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Trends in Biogas Technologies

Abstract
The presentation is meant to give a short overview on the state of the development of biogas technologies with special emphasis on the situation in Germany. Although the share of biogas based electrical energy among other types of renewable energies has become smaller, it still plays an important role for the compensation of fluctuating alternative energies and for the recycling of important substances like fertilisers as well. The growth of biogas capacities is limited due to the limited abundance of substrates. But newer technologies allow the biochemical production of biogas from carbon dioxide and hydrogen without any organic matter. Most probably, such processes will have the potential to change the common practise of biogas upgrading at least.

Keywords: biogas technologies, flexible operation, biodegradable waste, phosphorus and nitrogen recovery, methanation.

1. Basic technologies

The basic technologies in biogas production did not considerably change during the last five year and major improvements or other considerable finding are not expected in the near future. The biogas technologies are subjected to permanent improvement, e.g. stability, controllability, environmental and technological safety, reduction of energy consumption and higher yields. But this belongs to permanent improvement process and does not mean a qualitative leap as we could experience in the period between 1995 and 2010 (Torrijos, 2016; Scarlat et al., 2018).

Due to limited resources of substrates, the growth of the number and capacity of biogas plant is limited. The progress in biogas technology today is characterized by more intensive and specific pre- and after-treatment of the substrate and the residues, respectively, because waste materials replace gradually the traditional biogas crops. The conversion of biogas into (electrical) energy depends on the energy demand. Insofar, energy generation via biogas is incorporated in a complex system of energy management that involves other alternatives sources of energy production, mainly wind power and PV, as well.

Biogas plants are increasingly complemented with biogas upgrading technologies for producing biomethane. Biomethane is equivalent to natural gas and is favourably applied as a fuel for environmentally sound transportation-vehicles. It helps in emission reduction and can be used in almost all types of combustion engines with minor modification only.

2. Flexibilisation

The change of the world's climate requires fast and effective action in energy production and utilisation. The most common alternative energy source like wind and solar power deliver fluctuating energy with a dependency on weather and daylight period. For the compensation, either huge energy storage systems (hydro power, batteries, heat storage systems etc.) are required or, alternatively, the generation of energy from renewable resources on "demand". Biogas fits perfectly in such a system, but common biogas plant are designed for a constant steady-state operation mostly. Electrical energy from biogas plants is only needed if wind and solar power fail — hence, biogas plant of the future have to be flexible in energy production. There are three ways to gain this target:

1. Combination of huge biogas storage with increase capacity of the CHP. Biogas will be produced constantly, but stored until the energy is needed instead being simultaneously converted into electricity. The CHP should be able to convert the stored biogas into the energy at any time needed, and then within a short time span. This is the presently preferred technology of "transition to flexible operation" (or "flexibilisation").
2. Another way is the flexible generation of biogas. In that case, the energy is stored as a kind of "latent" chemical energy through the storage of hydrolysate and then converted into biogas, e.g. by high performance methanation technology on demand. Again, a CHP of high capacity is required in order to generate larger amounts of electrical energy in a shorter time.
3. The biogas is converted into "biomethane" which is equivalent to natural gas, transported via the European natural gas grid and might be locally converted into electrical energy whenever needed (Sahota, 2018). The biomethane can be produced by one the technologies for CO_2 — removal or via methanation of CO_2 and H_2 (Burkhardt, 2017).

3. Substrates

Due to the subsidies for alternative energy generation, a number of biogas plants was increasing rapidly in the years 1990's and early 2000's. The fervid debates during approximately 2010–2012, about the question what agricultural products should be used for, resulted in a growing substitution of biogas crops by municipal, agricultural and industrial biodegradable waste including biodegradable materials from landscape management (Achinas et al., 2017). Meanwhile, even straw and other heavily biodegradable materials are common substrates, though only after intensive pre-treatment.

The increasing utilization of biowaste from separate collection has risen a new problem: Due to a low technological discipline of individual waste producers (citizens), a lot of impurities accompany the biowaste. Among others, even toxic waste, mainly plastic materials enter the fermenters and, finally will be found in residues. They do not disturb the microbiological processes, but may create mechanical problems and, to a large extent, they will appear in the final compost. The increasing sensitivity for plastic as well as the suspected health effects of micro-plastic, reduce the acceptance of compost in which plastic is found. This is a clear and serious obstacle and reduces the profit from biogas plants because the compost is one of the major incomes.

By now, no technology is available for a complete automated removal of plastic with different particle sizes. So far, the only way to keep plastic out is a high separation discipline at a source.

4. Fertilizer

Despite that pig manure belongs to the earliest applied substrates, the biogas potential of manure has not been exhausted yet. In the light of nitrate emissions to the groundwater and of eutrophication of surface water by deploying manure, more attention is paid to this material nowadays. The removal of nitrogen from the manure, either before or after the fermentation process, hat been proven to be the key for both stabile fermentation process and reduction of nitrogen deployment. Nitrogen is favourably removed as Ammonia via stripping or desorption und then converted into a stable solid fertilizer, such as Ammonium sulphate, -nitrate, or into intermediate substances for urea production such as Ammonium carbonate, -carbamate and others (Buschmann, 2017). The latter might also be applied as supplier of Ammonia in the removal of gaseous nitrogen oxide emissions ("DeNox") from engines with internal combustion, e.g. CHP, cars, trucks, etc.

Furthermore, attention is paid to the recovery of phosphorus. Similar to the technology in sewage treatment plants, the precipitation of Magnesium-Ammonium-Phosphate (also: Struvite) is one of the promising ways. It is based on stripping of CO_2 with air to increase alkalinity, adding magnesium salts and, finally, sedimentation of the crystals. It was observed that phosphorus enriches solid residues of double-stage fermentation processes and, hence, could be recycled together with the compost made from the residues (Schönberg, 2014).

The production of compost becomes more and more attractive because it is a sink of carbon, contributes to humus reproduction and improves the fertileness of soil. Some special types of compost from biogas plants, and additionally treated by agglomeration and drying, may also replace turf. All in all, the profitability of biogas plants may even double if high quality compost is sold to the market.

5. Methanation of carbon dioxide and hydrogen

The direct biochemical conversion of carbon dioxide and hydrogen is one of promising processes that make biogas production independent of the availability of organic matter. The process delivers biogas with methane concentrations > 94% with a retention time of less than one to three hours and a high specific gas generation rate (Burkhardt, 2017). The main application of the process is more the upgrading of biogas by using the accompanying carbon dioxide as a source than the production of methane using the pure reactants. Even if hydrogen production via electrolysis becomes less expensive, pure carbon dioxide might become the bottleneck of the practical application.

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