SMALL SCALE UPGRADEX AND BUSINESS MODELS

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Why biogas upgrading at small scale biogas plants?

- Often hard to valorize all the heat that is produced at a small scale biogas plant
- Low electricity price – hard to achieve profitability
- Farmers are interested in energy autonomy to be in full control of in-put costs
- Significant need to reduce emissions in the transportation sector (GHG, particles, NOx)
When we did a scan in early 2016 we found these eight technology suppliers/developers in this space + ourselves.

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Technology</th>
<th>Approximate plant size [MWh/year]</th>
<th>Raw biogas flow [Nm³/h]</th>
<th>Specific cost [EUR/MWh]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biorega¹</td>
<td>Water scrubber</td>
<td>1000</td>
<td>19</td>
<td>65</td>
</tr>
<tr>
<td>Biosling²</td>
<td>Water scrubber</td>
<td>4500</td>
<td>86</td>
<td></td>
</tr>
<tr>
<td>Metener³</td>
<td>Water scrubber</td>
<td>600</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Neo-Zeo⁴</td>
<td>PSA</td>
<td>3100</td>
<td>59</td>
<td></td>
</tr>
<tr>
<td>Blue BONSAI</td>
<td>Membrane separation</td>
<td>100</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>MemfoACT AS⁵</td>
<td>Membrane separation</td>
<td>600</td>
<td>11</td>
<td>46</td>
</tr>
<tr>
<td>Biofrigas</td>
<td>Kryogenic separation</td>
<td>2200</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>Xebec</td>
<td>PSA/membrane</td>
<td>1000</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>JTI</td>
<td>In-situ methane enrichment</td>
<td>2600</td>
<td>49</td>
<td>15</td>
</tr>
<tr>
<td>JTI³</td>
<td>Ash filter</td>
<td>500</td>
<td>10</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1000</td>
<td>19</td>
<td>23</td>
</tr>
</tbody>
</table>

Wood ash rich of CaO for chemical fixation of CO$_2$ and H$_2$S from the biogas

CO$_2$ fixation is based on the principle of carbonation

The ashfilter works well as a simple on/off upgrader capable of delivering vehicle grade CBM

Wood ash filter

- Almost 0 % CO2 in outlet gas
- CO2 uptake: 0,1-0,2 g/g dry ash
- 0 % H2S in outlet gas (up to 3000 ppm H2S have been tested)
- pH in the ash is decreased by 2-3 units = stabilization
- Used ash is stable and works well to pelletize for forestry fertilization

Results from wood ash filter in lab scale:
Wood ash filter – system perspective
In-situ methane enrichment

Other components of the system is all existing off-the-shelf technology

- Drying
- Compression
- Odorization
- Storage
- Dispensing
- Distribution

1 – 2 c/kWh
For example plenty of suppliers sell time-fill solutions for fueling your car directly from your home natural gas connection.

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Model</th>
<th>Gas flow [m³/h]</th>
<th>Price (CAD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nardi compressori¹</td>
<td>CNG 1.0</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CNG 5.0</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Gasfill²</td>
<td>HOME</td>
<td>2</td>
<td>6 000-9 500³</td>
</tr>
<tr>
<td>BRC fuelmaker³</td>
<td>PHILL</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FMQ 2.5</td>
<td>3</td>
<td>14 000⁵</td>
</tr>
<tr>
<td></td>
<td>FMQ 10</td>
<td>12</td>
<td>42 000⁵</td>
</tr>
<tr>
<td>Motor Jikov CNG⁴</td>
<td>MJ compact 05</td>
<td>5</td>
<td>9 500⁸</td>
</tr>
<tr>
<td>CNG Canada Inc.⁶</td>
<td>MCH5 CNG</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Compressor</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MCH10 CNG</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

On the user side there is plenty of CNG/CBG cars and trucks. A new development is that we are also seeing biogas tractors coming to market.

- **Valtra:** dual fuel tractors
  - Diesel engine, catalytic methane converter
  - 3 models – same capacity as when run on diesel
  - Ready for market – awaits EU standard for biogas use in a diesel engine

- **New Holland:** T6.140 Methane Power
  - Otto-cycle engine
  - 135 hp och 620 Nm torque
  - Emission standard EURO 4
  - Not quite ready for market intro

- **Deutz and Steyr** are also developing NGV tractors that are warranted also for biogas use
Calculations full scale

### Wood ash filter (standalone)

<table>
<thead>
<tr>
<th>Biogas production</th>
<th>MWh/yr</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry ash</td>
<td>ton/yr</td>
<td>325</td>
<td>650</td>
<td>1300</td>
</tr>
</tbody>
</table>

### In-situ methane enrichment + wood ash filter
- 2000 MWh biogas prod
- 490 ton ash/yr

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**Fixed and operating costs**

**Wood ash filter**

**In-situ methane enrichment + wood ash filter**
Projects: Biogas2020

Demonstration of a combination of In-situ methane enrichment and ash filter at an industrial pilot scale – 10 Nm3/h

Construction of a small scale fueling system for 8 vehicles and 1 tractor used on the farm.
Projects: Biogas2020

In-situ methane enrichment
Projects: Biogas2020
Ash filter – setting up a gas filter – 1 person 25 min
Projects: Biogas2020

Ash filter – gas upgrading, fueling and emptying the filter
THANK YOU!

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