Biogas cogeneration

Biogas cogeneration systems are most typically suited to locations where there is a ready supply of organic waste material available to produce the Biogas fuel source through processes such as Anaerobic Digestion. These AD processing sites are usually located near agricultural farms, food manufacturing sites and large scale waste disposal locations in order to minimise the transportation costs and manage the quality of ‘raw fuel’ being delivered.

The prime benefits for AD and Biogas generation is the production of a renewable power on site through combined heat and power cogeneration which reduces the need for national grid electrical power dependency, lowering electrical bills, reducing landfill bills whilst providing a useful diversity for the animal waste to produce low carbon fertilizer and provide a reduction in local carbon emissions.

Biogas upgrading to biomethane

In Germany alone there were around 4,500 anaerobic digestion (AD) plants in 2012 using almost entirely agricultural wastes and purpose-grown crops covering over one million hectares. (Prag, Peter. Renewable Energy in the Countryside, Estates Gazette, Limited, 2012.)

Upgrading of biogas to biomethane offers several advantages over direct utilization of raw biogas (e.g. in combined heat and power plants (CHPs) at the site of production). In remote areas, heat consumption over the whole year is often not guaranteed and thus heat has to be vented. Biogas upgrading and grid injection of biomethane enables transportation of the gas to places where the complete energy (power and heat) is needed, thus offering the chance to increase the overall efficiency of gas utilization. In summary, biomethane offers the following advantages: temporary decoupling of production and utilization local decoupling of production and utilization storage capability flexibility regarding several utilization paths: electricity (combined with full utilization of heat); heat (combined with power or in natural gas burners); vehicle fuel (for natural gas vehicles); and primary product for the chemicals industry. Nowadays, biogas upgrading is especially focused on Europe and partly North America. Outside of these two continents, there are only a few plants in operation.

In Germany, 83 biogas upgrading plants were in operation by the end of 2011.

Humidity removal and drying

Biogas leaving the digester is saturated with water vapour. This water has to be separated from the gas flow to avoid disruptions in operation of the subsequent biogas upgrading steps.

The removal of water is usually carried out at two positions in the upgrading chain. If compression is necessary before the biogas upgrading step (e.g. scrubber column, molecular sieve or membrane module), the raw biogas is cooled after the compressor(s). Because the biogas is heated by the compression, humidity condenses while the gas cools down. This is done to avoid unwanted condensation effects in the downstream system. If using scrubber technologies there is also a need to dry the upgraded product gas after the outlet of the scrubber column because the gas leaves this column saturated with humidity. For drying the upgraded gas, adsorptive drying systems such as molecular sieves or silica gel are most commonly used. Usually, no final drying is required when using glycol compounds as the absorbent in the scrubber column. In these systems, simultaneous absorption of humidity takes place.

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Desulphurization

Depending on the composition of the fresh substrate, raw biogas may contain hydrogen sulphide (H2S) in concentrations of <100 mg/m_n^3 up to 10,000 mg/m_n^3 – in exceptional cases up to 30,000 mg/m_n^3. During oxidation (burning) sulphurous acid can be formed. To avoid corrosion effects in plant components and to ensure the quality requirements for grid injection or use as vehicle fuel, desulphurization is required. Basically, two steps of desulphurization can be differentiated – primary and precision desulphurization; the first reduces the H2S level to <500 ppm (mostly down to ~100ppm) while the second is for fine tuning according to the specifications of the upgrading plant and/or the requirements for gas utilization or grid injection. Furthermore, desulphurization methods can be also divided into internal/external methods (inside or outside of the digester) with or without addition of oxygen.

For primary desulphurization in agricultural biogas plants without biogas upgrading, the internal method is used as a standard application and involves dosing of air into the gas space of the digester. The H2S is then biologically oxidized to elementary sulphur. The main advantage of this sulphur reduction step is that it is a very cheap technique because only air and a simple membrane pump combined with a flow meter are needed. At the same time, this economic advantage becomes the main disadvantage because N2 is inert and does not react in the gas flow. As a consequence of this, N2 is accumulated in the raw gas. Because most upgrading technologies are not able to separate N2 it will be found in nearly the same amounts but in higher concentrations in the biomethane. Air addition for desulphurization is thus commonly not the method of choice before gas upgrading. There are two exceptions, as follows:

- If biomethane is injected into natural gas grids with low heating values (L-gas grids), it will be necessary to decrease the CH4 concentration, and respectively the heating value of the biomethane, by mixing with air. In that case it can be advantageous to apply this cost-efficient desulphur- ization method.
- If using pure oxygen instead of air for dosing into the raw gas flow, the above-described dilution effect by N2 does not occur. Pure oxygen can, for example, be provided directly at the plant by a small PSA system.

In both cases (using air or pure oxygen), added oxygen will be found in the gas flow after the biological desulphurization. This becomes an advantage if using an activated carbon filter for the subsequent precision desulphuriza- tion. Because this filter needs a small amount of oxygen for the catalytic oxidation of H2S, this oxygen can be provided automatically by the former dosing.
To avoid the dilution effects with air or oxygen, the primary desulphurization techniques mostly applied when biogas is upgraded to biomethane are

- external biological H2S reduction with separated absorption/oxygenation steps
- combination of external biological H2S reduction with a basic scrubber
- chemical precipitation using iron salts (sulphide precipitation)
- chemical precipitation using iron hydroxide.

For precision desulphurization, impregnated or doted activated carbon is normally used (catalytic oxidation and following adsorption).

Alternatively, chemisorption on iron oxide- or hydroxide-coated materials in an external column can be applied for precision desulphurization. Chemisorption using zinc oxide in external columns is basically also applicable, but currently not state-of-the-art for precision desulphurization of biogas.

The six most widespread technologies are

1. pressure swing adsorption,
2. water scrubber,
3. physical absorption (using organic solvents),
4. chemical absorption (using organic solvents),
5. high-pressure membrane separation and
6. cryogenic upgrading.