/record/464668/files/464668.pdf

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