In-Situ CO$_2$ Capture in a Dual Fluidized Bed Biomass Gasifier. Experiences in pilot and demonstration mode.

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Content

- Description of the process
- Cold flow modelling
- Experience from a 100 kW\textsubscript{th} pilot plant
- Experience from a 8 MW\textsubscript{th} demonstration plant
- Conclusions
Dual fluidised bed gasification process

**Institute of Chemical Engineering**

**Working group: Future Energy Technology**

- **Producer Gas**
  - (CH₄, CO, H₂, CO₂, H₂O)

- **Gasification** (~ 850 °C)
- **Combustion** (~ 920 °C)

- **Flue gas**

- **Biomass**
- **Steam**
- **Circulation** (bed material, char coal)
- **Air**

**Heat**

**Add. fuel**

**Principle of the process**
### Dual fluidized bed gasification process

![Diagram of the dual fluidized bed gasification process](image)

**Bed material:** Olivine

<table>
<thead>
<tr>
<th>Component</th>
<th>Conventional process</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂O, vol%</td>
<td>30…45</td>
</tr>
<tr>
<td>CH₄, vol%db</td>
<td>10…11</td>
</tr>
<tr>
<td>C₂H₄, vol%db</td>
<td>2…2.5</td>
</tr>
<tr>
<td>C₃-Fract., vol%db</td>
<td>0.5…0.7</td>
</tr>
<tr>
<td>CO, vol%db</td>
<td>24…26</td>
</tr>
<tr>
<td>CO₂, vol%db</td>
<td>20…22</td>
</tr>
<tr>
<td>H₂, vol%db</td>
<td>38…40</td>
</tr>
<tr>
<td>Tar g/m³ₙ db</td>
<td>2…5</td>
</tr>
<tr>
<td>LHV MJ/m³ₙ db</td>
<td>12.9…13.6</td>
</tr>
</tbody>
</table>
Equilibrium partial pressure of CO₂ for the calcinations of MgO and CaO

\[ \text{MgO} + \text{CO}_2 \rightleftharpoons \text{MgCO}_3 \]
\[ \text{CaO} + \text{CO}_2 \rightleftharpoons \text{CaCO}_3 \]

Temperature [°C] vs. Equilibrium CO₂ partial pressure [bar]
Absorption enhanced reforming (AER) principle

Principle of the process

- **Producer gas (H₂-rich)**
- **Flue gas (+CO₂)**
- **Gasification + carbonation**: Biomass (600...700°C) to Producer gas, CaO, CaCO₃ circulation (bed material, char coal)
- **Combustion + calcination**: Flue gas to Combustion, CaO, CaCO₃ circulation (bed material, char coal)
- **Heat**
- **Add. fuel**

**Steam**

- Circulation (bed material, char coal)

**Air**
Dual fluidized bed cold model

- Full set of scaling criteria applied
- Hot conditions: 850-950°C, atmospheric pressure, olivine particles
- Cold flow model: air, ambient temperature and pressure
- Linear scale 1:4
- Bronze particles in CFM
Dual fluidized bed cold model

- Filter tube
- Cyclone
- Gasifier
- Connecting chute
- Steam 1
- Steam 2
- Air (from blower)
- Secondary air
- Primary air
- Bottom air
- Air (from compressor)
- Pressure reducing valve (10 bar to 400 mbar)
Circulation rate depending on fluidisation of the combustion zone

- Bottom air 5 (Nm³/h)
- Bottom air 10 (Nm³/h)
- Bottom air 20 (Nm³/h)
Circulation rate depending on the bed material size

- **large (950µm)**
- **medium (750µm)**

**Graph:**
- Vertical axis: Circulation rate [kg/m²s]
- Horizontal axis: Ratio sec. / total air
- Two lines representing large and medium bed material sizes
- Data points indicating the relationship between circulation rate and ratio sec. / total air.
Flow sheet of the 100kW\textsubscript{th} pilot plant
Overview gas composition

Product Gas - Average Concentration [vol% db]

- Olivine*
- C14
- C1 10% CO2
- C1 18% CO2
- C1
- C35
- C38

* Standard gasification

CO2
CO
CH4
H2

69.9 % 69.2 % 65.3 % 62.2 % 60.6 % 58.9 % 37.8 %
Tar values: standard gasification vs. AER gasification

According to the tar protocol EEN5-1999-00507
**Tar composition: standard gasification vs. AER gasification**

**Bed material:** Olivine  
**Gasification Temperature:** 850°C  
**Fuel:** Wood pellets

**Bed material:** Calcite  
**Gasification Temperature:** 660°C  
**Fuel:** Wood pellets
Combined heat and power (CHP) plant in Guessing/Austria

<table>
<thead>
<tr>
<th>Power Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel power</td>
<td>8 MW</td>
</tr>
<tr>
<td>Electrical power</td>
<td>2 MW</td>
</tr>
<tr>
<td>Thermal power</td>
<td>4.5 MW</td>
</tr>
<tr>
<td>Operation hours gasifier</td>
<td>38,000 h</td>
</tr>
<tr>
<td>CHP operation</td>
<td>33,000 h</td>
</tr>
</tbody>
</table>
Flowsheet of the biomass CHP
AER operation

- Temp. Siphon
- Temp. combustion zone
- Bedtemp. gasifier
- Generator output
- Biomass feeding screw
- Pressure drop gasification zone

Graph showing temperature, percentage, and electrical output over time.
Cumulative distribution of the Greek Calcite before and after experiment

Product gas composition [vol-%, dry]

- H₂
- CO
- CH₄
- CO₂
- CₓHᵧ [a]

Time [h] - steady state

Temperature [°C]

Gasification temperature
Gasification temperature vs. CO₂ content in product gas
CO content vs. H₂ content in product gas

CO-Shift reaction: \[ CO + H₂O \rightleftharpoons CO₂ + H₂ \]
Typical producer gas composition ranges for conventional dual fluidized bed steam gasification and AER process.
Conclusions

- High $\text{H}_2$ contents in producer gas
- Low tar contents in the producer gas despite low gasification temperature
- Calcite reactivity is high enough for long term operation
- Bed material attrition is not critical
- Higher gas generation efficiency because of lower gasification temperatures
Thank you for your attention!

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Project web page: www.aer-gas.de

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