Developments in Biogas Cleaning & Upgrading Technologies

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A view into the early history

- PSA Water Scrubber
- Selexol
- Landfill & Sewage sludge gas

US: 1  
NZ: 5  
NL: 11 units
1981 1986 1993

R&D activities

Alternative use of local available (renewable) fuel

US: 1  
NZ: ~3  
NL: ~5 suppliers
1981 1986 1993
A view into the developing history

**Water Scrubber**
- Membrane
- Landfill & Sewage sludge gas
- + organic waste, manure....

**Chemical scrubbers**
- PSA

**Organic scrubbers**
- PSA

1993 → 1998 → 2003

11 → 19 → 39 units

A view into the developing history – drivers & competition

**R&D activities**

**Strategic enforcement & incentives**

**Alternative use of local available renewable fuel**

1993 → 1998 → 2003

~5 → ~8 → ~10 suppliers
A view into the last years history

Water Scrubber
- Amine scrubbers
  - PSA
  - Organic scrubbers
Landfill & Sewage sludge gas
  + organic waste, manure....
  + energy crops

Membrane
- UK, I, Asia, N ?
- 280 units

UK, DE, CH, SE, UK, I, DK, I, BRA
Many more....

2003  2008  2014

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A view into the last years history – drivers & competition

Strong environmental requirements
Strategic enforcement & incentives
Intensive competition
New markets
Increased use of the only available alternative to natural gas

~10  ~12  ~40 suppliers

2003  2008  2014

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Developments – biogas cleaning

- Independent on application, cleaning is most important to reduce maintenance & upgrading costs
- Biogas drying: technical drying promises less corrosion & longer maintenance intervals, zeolites are an option
- Desulphurisation: no clear trend
  - Internal biological: cost efficient for 1st stage; but N₂-source
  - Internal chemical: costly
  - External: most efficient
    - Biological processes
    - Adsorption
- O₂ removal with ABC₄O₇ materials
  \( A = \text{rare earth element; } B = \text{Barium} \)
  \( C = \text{Cobalt} \)

Developments – upgraded gas quality

- All required gas specifications of European gas grids can be fulfilled
- High pressure transmission & underground gas storages: oxygen concentration requirements still a challenge
- All impurities can be reduced to the detection limits
  - Landfill gas upgrading is an increasing topic (out of central Europe)
- Development of methods and measurement standards (e.g. European Metrology Research Programme)
Market share

Source: Persson 2014, IEA task 37

Increased environmental requirements & cost efficiency are drivers
- Slip is reduced from ~10% in the first plants to less than 2% at all technologies today
- < 1% at water scrubbers, membranes with more stages, organic scrubbers
- < 0.1% amine scrubbers
- Increased selectivity of membranes
- Typically less than 0.5% can be guaranteed
- Regularly used for process heat supply
- Oxydation technologies available at all technology suppliers
Developments – energy consumption

- Increased environmental requirements & cost efficiency are drivers for R&D activities
- Decreased operational pressures (water scrubber, amine scrubber, organic scrubbers, PSA)
- Decreased/optimised temperature (water scrubber, amine scrubber – e.g. desorption with vacuum at temperatures below 100 °C)
- Use of internally available heat sources (e.g. compressors)
- Combination of both (amine scrubber) for site adaption
- Improved amine mixtures & enzyme additives
- Electricity demand < 0.2 kWh/m³ offered

Developments – new markets

- LNG market develops – LBG is an additional option for biogas
  - Higher energy density
  - Increased efforts & energy demand for production
- Pure Liquid Carbon Dioxide as valuable by product
- Synergies with PtG technologies and gasification
- Biomethane as carbon resource in Biorefineries
Developments – technologies & synergies

- Technology combinations offer improved operational performance or better product quality
- Waste heat utilisation (e.g. from compressors & RTO)
- Small scale upgrading seems to have a market (membranes, water scrubber, PSA)
- Upgrading technologies go towards low cost solutions outside Europe (Brazil, India)
- Landfill gas will play an increasing role (out of central Europe)
- South America and Southeast Asia seem to be the most growing markets.

Developments – emerging technologies

- Cryogenic gas separation: 1 pilot plant
- High pressure water scrubber: small scale applications are working
- Some technologies in research scale
  - PCC precipitated calcium carbonate;
  - Internal enrichment, pressurised fermentation
  - Ash filter (CO₂ is fixed by calcium oxide under the formation of calcite)
  - Temperature swing adsorption
  - Solid state amine adsorption
- Upgraded biogas will play a role in Power to Gas technologies
  - Renewable CO₂ source
  - Combined with electrolysers increased methane yields (microbial methane enrichment)
Specific investment costs

Differences in requirements for gas pretreatment, waste gas treatment, pressure, gas quality, energy consumption and heat recovery will affect the total budget.

Source: Persson 2014, IEA task 37

Specific energy demand

To be observed: product gas is supplied at different pressures!

Source: Persson 2014, IEA task 37
Conclusion

- Rapid market growth in Europe and international
- Process efficiency raised strongly in the past
  - Energy demand and waste energy utilisation
  - Reduced methane slip
  - Increased methane recovery
- No general advantages of a single technology visible
- High dependency on the given economical framework
- Local situation defines technology choice

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