Country report Sweden

November 2016

Mattias Svensson
## Biogas Plant Inventory 2015

<table>
<thead>
<tr>
<th>Substrate/Plant type</th>
<th>Number of plants</th>
<th>Production * (GWh/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sewage sludge</td>
<td>140 (+1)</td>
<td>697 (+18)</td>
</tr>
<tr>
<td>Biowaste**</td>
<td>35 (+/- 0)</td>
<td>854 (+137)</td>
</tr>
<tr>
<td>Agriculture**</td>
<td>40 (+3)</td>
<td>50 (+6)</td>
</tr>
<tr>
<td>Industrial</td>
<td>6 (+1)</td>
<td>121 (-2)</td>
</tr>
<tr>
<td>Landfills</td>
<td>60 (+/- 0)</td>
<td>187 (-32)</td>
</tr>
<tr>
<td>Thermal gasification</td>
<td>1 (+/-0)</td>
<td>38 (+37)</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td><strong>282 (+5)</strong></td>
<td><strong>1 947 (+164)</strong></td>
</tr>
</tbody>
</table>

* = energy content in the produced biogas independent of the utilisation

** = redefinition of 6 agriculture plants as biowaste plants
### Biogas Utilisation 2015

<table>
<thead>
<tr>
<th>Utilisation</th>
<th>GWh</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>62 (+4)</td>
<td>3%</td>
</tr>
<tr>
<td>Heat</td>
<td>387 (-47)</td>
<td>20% (-4)</td>
</tr>
<tr>
<td>Upgraded, automotive fuel</td>
<td>1,219 (+202)</td>
<td>63% (+6)</td>
</tr>
<tr>
<td>Industrial use*</td>
<td>49 (-26)</td>
<td>3% (-1)</td>
</tr>
<tr>
<td>Other use**</td>
<td>19</td>
<td>1%</td>
</tr>
<tr>
<td>Flare</td>
<td>198 (+7)</td>
<td>10% (-1)</td>
</tr>
</tbody>
</table>

* = new utilisation category 2014, earlier defined as heat or other  
** = new utilisation category 2015, to avoid misfiling of non-categorized use

### CNG/CBG/LNG/LBG as automotive fuel, end 2016
- Number of refuelling stations: 167 (excl. 60 non-public), incl. 6 for LNG/LBG
- Number of vehicles: 54,439 cars (1%)*, 2,331 busses (18%)*, 821 trucks (1%)* incl. approx. 50 LNG trucks
- 1,572 GWh (73% renew. on energy basis, 1,147 GWh, incl. imports)

* = % national market
Biogas upgrading

- Biomethane production 2015: 1,219 GWh/year (470 GWh injected into the grid)
- LBG production: 1 plant produced 37 GWh during 2015
- No power to gas installations exist in Sweden

A complete list of all upgrading plants will be available early next year at [http://www.iea-biogas.net](http://www.iea-biogas.net)
Biogas trends (1)

30 000 ton 2005 – 337 000 ton 2014

Food waste collection in 212 of Sweden’s 290 municipalities
Biogas trends (2)

Biogas utilisation 2005-2015

- Missing data
- Flaring
- Electricity
- Heat
- Industrial
- Other
- Automotive fuel

Biogas trends (3)

Biogas potential until 2030

Three scenarios with good, moderate or poor development of financial support system, technology and the price of fossil fuels.

1–3 TWh in scenario 3 (poor development)
5–8 TWh in scenario 2 (moderate development)
5–10 TWh in scenario 1 (good development)

Source = Dahlgren S (2013) “Realiserbar biogaspotential i Sverige 2030 genom rötning och förgasning”, WSP
## Digestate handling 2015

<table>
<thead>
<tr>
<th>Plant type</th>
<th>Digestate (Mtonnes wet)</th>
<th>Fertiliser usage</th>
<th>certified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sewage sludge</td>
<td>651 (-23)</td>
<td>28% (+9)</td>
<td>&gt;50%</td>
</tr>
<tr>
<td>Biowaste</td>
<td>1,710 (+332)</td>
<td>99%</td>
<td>~70%</td>
</tr>
<tr>
<td>Agriculture</td>
<td>315 (+37)</td>
<td>100%</td>
<td>-</td>
</tr>
</tbody>
</table>

Sources: Avfall Sverige, Svenskt Vatten
Financial support system

The support system in Sweden is mainly focused on increasing the usage of biomethane as vehicle fuel. The existing support systems are:

- No carbon dioxide or energy tax on biogas until the end of 2020 (extension 2018 for liquid biofuels, with energy tax recalculated biannually to avoid “overcompensation”). Corresponding to around 706 kr/MWh (74 €) compared to petrol and 567 kr/MWh (60 €) compared to diesel
- 40% reduction of income tax for use of company NGVs until end 2019 (10 kSEK cap)
- Investment grants for marketing of new technologies and new solutions for biogas during 2010-2016. Maximum 45% or 25 MSEK (~3M€) of investment cost
- Climate investment grant for municipalities: Total budget 1,925 MSEK (~200 M€) until the end of 2018. Similar to KLIMP!
- A joint electricity certificate market between Norway and Sweden. The producer get one certificate for every MWh electricity produced from renewable resources and electricity consumers must buy certificates in relation to their total use. Price span 2014-2015 140-190 kr/MWh (~15-20 €)
- 0.4 kr/kWh (~€ 0.043/kWh) for manure based biogas production to reduce methane emissions from manure. Total budget 355 MSEK (2014-2023)
National strategies

- Government 2020 goals for renewables already reached
  - 50% of the total energy utilisation
  - 10% goal in transports

- Vision to have a fossil free transportation sector by 2050.
  - Still awaiting government strategy for meeting these goals

- The gas industry’s biomethane vision is 100% in NGV market by 2030, and 100% in the national grid by 2050
  - Specific target 15 TWh 2030, thereof 12 in the transport sector
### Performance and economic data

Median cost estimate (average cost estimate) from nine Swedish biogas plants (2012). Unit: SEK/kWh, 1 € = 9.5 SEK

<table>
<thead>
<tr>
<th></th>
<th>Crude biogas</th>
<th>Upgrading</th>
<th>Distribution in grid</th>
<th>Distribution by road</th>
<th>Refuelling</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.54 (0.86)</td>
<td>0.31 (0.32)</td>
<td>0.06 (0.08)</td>
<td>0.12 (0.15)</td>
<td>0.04 (0.07)</td>
<td>0.97 (1.35)</td>
</tr>
</tbody>
</table>

Average price of CNG in Sweden Oct 2016: 1.30 kr/kWh (2012: 1.41 kr/kWh)

Source: SGC report 296

Kostnadsbild för produktion och distribution av fordonsgas, Johan Vestman, Stefan Liljemark, Mattias Svensson 2014:296
https://energiforskmedia.blob.core.windows.net/media/17766/kostnadsbild-foer-produktion-och-distribution-av-fordonsgas-energigasteknik-296.pdf
Obstacles for the biogas development

• Long term conditions from the government and EU is missing (1-5 years planning horizon…)
• Substrate competition
• Suggestion of new very tough regulations on digestate as fertiliser (limits on content of heavy metals)
• Unclear situation regarding import/export of biogas (mass balance limitations)
• Uncertainties concerning ILUC
Anaerobic digestion at thermophilic or mesophilic temperature – which is the best?

Simon Isaksson, Peter Malmros, Anna Hörberg, Sara Frid, Ewa Lie and Anna Schnürer*

Cooperation between SLU and the two companies Uppsala Vatten and Jönköping Energi

* www.slu.se/biogas
Significance of temperature – what is known?

Temperature has in recent publications been proposed to be one of the largest impact factors, together with ammonia, on the composition and function of the microbial consortium in the biogas process.

**Thermophilic**
- Short retention time
- High load
- High methane formation rate
- Considerable killing of pathogens
- Lowered viscosity
- Less "stable" process
- Low microbial diversity
- Risk of ammonia inhibition

\[ \text{NH}_4^+ \rightleftharpoons \text{NH}_3 \]

**Mesophilic**
- Good stability
- Less energy consumption
- High microbial diversity
- More efficient degradation of certain organic pollutants
- Slower degradation rate
- Longer retention time
Goal:
To evaluate the significance of temperature for biowaste (food waste) biogas production

Test objects
Uppsala biogas plant
Initial temperature; 52 °C
Main substrate; Source-sorted organic fraction of municipal household waste + slaughterhouse waste (9.5 % VS)

Jönköping biogas plant
Initial temperature; 37 °C
Main substrate; Source-sorted organic fraction of municipal household waste (9.7% VS)

Lowering temperature (and NH$_3$ conc) improves stability?
Higher load possible at higher temperature? Integrated hygienisation effect?
Results temperature change

Uppsala, thermophilic-to-mesophilic

Jönköping, mesophilic-to-thermophilic
Conclusion temperature change

No problems changing the temperature either up or down

Slight process disturbance occurred in both cases around 42 °C
## Conclusion temperature change - Altered ammonia concentrations

<table>
<thead>
<tr>
<th></th>
<th>Uppsala</th>
<th>Jönköping</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Thermophilic</td>
<td>Mesophilic</td>
</tr>
<tr>
<td><strong>Total nitrogen</strong></td>
<td>4.2 g L$^{-1}$</td>
<td>4.0 g L$^{-1}$</td>
</tr>
<tr>
<td><strong>Ammonium nitrogen</strong></td>
<td>2.4 g L$^{-1}$</td>
<td>1.3 g L$^{-1}$</td>
</tr>
<tr>
<td><strong>Free ammonia</strong></td>
<td>0.7-0.9 g L$^{-1}$</td>
<td>0.07-0.09 g L$^{-1}$</td>
</tr>
</tbody>
</table>

Decrease of temperature in Uppsala case lowered the mineralisation significantly, lowering the ammonium concentration. That together with the temperature effect led to a significantly lower ammonia concentration.

In Jönköping the degree of nitrogen mineralisation was similar at both temperatures, but the ammonia level increased due to the change to thermophilic temperature.

In both cases of thermophilic temperature the ammonia is at potentially inhibitory levels.
Results – loading rate increase

52°C
1.2 NL CH₄/L reaktor → 3.4 NL CH₄/L reaktor

37 och 52°C
1.5 NL CH₄/L reaktor → 2.9 NL CH₄/L reaktor

Uppsala
HRT going from 36 to 15 days

Jönköping
HRT going from 34 to 15 days
High loading rate/short retention time is feasible for both inoculums at thermophilic temperature, but not at the mesophilic temperature for the converted inoculum of the Uppsala process (fed slaughterhouse containing substrate, whereas Jönköping setup was not)
Thermophilic or mesophilic anaerobic digestion of the organic fraction of municipal solid waste (OF-MSW) – no real difference in performance

High OLR/short HRT possible for OF-MSW

Thermophilic/mesophilic temperature – probably no difference in performance in the treatment of OF-MSW in itself, but loading rate levels and supplementing co-digesting substrates will affect the performance at different temperatures.
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