Boosting the production of liquid biofuels through the addition of renewable hydrogen

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1. IEA Bioenergy Task 33
2. Thermal biomass gasification
3. Liquid biofuels
   • FT liquids
   • Gasoline
4. Economics
5. Conclusions
Participating countries
- Austria
- Germany
- Denmark
- Italy
- Netherlands
- Norway
- Sweden
- Switzerland
- USA

Task leader
Prof. Kevin Whitty
University of Utah, USA
Task 33 – actual projects

• SP1: Waste gasification
• SP2: Fuel pretreatment for gasification systems
• SP3: Biomass gasification for CCUS
• SP4: Biomass gasification success stories
• SP5: Gasification-based hybrid systems
• SP6: Hydrogen production via gasification
• SP7: Biomass and waste gasification status report
• SP8: Biomass gasification history and lessons learned
• SP9: Valorization of byproducts from small scale gasification
• SP10: Gas analysis report
Task 33 – actual projects

Gasification-based hybrid systems

Aim: Optimal utilization of renewable electricity surplus (solar- and wind energy) in combination with thermal biomass gasification for increase of production of gaseous and liquid fuels.

Gasification as a carbon source together with renewable hydrogen from surplus electricity for production of gaseous and liquid fuels.

-Power to Gas (PtG)
Focus on hydrogen and methane

-Power to Liquids (PtL)
Focus on FT products and methanol
Thermal biomass gasification as a source of carbon for electrofuels production

Biomass as feedstock \(\rightarrow\) Gasification \(\rightarrow\) Product gas

For the conversion of biomass to transportation fuels there is too less hydrogen and too much oxygen in the feedstock. \(\text{C}_1\text{H}_{1.44}\text{O}_{0.66}\)

Most fuels have composition \(-(\text{CH}_2)_n\)-

This results in lower efficiencies compared to e.g. natural gas as feedstock.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Air gasification</th>
<th>Oxygen gasification</th>
<th>Steam gasification</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Fixed bed</td>
<td>Entrained flow</td>
<td>Fluidized bed</td>
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<tr>
<td>CO</td>
<td>Vol. % 13-18</td>
<td>45-55</td>
<td>25-30</td>
</tr>
<tr>
<td>CO(_2)</td>
<td>Vol. % 12-16</td>
<td>10-15</td>
<td>20-25</td>
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<tr>
<td>H(_2)</td>
<td>Vol. % 11-16</td>
<td>23-28</td>
<td>35-40</td>
</tr>
<tr>
<td>CH(_4)</td>
<td>Vol. % 2-6</td>
<td>0-1</td>
<td>9-11</td>
</tr>
<tr>
<td>N(_2)</td>
<td>Vol. % 45-60</td>
<td>0-1</td>
<td>0-5</td>
</tr>
<tr>
<td>Calorific value</td>
<td>MJ/Nm(^3)</td>
<td>4-6</td>
<td>10-12</td>
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Synthesis gas utilization
Synthesis gas utilization

Diagram showing the utilization of synthesis gas from dry biomass, including:
- FT-Fuels (FT-Diesel)
- Mixed alcohols
- Methanol / DME
- Combined Heat and Power (gas engine, gas turbine, fuel cell)
- High Temperature Heat (lime kiln, industry)
- Co-Firing
From synthesis gas to FT products

• Synthesis gas – H₂ and CO mixture
• For FT synthesis necessary ratio H₂:CO = 2:1

• Surplus carbon in product gas is not used in the synthesis process, as there is not enough hydrogen for the conversion

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Boosting the production with external hydrogen - Fischer Tropsch products

Using of additional (external) hydrogen the FT products amount could be doubled

Advantages:
- Conversion of surplus electricity and surplus carbon to high valuable products
- Higher carbon utilization
- Biomass acts as base load (8000 oph/y possible), no start-stop operation, only load change
Advantages of this concept:

- As the H\textsubscript{2} should come from excess electricity, the Winddiesel plant that is based on biomass gasification and Fischer Tropsch synthesis can be operated in its main parts with high annual operating hours.
- The addition of H\textsubscript{2} from excess electricity brings a surplus in product yield and conversion rate of the used biomass but is not necessary for the synthesis process.

The additional CO\textsubscript{2}, which is used as a fluidizing agent together with steam causes the shift of H\textsubscript{2} : CO ratio in favor of CO, thus the ratios between 0,5:1 and 1,9:1 can be achieved.
Synthesis gas utilization
Methanol production

Methanol could be produced according to
\[ \text{CO}_2 + 3 \text{H}_2 \rightarrow \text{CH}_3\text{OH} + \text{H}_2\text{O} \]
\[ \text{CO} + 2 \text{H}_2 \rightarrow \text{CH}_3\text{OH} \]

Disadvantages:
- No existing infrastructure for direct usage in transportation sector
- For the production process of renewable methanol, it is necessary to consider:
  - storage of hydrogen
  - production, storage and distribution of methanol
  - methanol utilization
Methanol production

Advantages:
- Relatively simple and efficient production
- It is possible to convert methanol to gasoline

\[ n\text{CH}_3\text{OH} \rightarrow (\text{CH}_2)_n + n\text{H}_2\text{O} \]

Gasoline can be used immediately in existing infrastructure
Boosting the production with external hydrogen
- Gasoline

Configurations
- Allothermal gasif./steam
- Autothermal gasif./steam+oxygen

Input
- 100 MW (LHV) of wet (50%) biomass (5,92 kg/s of dry biomass)

Output gasoline
Steam gasification
- 51,0 MW / 98,0 MW

Oxygen gasification
- 51,8 MW / 134,0 MW
Boosting the production with external hydrogen - Gasoline

By an external hydrogen source following maximal fuel output could be achieved:

- 1,9 – fold for steam gasification
- 2,6 – fold for oxygen gasification

Overall carbon conversion for enhanced configurations:

- 58,4 % for steam gasification
- 79,4 % for oxygen gasification

Economically feasible over base case when hydrogen cost is lower than:

- 2,7 €/kg for steam gasification
- 2,8 €/kg for oxygen gasification
Economics

Important parameters influencing the electrofuel price:

- Costs of renewable hydrogen
- Costs of biomass
- Size of gasification unit
- Number of operating hours
- Heat utilization
- Usage or selling of oxygen from electrolysis
- Subsidy
Conclusions

• Thermal gasification as a source of carbon for electrofuels production offers a great possibility of technologies and products synergies

• Renewable hydrogen access is not essential for the gasification process but boosts the amount of final product (fuel) significantly

Price of electrofuels is still higher as of fossil ones, but what price do we really pay for fossils?
Thank you very much for your attention