GoBiGas – 10 000 Hours of Operation

Anton Larsson
IEA FBC and IEA Bioenergy Task 33 – joint workshop
2017-10-24
Our owners say:

“Göteborg Energi shall actively contribute to the development of a sustainable Göteborg”

Our tools:
- Infrastructure
- Recycling of energy
- Innovative technology
- Innovative business models

Göteborg is mainly heated with recycled energy
GoBiGas is: The world’s first large-scale plant for production of bio-methane from biomass through gasification.

Swedish Energy Agency invested 222 million SEK

<table>
<thead>
<tr>
<th>Estimated Production</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Biogas</td>
<td>160 GWh/y</td>
</tr>
<tr>
<td></td>
<td>20 MW</td>
</tr>
<tr>
<td>District heating</td>
<td>50 GWh/y</td>
</tr>
<tr>
<td></td>
<td>5 MW</td>
</tr>
<tr>
<td>Heat to heat pumps</td>
<td>6 MW</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Estimated Consumption</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass</td>
<td>32 MW</td>
</tr>
<tr>
<td>Electricity</td>
<td>3 MW</td>
</tr>
<tr>
<td>RME (bio-oil)</td>
<td>0.5 MW</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Performance Goals</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass to Biogas</td>
<td>&gt; 65 %</td>
</tr>
<tr>
<td>Total efficiency</td>
<td>&gt; 90%</td>
</tr>
<tr>
<td>Operation</td>
<td>8000 h/y</td>
</tr>
</tbody>
</table>
GoBiGas – step by step to commercialization

Chalmers Lab reactors

“Chalmers gasifier” Chalmers 2-4 MW Pilot plant

GoBiGas Stage 1 20 MW biogas Demonstration plant

GoBiGas Stage 2 80-100 MW biogas Commercial plant

2008 2012 2016
The GoBiGas process

- Removal of light tar
- Gas cooling, removal of particles and tar
- Gasification
- Flue gas train
- Hydrogenation of olefines and COS
- H2S scrubber
- WGSR & Pre-methanation
- CO2 scrubber
- Methanation
- Drying and compression
Operation of the GobiGas-Gasifier

Limiting factors:
- Tar
- Feeding screw
- Alkali balance

Fuel feed, fuel availability

Operational Hours [h]

Operational Hours, Accumulated [h]
# GoBiGas Performance with Different Fuels

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Pellets</th>
<th>Wood chips</th>
<th>Bark</th>
<th>Recovered Wood (A1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hours of operation (h)</td>
<td>&gt;8000</td>
<td>900</td>
<td>750</td>
<td>~80</td>
</tr>
<tr>
<td>Load</td>
<td>80-93%</td>
<td>55-70</td>
<td>40-70%</td>
<td>55-85%</td>
</tr>
<tr>
<td>Limiting factor</td>
<td>Carbon beds</td>
<td>Moisture, fuel feed - mechanical</td>
<td>Fuel feed - mechanical</td>
<td>Fuel feed - mechanical</td>
</tr>
<tr>
<td>Biomass to biogas efficiency</td>
<td>58-63%</td>
<td>40-55%</td>
<td>45-55%</td>
<td>45-55%</td>
</tr>
<tr>
<td>$\text{CO}_2\text{eq}$ reduction compared to gasloien/diesel (well-to-wheel)</td>
<td>80-85%</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
## Gas Quality with Different fuels

<table>
<thead>
<tr>
<th></th>
<th>Typical operation wood pellets</th>
<th>Typical operation wood chips</th>
<th>Typical operation bark</th>
<th>Typical operation Return wood (A1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasifier temp. (°C)</td>
<td>870-830</td>
<td>790-830</td>
<td>850-820</td>
<td>830</td>
</tr>
<tr>
<td>CO (%vol dry)</td>
<td>21-24</td>
<td>22-23</td>
<td>17-21</td>
<td>17-21</td>
</tr>
<tr>
<td>CO2 (%vol dry)</td>
<td>20-27</td>
<td>21-23</td>
<td>23-25</td>
<td>23-25</td>
</tr>
<tr>
<td>CH4 (%vol dry)</td>
<td>8.0-9.0</td>
<td>7.9-8.6</td>
<td>7.1-8.7</td>
<td>7.1-8.7</td>
</tr>
<tr>
<td>Tar (excluded BTX), (g/m\textsubscript{3} dry gas)</td>
<td>3.0-8.7</td>
<td>8.9-12.7</td>
<td>7.9-15.0</td>
<td>8.5-14</td>
</tr>
<tr>
<td>Tar (including BTX), (g/m\textsubscript{3} dry gas)</td>
<td>9.7-23.3</td>
<td>22.1-29.5</td>
<td>21.7-33.4</td>
<td>22-26</td>
</tr>
</tbody>
</table>

- The GoBiGas Gasifier can be operated with a wide variety of fuels with a stable gas quality.
- The temperature can be varied in the range of 790-870 °C with retained gas quality.
The gas quality (tar level) are controlled by adding potassium to the process. Specifically K₂CO₃ solved in water (40%) are added to the combustion side.

J. Marinkovic et.al, Characteristics of olivine as a bed material in an indirect biomass, Chemical Engineering Journal.
Alkaline Balance of the GoBiGas-Gasifier

- Alkaline in fuel
- Loss with product gas
- Loss with flue gas
- Addition of K$_2$CO$_3$ to control %CH$_4$
- Transport with the bed material
- Particles, Char, soot, ash
- Particles, ash
- Fly ash

Alkaline in fuel at 350°C, 830°C, 200°C, 900°C

Addition of K$_2$CO$_3$ to control %CH$_4$
Clogging of the Fuel Feeding

Feeding the fuel with a screw directly to the bubbling bed of the gasifier cause warm sand to enter the screw and start pyrolysis the fuel, which eventually clogs.

By Claes Breitholtz, Valmet AB
Film by Dr. Erik Sette och Rustan Hvitt, Chalmers Gasifier from above operating with wood pellets

Energiforsk Report: D. Pallares et.al. Char conversion in fluidized bed indirect gasification:  
Clogging of the Fuel Feeding

With sufficient “activation” of the bed material the bed height are of minor importance for gas quality.

By lowering the bed height the problems with the fuel feeding screw has bed reduced but not diminished.
Performance of the GoBiGas Gasifier and Extrapolation to a 100MW Commercial-Scale

- Efficiency can be increased with larger scale.
- Biomass to biogas efficiency >70% is possible
- Biomass to Syngas efficiency > 80% is possible
- Drying of the fuel is crucial


![Graph showing efficiency of GoBiGas gasifier performance](image-url)
Overview of the GoBiGas Plant Potential

Legend
- Current Process
- Optional Production
- Potential Byproducts
- Optional input

Biomass Raw Gas Syngas

Potential Byproducts
- BTX
- Phenol

Optional input
- Plastic, Recovered Materials
- Could reduce the production cost

Current Process

Optional Production

District heating Value in winter

Gasification

Raw Gas

Gas Cleaning

Synthesis

Syngas

BTX

Phenol

CO₂

Olefins

Electrolysis

PSA

H₂, CH₄

Up to 5-15 MW

H₂

Electrolysis

Biogas

Anton Larsson
Conclusions

• Good fuel-flexibility has been demonstrated.

• High efficiency (up to about 70% biomass to biogas) can be reach with dry fuels.

• With some modification on the fuel feed and product gas cooling the process is technically ready for commercialization.

• Increased understanding of the function of potassium as well as the tar chemistry are required to optimize the gasification process and gas cleaning.