Techno-Economic Assessment of Polygeneration based on Fluidized Bed Gasification

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Overview

- Background and Motivation: the FABIENE project
- Scope of this investigation
- Assumptions
- Results
- Outlook
Motivation

- Polygeneration
  - Concept for production of electricity and fuels/chemicals in the same plant

- Fluctuating renewable sources (wind, solar)
  - Other generating resources must be able to accommodate
  - Resulting in low capability factors for conventional power generation

- Reduction of GHG emissions
  - Highly efficient power production
  - Part of the carbon is stored in the produced chemicals
  - Possibility to integrate pre-combustion carbon capture
FABIENE Project

- Development of a polygeneration plant
  - Highly efficient IGCC process
  - Possible fuels/chemicals: Fischer-Tropsch fuels, methane, methanol, ammonia, …

- Experimental investigation in pilot scale
  - 4 two-week test campaigns
  - Dynamic optimization of load changes (power ↔ fuels)
Scope of this investigation

Implementation of a polygeneration process model in ASPEN Plus
- Commercial scale
- Including all high-energy demanding process steps

Investigation of possible process optimizations, e.g.
- Influence of pre-drying level
- Integration of hydrogen from renewable sources via electrolysis

Assessment of the process with several KPIs
- Part of the carbon is stored in the produced chemicals
- Possible integration of pre-combustion carbon capture
Model Assumptions
Model Assumptions – Feedstock

- Rhenish lignite

<table>
<thead>
<tr>
<th>Element</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>54</td>
<td>wt.% (as received)</td>
</tr>
<tr>
<td>Fixed carbon</td>
<td>36</td>
<td>wt.% (dry basis)</td>
</tr>
<tr>
<td>Volatile matter</td>
<td>44</td>
<td>wt.% (dry basis)</td>
</tr>
<tr>
<td>Ash</td>
<td>20</td>
<td>wt.% (dry basis)</td>
</tr>
</tbody>
</table>
Model Assumptions – Gasification Unit

- Fluidized Bed Drying
  - stationary fluidized bed with low expansion with internal heat reinjection
  - Operation conditions: 1.1 bar; 180 °C steam

Source: RWE „WTA TECHNOLOGY - A modern process for treating and drying lignite“, 2009
Model Assumptions – Gasification Unit

- High temperature Winkler (HTW©) gasifier
  - Pressure: 30 bar
  - Temperature after the post gasification zone: 1000 °C
  - Carbon Conversion: 96 %
Model Assumptions – Gas Purification

- Syngas Cooling and Scrubbing
  - Gas saturated at 150 °C

- CO-Shift Unit
  - H₂:CO ratio adjusted for designated product
  - No adjustment for power with carbon capture
  - 2:1 for methanol
  - 20:1 for power with carbon capture

- Acid gas removal
  - Rectisol Process
  - Designed for syngas purity of 3 Mol-% CO₂ und 0,1 ppm H₂S
  - Solvent flow is adjusted for different operation points
Model Assumptions – Flexible Production

- Methanol Synthesis
  - 50 bar, 185 °C

- Gas Turbine for Syngas Combustion
  - Gas dilution with nitrogen from ASU and steam
  - 1500 °C, $\lambda = 1.2$

- HRSG and steam cycle from Prai CC Power Station, Malaysia
  - Validated process model
Model Assumptions – Auxiliary Units

- Not modelled within ASPEN, integrated via their specific energy demand

- Air Separation Unit
  - 0.2 kWh/kg O\textsubscript{2}

- Electrolysis
  - Power demand of 100 kWh/Nm\textsuperscript{3}
  - Alkaline electrolyzer
Methodology

- Heat integration into steam cycle with exergy balance
  - Exergetic efficiency of the steam cycle: 59 %

- Calculation of different operation points
  - Different plant configurations
  - Different pre-drying levels
  - Integration of renewable hydrogen

Plant Configurations

- Remaining Moisture after Predrying
  - 5 wt.-%
  - 16 wt.-%
  - 25 wt.-%

- Power Production w/ CCS
- Power Production w/o CCS
- Methanol Synthesis w/ CO-Shift
- Methanol Synthesis w/ Electrolyzer
Results

Assessment

Technical/Energetic
- Cold Gas Efficiency
- Thermal Efficiency
- Stored Carbon

Ecological
- Feed specific emissions
- Product specific emissions

Economical
- Product revenue comparison
Results – Emissions

- Methanol w/ CO-Shift:
  - captured: 2000 g CO₂/kg CH₃OH
  - stored in product: 2000 g CO₂/kg CH₃OH
  - emitted: 2000 g CO₂/kg CH₃OH

- Methanol w/ Electrolysis:
  - captured: 2000 g CO₂/kg CH₃OH
  - stored in product: 2000 g CO₂/kg CH₃OH
  - emitted: 2000 g CO₂/kg CH₃OH

- Power w/ CCS:
  - 110 g CO₂/kg coal

- Power w/o CCS:
  - 890 g CO₂/kg coal

- Methanol Synthesis:
  - 210 g CO₂/kg coal

- 16 % remaining moisture
**Results – Economics**

**Inversion Curve**

X Current Price

**CO₂ allowance:** 15 €/t  
**Methanol:** 408 €/t  
**Electricity:** 40 €/MWh

- **Assumptions:**
  - Only cost of allowances and products vary
  - Fixed operational costs and invest are constant
  - Constant fuel feed

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**Price ratio of power to CO₂ allowances [€/kWh per €/kg]**

**Price ratio of methanol to CO₂ allowances [€/kg per €/kg]**

- Power production favored
- Methanol production favored
Conclusion & Outlook

Conclusion:

- The polygeneration process based on the HTW gasification was investigated with a process model
- Polygeneration is a feasible approach for significantly limiting the GHG emissions while still be able to use abundantly available fossil resources
- The relevant prices are in a range, where power production becomes feasible during times of high energy demand

Outlook:

- The investigation will be supplemented with further possible products (SNG, FT-Fuels, OME)
- LOE will be calculated
Acknowledgement

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