Biorefinery and Biobased Economy

Possible Role of a Biorefinery’s Syngas Platform in a Biobased Economy – Assessment in IEA Bioenergy Task 42 “Biorefining”

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The Austrian participation in Tasks 42 of IEA Bioenergy is financed by the Federal Ministry for Transport, Innovation and Technology / Department for Energy and Environmental Technologies.
This is Biomass for the Biobased Economy
There is Competition for Different Biomass Uses

Biomass

*Bioenergy*  
(heat, electricity, transportation fuels)

Food  
(e.g. vegetables, meat)

Biomass

Feed

Biomaterials  
(e.g. paper, construction material, cotton, rubber, fertilizer)
This is the Biorefinery

Biomass Resources
- oil
- starch
- sugar
- lignocellulose
- ....

Bioenergy
- liquid/gaseous transport biofuels
- electricity
- heat
- solid fuels

Bioproducts
- bulk chemicals
- fine chemicals
- animal feed
- food
- materials
- fertilizer
- gases
- ....

Based on different conversion processes
- Bio-chemical
- Thermo-chemical
- Physical-chemical
- Others
Outline

Introduction

Biorefineries with Syngas Platform

Biorefinery Fact Sheet: Example

Outlook
Definition of IEA Task 42 “What is a Biorefinery?”

“Biorefinery is the sustainable processing of biomass into a spectrum of marketable products”

- **Biorefinery**: concepts, facilities, processes, clusters of industries
- **Sustainable**: maximising economics & social aspects, minimising environmental impacts, fossil fuel replacement, closed cycles
- **Processing**: upstream processing, transformation, fractionation, thermo-chemical and biochemical conversion, extraction, separation, downstream processing
- **Biomass**: wood & agricultural crops, residues, forest residues, aquatic biomass
- **Spectrum**: multiple energetic and non-energetic products
- **Marketable**: Present and forecasted (volume and prices)
- **Products**: both intermediates and final products (i.e. food, feed, materials, chemicals, fuels, power, heat)
Two Different Motivations for A Biorefinery

**Biorefinery**

- **“Bioproduct-driven” Biorefinery**
  - e.g. pulp&paper, lactic acid

- **“Bioenergy-driven” Biorefinery**
  - e.g. bioethanol, FT-biofuels
The 4 Features to Characterise A Biorefinery Systems

1. Platforms
2. Products
3. Feedstocks
4. Processes

Biorefinery

Naming:
- Number platforms (Name of platforms)/Feedstock/Products/Processes
- e.g. 2-platform (electricity&heat, syngas) biorefinery/wood chips/FT-biofuels, electricity, heat, waxes/steam gasification
Application of Classification System

**Generic system**

1. **Feedstock**
2. **Mechanical process**
3. **Chemical process**
4. **Platform**
5. **Biochemical process**

- **Bioproducts**
- **Bioenergy**

**Example**

1. **Wood chips**
2. **Steam gasification**
3. **Syngas**
4. **Catalytic reaction (FT-synthesis)**
5. **Combustion**
6. **Upgrading**
7. **Electricity and heat**
8. **FT-biofuels**
9. **Waxes**
Classification System is Now in Use ....
Outline

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Outlook
Based on this first selection of most promising biorefinery concepts to produce large volumes of road transportation biofuels by 2025 the Task 42 is assessing the sustainability of these biorefinery concepts by analyzing economic, environmental and social aspects in comparison to conventional processes and products.

In a next step a “biorefinery fact sheet” for each of these selected “energy driven” biorefineries is developed, key characteristics for a specific production capacity of road transportation biofuel ……….
14 Biofuel-driven Biorefineries for Biobased Economy in 2025
Selected Biofuel-driven Biorefineries with a Syngas Platform

1. “4-platform (electricity&heat, hydrogen, biomethane, syngas) biorefinery using wood chips for biomethane (SNG), hydrogen and carbon dioxide”

2. “2-platform (electricity&heat, syngas) biorefinery using wood chips for FT-biofuels, electricity, heat and waxes with steam gasification”

3. “4-platform (pulp, syngas, electricity&heat) biorefinery using wood chips for FT-biofuels, electricity, heat and pulp”

4. “3-platform (pyrolysis oil, syngas, electricity&heat) biorefinery using straw for FT-biofuels and methanol with oxygen gasification”

5. “5-platform (C6 sugars, C5&C6 sugars, lignin, syngas, electricity&heat) biorefinery using starch crops and straw for bioethanol, FT-biofuels, feed, electricity and heat”
Biomethane from Wood

4-platform (electricity&heat, hydrogen, biomethane, syngas) biorefinery using wood chips for biomethane (SNG), hydrogen and carbon dioxide
FT-biofuels from Wood (I)

2-platform (electricity&heat, syngas) biorefinery using wood chips for FT-biofuels, electricity, heat and waxes with steam gasification
FT-Biofuels from Wood (II)

4-platform (pulp, syngas, electricity&heat) biorefinery using wood chips for FT-biofuels, electricity, heat and pulp
FT-Biofuels from Straw

3-platform (pyrolysis oil, syngas, electricity&heat) biorefinery using straw for FT-biofuels and methanol with oxygen gasification
FT-Biofuels and Bioethanol from Straw and Starch crops

4-platform (C6 sugars, C5&C6 sugars, lignin, syngas, electricity&heat) biorefinery using starch crops and straw for bioethanol, FT-biofuels, feed, electricity and heat
Purpose of the Biorefinery Fact Sheet

What are the facts & figures of different biorefineries?

Look here, you find facts & figures in our Biorefinery Fact Sheet

„Biorefinery Fact Sheets“ is linking element of Task 42 activities:

- Market deployment aspects for biorefineries (success factors, changing technologies, central/decentral processing, Biorefinery-Complexity-Index)
- Stakeholder support for future BioEconomy (integration in existing industrial infrastructures, Factsheets major biorefineries, National case-studies, added-value products)
- Optimal sustainable biomass valorization (supply chains, biomass demand, optimal biomass valorisation)
- Policy & decision advice (roadmap, policies, country reporting)
- Dissemination & training activities (task & stakeholder meetings, website incl. data-base biorefineries, newsletters, reports, brochures & leaflets, presentations, training course)
Overview

Biorefinery Fact Sheet

Part A: Biorefinery Plant

Part B: Value Chain Assessment

Annex:

Methodology of sustainability assessment and data with references
Part A: Biorefinery Plant Classification Scheme

“2-platform (electricity&heat, syngas) biorefinery using wood chips for FT-biofuels, electricity, heat and waxes with steam gasification”
Part A: Biorefinery Plant
Mass and Energy Balance

“2-platform (electricity&heat, syngas) biorefinery using wood chips for FT-biofuels, electricity, heat and waxes with steam gasification”

Own calculations based on Austrian feasibility study (Hofbauer et al. 2008)
Part A: Biorefinery Plant
Share of Costs and Revenues

"2-platform (electricity&heat, syngas) biorefinery using wood chips for FT-biofuels, electricity, heat and waxes with steam gasification"

**Costs**
- wood chips, 66.3%
- capital, 19.3%
- materials, 4.5%
- aux. energy, 0.0%
- insurance, 2.3%
- personal, 0.7%
- maintainance, 6.8%

**Revenues**
- FT-diesel, 57%
- FT-gasoline, 36%
- waxes, 6%
- heat, 1%

*Own calculations based on Austrian feasibility study (Hofbauer et al. 2008)*
Part B: Value Chain Assessment
System Boundaries & Reference System

A 2-Platform (electricity & heat, syngas) Biorefinery Using Wood Chips for FT-biofuels, Heat and Waxes

Collection Forest Residues
- Transport
- Biorefinery
  - FT-Diesel, FT-Gasoline
  - Heat
  - Waxes
  - Recycling/energy generation (*)

Conventional Reference System
- Extraction
  - Transport
  - Refinery
    - Diesel/Gasoline
    - Heat
    - Waxes
    - Recycling/energy generation (*)

Use
- Distribution
- Product Services

*) incl. transportation
Part B: Value Chain Assessment Overview

“2-platform (electricity&heat, syngas) biorefinery using wood chips for FT-biofuels, electricity, heat and waxes with steam gasification”

<table>
<thead>
<tr>
<th>Whole value chain</th>
<th>range</th>
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</thead>
<tbody>
<tr>
<td>Greenhouse gas emissions</td>
<td>[kt CO2-eq/a]</td>
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<tr>
<td>biorefinery</td>
<td>70 (66 to 81)</td>
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<tr>
<td>reference system</td>
<td>690 (640 to 790)</td>
</tr>
<tr>
<td>saving</td>
<td>-90 (-87 to -92)</td>
</tr>
<tr>
<td>Cumulated energy demand</td>
<td>[PJ/a]</td>
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<tr>
<td>fossil</td>
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<td>biorefinery</td>
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<tr>
<td>reference system</td>
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<tr>
<td>saving</td>
<td>-93 (-92 to -95)</td>
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<tr>
<td>total</td>
<td></td>
</tr>
<tr>
<td>biorefinery</td>
<td>14.9 (14 to 17)</td>
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<tr>
<td>reference system</td>
<td>9.8 (9.1 to 11)</td>
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<td>52 (27 to 87)</td>
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<td>Agricultural area demand</td>
<td>[ha/a]</td>
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<td>feedstock</td>
<td>- (0 to 0)</td>
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<td>Costs</td>
<td>[Mio €/a]</td>
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<tr>
<td>annual costs</td>
<td>220 (200 to 250)</td>
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<td>specific costs</td>
<td>1,200 (1100 to 1400)</td>
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<tr>
<td>Revenues</td>
<td>[Mio €/a]</td>
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<tr>
<td>annual revenues</td>
<td>224 (210 to 260)</td>
</tr>
<tr>
<td>specific revenues</td>
<td>1,200 (1100 to 1400)</td>
</tr>
</tbody>
</table>

Communication in typical ranges & orders of magnitude!

Own calculations based on Austrian feasibility study (Hofbauer et al. 2008)
Part B: Value Chain Assessment
Primary Energy & GHG Emissions

“2-platform (electricity & heat, syngas) biorefinery using wood chips for FT-biofuels, electricity, heat and waxes with steam gasification”

Own calculations based on Austrian feasibility study (Hofbauer et al. 2008)
Part B: Value Chain Assessment
Cost and Revenues

“2-platform (electricity & heat, syngas) biorefinery using wood chips for FT-biofuels, electricity, heat and waxes with steam gasification”

Own calculations based on Austrian feasibility study (Hofbauer et al. 2008)
Annex: Methodology

Based on

- Whole value chain
- Life cycle
- Functional unit: „Product basket“
- Comparison to reference system
### Annex: Data and Assumptions

#### Heating Value

<table>
<thead>
<tr>
<th>Product</th>
<th>Heating Value [GJ/t]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rape seed cake</td>
<td>18.65</td>
</tr>
<tr>
<td>Glycerin</td>
<td>16.00</td>
</tr>
<tr>
<td>Rape seed oil</td>
<td>36.00</td>
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<tr>
<td>Cooking oil</td>
<td>35.28</td>
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<tr>
<td>DDGS</td>
<td>16.00</td>
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<tr>
<td>Bio oil</td>
<td>21.80</td>
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<tr>
<td>Biodiesel</td>
<td>37.20</td>
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<tr>
<td>Bioethanol</td>
<td>26.81</td>
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<tr>
<td>FT-biofuel</td>
<td>42.00</td>
</tr>
<tr>
<td>FT-diesel</td>
<td>42.00</td>
</tr>
<tr>
<td>FT-gasoline</td>
<td>40.00</td>
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<tr>
<td>Waxes</td>
<td>43.00</td>
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<tr>
<td>District heat</td>
<td></td>
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<tr>
<td>Methanol</td>
<td>19.90</td>
</tr>
<tr>
<td>Potassium sulphate (K2SO4)</td>
<td>0,00</td>
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<tr>
<td>Phenols</td>
<td>40.50</td>
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<tr>
<td>Pellets</td>
<td>19.78</td>
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### GHG Emissions

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<tr>
<th>GHG</th>
<th>Energy Consumption</th>
<th>Substitution Factor</th>
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<tr>
<td>kt CO2-eq/a</td>
<td>PJJosual/a</td>
<td>PJJbiomass/a</td>
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<tr>
<td>Gasoline</td>
<td>362.4</td>
<td>4.66</td>
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<tr>
<td>Electricity</td>
<td>37.3</td>
<td>0.6</td>
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<tr>
<td>Con. Phenols</td>
<td>11.8</td>
<td>0.1</td>
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### Yield

<table>
<thead>
<tr>
<th>Product</th>
<th>Yield [MJEthanol / MJCorn]</th>
</tr>
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<tbody>
<tr>
<td>Ethanol</td>
<td>0.515724</td>
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<tr>
<td>Co-product DDGS</td>
<td>1.39 tonDDGS / tonEthanol</td>
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<td>Ethanol</td>
<td>3.909 twood DM / EIOH</td>
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<td>Co-product phenols</td>
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<td>Intermediate lignin</td>
<td>2600 GJ / EIOH</td>
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### Energy Consumption

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<thead>
<tr>
<th>Product</th>
<th>Energy Consumption [PJ]</th>
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<tbody>
<tr>
<td>Electricity (NG CCGT)</td>
<td>0.08 MJ / MJEthanol</td>
</tr>
<tr>
<td>Steam (from NG CHP)</td>
<td>0.68 MJ / MJEthanol</td>
</tr>
</tbody>
</table>

### Other Energy Share (%)

- 0.020

### Life Time (a)

- 20

### Calculated Interest Rate [%]

- 7%

### Personal Costs [€/(Person*a)]

- 45,000

### Insurance [% of Investment]

- 0.01

### Maintenance Costs [% of Investment]

- 0.03

### Waste Water Treatment [€/m³]

- 0

### Transport Distance “End of Life” Biochemicals [km]

- 200

### Collecting Rate Biochemicals

- 70%

### Refining

- Rapeseed oil 0.9600 MJOil / MJOil
- Electricity EU mix MV 0.0008 MJ / MJOil
- Steam (from NG boiler) 0.0115 MJ / MJOil
- Fuller’s earth 0.0002 MJ / MJOil

### Extratification

- FAME 0.9782 MJFAME / MJOil
- Co-product refined glycerol 0.0432 MJ / MJFAME
- Co-product bio-oil 0.0195 MJ / MJFAME
- Co-product Potassium sulphate (K2SO4) 0.1747 MJ / MJFAME
- Phosphoric acid (H3PO4) 0.0005 kg / MJFAME
- Potassium hydroxide (KOH) 0.0005 kg / MJFAME
- Methanol 0.0847 MJ / MJFAME

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<tr>
<td>Electricity for EIOH</td>
<td>0.050 GJ / EIOH</td>
</tr>
<tr>
<td>Heat for phenol</td>
<td>3,150 twood DM / Pellets</td>
</tr>
<tr>
<td>Heat for EIOH</td>
<td>2,600 GJ / EIOH</td>
</tr>
<tr>
<td>Potassium hydroxide (KOH)</td>
<td>0.216 GJ / EIOH</td>
</tr>
<tr>
<td>Methanol</td>
<td>18,000 GJ / EIOH</td>
</tr>
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Biorefinery Fact Sheet: Example

Outlook
Comparison of Biorefineries

Fact Sheet Biorefinery 1

Fact Sheet Biorefinery 2

Fact Sheet Biorefinery 3
Aims of IEA Bioenergy Task 42

The framework of the activities of IEA Bioenergy Task 42 is the sustainable processing of biomass into a spectrum of Biobased Products and Bioenergy.

The aims of Task 42 are:

1. Assess the worldwide position and potential for biorefineries.
2. Gather new insights for the simultaneous production of human food, animal feed, chemicals, materials, fuels, power and/or heat from biomass in a socially and environmentally acceptable and economically profitable way.

More about IEA Bioenergy and Task 42 partners
Workshop Announcement

The Role of Biorefinery in a Future BioEconomy

Austrian Stakeholder Workshop of IEA Bioenergy Task 42 “Biorefining”

Graz/Austria
October 24, 2013
Conclusions

**Stepwise publication** of Biorefinery fact sheets to stimulate discussion by Task 42

**Data collection** for various international biorefinery systems is ongoing (incl. Syngas-Biorefineries)

**Biorefinery fact sheet** gives facts & figures on biorefinery plant and value chain sustainability assessment

We need common format for **facts & figures** of biorefineries for developing technologies and systems for a future BioEconomy

Biorefineries with **Syngas** from wood and straw for **FT-biofuels and biomethane** have key role for Biobased Economy

Selection of interesting “**Biofuel-driven Biorefineries**” for Biobased Economy 2025 by IEA Bioenergy Task 42 “Biorefinery”

**Classification of biorefineries** via 4 features: platforms, products, feedstocks, processes