Co gasification of biomass and lignite

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Biomass gasification and SNG production

• Natural gas is the main source of energy in the Netherlands and fossil natural gas reserves are in decline -> renewable alternative required.

• SNG has many applications: Heat and electricity production, feedstock for chemical industry and recently as a transport fuel.

• Biomass will become expensive, so a high overall efficiency from biomass (wood) to fuel is required. Efficiency Substitute Natural Gas up to 70%.
Simplified Bio-SNG system
Expected yields ECN Bio-SNG concept commercial scale

MILENA gasifier

OLGA gas cleaning
Why co gasification with coal?

• Coal is cheaper than biomass and therefore a combination of the two will increase the economic margin of an SNG production facility.
• Coal is still abundantly available and can help the start up of SNG production facilities.
• Coal might simplify the SNG production facility.
• ECN develops a fuel flexible gasifier, therefore testing different fuels is necessary.
Experimental work

MILENA

Riser

Wood
Lignite

Primary air & CH₄
Secondary Air
Gas + Solids
Solids

Screw feeder
Steam

Flue gas to flare
Product gas to flare
Ash

Combustor
## Experimental settings

<table>
<thead>
<tr>
<th></th>
<th>[nl/min]</th>
<th>99</th>
<th>119</th>
<th>119</th>
<th>119</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary air combustor</td>
<td></td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>Secondary air combustor</td>
<td></td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Methane combustor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beech wood chips</td>
<td>[gram/h]</td>
<td>5900</td>
<td>4200</td>
<td>2000</td>
<td>2000</td>
</tr>
<tr>
<td>Lignite</td>
<td>[gram/h]</td>
<td></td>
<td>1655</td>
<td>2440</td>
<td>2440</td>
</tr>
<tr>
<td>Percentage of brown coal</td>
<td>[%]</td>
<td>0</td>
<td>28</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>Steam on the riser</td>
<td>[kg/h]</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>N₂ on the riser</td>
<td>[nl/min]</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>CO₂ on the feeding screw</td>
<td>[nl/min]</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>
Day 1 – 28% lignite co gasification

![Graph showing gas concentrations and temperature over time]

- **CO**
- **H₂**
- **CO₂**
- **CH₄**
- **T_{gasifier}**
- **O₂-combustor**

Gas concentration vol %

- 800
- 820
- 840
- 860
- 880

Temperature °C

- 800
- 820
- 840
- 860
- 880
- 900

Time

- 9:30
- 10:42
- 11:54
- 13:06
- 14:18
- 15:30
Effect of lignite on tar

The figure shows the effect of increasing amounts of lignite on tar concentration. The x-axis represents the amount of lignite added, with 0%, 28%, 55%, and 55% indicated. The y-axis shows the tar concentration in mg/Nm³.

- **Total tar**
- **Class 4 tar**
- **Unknown tar**
- **Class 2 tar**
- **Class 5 tar**
- **Class 3 tar**

The graph indicates:
- **16% reduction** in tar concentration for 28% lignite addition.
- **47% reduction** in tar concentration for 55% lignite addition.
- **50% reduction** in tar concentration for 55% lignite addition.

This suggests that lignite is effective in reducing tar concentration in the processes being studied.
### Gasifier mass balance

<table>
<thead>
<tr>
<th>Percentage of brown coal</th>
<th>[%]</th>
<th>0</th>
<th>28</th>
<th>55</th>
<th>55</th>
</tr>
</thead>
<tbody>
<tr>
<td>C in CO / C in fuel</td>
<td>[wt. %]</td>
<td>35.8%</td>
<td>30.2%</td>
<td>24.1%</td>
<td>25.0%</td>
</tr>
<tr>
<td>C in CO2 / C in fuel</td>
<td>[wt. %]</td>
<td>18.3%</td>
<td>20.2%</td>
<td>23.6%</td>
<td>27.0%</td>
</tr>
<tr>
<td>C in CH4 / C in fuel</td>
<td>[wt. %]</td>
<td>11.7%</td>
<td>10.3%</td>
<td>8.5%</td>
<td>8.6%</td>
</tr>
<tr>
<td>C in C2H2 / C in fuel</td>
<td>[wt. %]</td>
<td>0.8%</td>
<td>0.7%</td>
<td>0.4%</td>
<td>0.4%</td>
</tr>
<tr>
<td>C in C2H4 / C in fuel</td>
<td>[wt. %]</td>
<td>8.9%</td>
<td>7.5%</td>
<td>6.1%</td>
<td>5.0%</td>
</tr>
<tr>
<td>C in C2H6 / C in fuel</td>
<td>[wt. %]</td>
<td>0.7%</td>
<td>0.5%</td>
<td>0.4%</td>
<td>0.2%</td>
</tr>
<tr>
<td>C in C6H6 / C in fuel</td>
<td>[wt. %]</td>
<td>4.9%</td>
<td>4.8%</td>
<td>4.3%</td>
<td>4.6%</td>
</tr>
<tr>
<td>C in C7H8 / C in fuel</td>
<td>[wt. %]</td>
<td>0.9%</td>
<td>0.8%</td>
<td>0.7%</td>
<td>0.4%</td>
</tr>
<tr>
<td>C in tar</td>
<td>[wt. %]</td>
<td>5.1%</td>
<td>4.4%</td>
<td>2.9%</td>
<td>2.6%</td>
</tr>
<tr>
<td>C in char</td>
<td>[wt. %]</td>
<td>14.5%</td>
<td>22.4%</td>
<td>30.9%</td>
<td>28.1%</td>
</tr>
<tr>
<td>H in H2 / H in fuel</td>
<td>[wt. %]</td>
<td>15.2%</td>
<td>20.8%</td>
<td>40.1%</td>
<td>44.5%</td>
</tr>
<tr>
<td>Carbon conversion [%]</td>
<td></td>
<td>85.5%</td>
<td>77.6%</td>
<td>69.1%</td>
<td>71.9%</td>
</tr>
<tr>
<td>Gasifier temperature [°C]</td>
<td></td>
<td>757</td>
<td>776</td>
<td>776</td>
<td>801</td>
</tr>
<tr>
<td>CO shift equilibrium temp.</td>
<td>[°C]</td>
<td>2252</td>
<td>1342</td>
<td>1005</td>
<td>895</td>
</tr>
<tr>
<td>ER gasifier [-]</td>
<td></td>
<td>0.096</td>
<td>0.093</td>
<td>0.095</td>
<td>0.110</td>
</tr>
</tbody>
</table>

| [vol.% wet] | CO | 21.5% | 19.1% | 14.5% | 14.8% |
| [vol.% wet] | H2 | 12.3% | 17.7% | 22.6% | 24.7% |
| [vol.% wet] | CO2| 10.9% | 12.7% | 14.1% | 15.9% |
| [vol.% wet] | O2 | 0.0%  | 0.0%  | 0.0%  | 0.0%  |
| [vol.% wet] | H2O| 42.1% | 37.8% | 38.4% | 34.9% |
| [vol.% wet] | CH4| 7.0%  | 6.5%  | 5.1%  | 5.1%  |
| [vol.% wet] | Ar | 0.0%  | 0.0%  | 0.0%  | 0.0%  |
| [vol.% wet] | C2H2| 0.2%  | 0.2%  | 0.1%  | 0.1%  |
| [vol.% wet] | C2H4| 2.6%  | 2.4%  | 1.8%  | 1.5%  |
| [vol.% wet] | C2H6| 0.2%  | 0.1%  | 0.1%  | 0.1%  |
| [vol.% wet] | C6H6| 0.5%  | 0.5%  | 0.4%  | 0.4%  |
| [vol.% wet] | C7H8| 0.1%  | 0.1%  | 0.1%  | 0.0%  |
| [vol.% wet] | N2 | 2.5%  | 2.9%  | 2.7%  | 2.4%  |
Summary of the tests

• Lower carbon conversion, due to less volatiles in lignite
• Less tar production, due to less complex fuel will improve the gas cleaning line up
• Increase in sulphur – incomplete S balance – impact on the gas cleaning is unknown
• Co gasification of biomass and lignite is possible in the indirect gasifier MILENA
Bio-SNG CO₂ performance
1GW\textsubscript{th input} bio SNG plant

- 35 w-% Lignite \rightarrow Saves \sim 30 \text{ M\euro} on feed costs
- 35 w-% Lignite \rightarrow Reduces tar concentrations with \sim 30\%
- 35 w-% Lignite \rightarrow Will change gas compositions and impurities. Need for a different gas cleaning?
- 35 w-% Lignite \rightarrow Overall CO\textsubscript{2} balance is 0\% extra emissions to the environment.
Transport fuel - Policy

- UK 5% in 2013-2014
- US 36 billion gallons in 2022
- NL 4% in 2010
- EU P10% in 2020 and 25% in 2030

Transport fuel - Prices

- NL as Substitute Natural Gas → 6 €/GJ
- NL as Compressed Natural Gas → 20 €/GJ
Conclusions

- Co gasification of lignite and biomass is possible for more than 50 w-% of lignite
- 35 w-% lignite is identified as the optimum regarding CO$_2$ emissions
- Co gasification reduces the amount of tar
- Producing SNG as a transport fuel in combination with co gasification of lignite and biomass seems to be the best economical option
MORE INFORMATION

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