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CATALYTIC CONVERSION OF BIOGAS TO BIOMETHANE THROUGH DIRECT METHANATION

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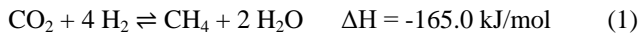
Biogas, as a result of complex biological and chemical conversion processes, is a mixture of different gas components, mainly consisting of methane (45 – 75 %), carbon dioxide (25 – 45%), water vapor and other gases such as hydrogen sulphide, ammonia, nitrogen and oxygen. A huge increase in biogas production is recognized in the EU, caused by the renewable energy policies in European countries combined with economic, environmental and climate benefits. According to the European Biogas Association more than 19,000 biogas plants and 725 biomethane plants are already in operation, producing around 167 TWh of biogas and 26 TWh of biomethane. Europe is the world's leading producer biomethane for the use as a vehicle fuel or for injection into the natural gas grid and a further increase (at least doubling of the production capacities) is expected until 2030. The process of upgrading biogas to biomethane is meanwhile state of the art and generates new possibilities for its use, since it can then replace natural gas, which is used extensively in many of the European countries. The currently available biomethane upgrade technologies are characterized by the removal of undesired gas components such as water vapor, hydrogen sulphide and most important to remove the carbon dioxide to enhance the caloric value of the upgraded gas. Especially the removal of the carbon dioxide results in enriched biogas with higher methane content, which should be close to the value of natural gas. The removal of the carbon dioxide can be achieved by various techniques, such as adsorption, absorption, membrane or cryogenic upgrading techniques. The most commonly used techniques are:

- water scrubbing,
- organic solvent scrubbing,

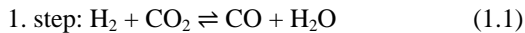
- chemical absorption,
- pressure Swing Adsorption (PSA),
- membrane separation:

Each of the above mentioned upgrading technologies is suitable to meet the gas purification requirements for feed in into gas pipelines or vehicle fuel specifications. But it is not possible to generalize which of the techniques is most appropriate. The technologies which are dominating the market today are water scrubbing, PSA, amine scrubbing and membrane separation technologies.

Up to now, the carbon dioxide separated from the biogas in conventional biomethane upgrade applications (about 1/3 of the produced biomethane) is mostly released into the atmosphere. The aim is to avoid this emission, and to convert this carbon dioxide with hydrogen into methane. The basic reaction used for the methanation is known as the Sabatier reaction, discovered by the French chemist Paul Sabatier, about 100 years ago:



The reaction is exothermic and takes place in 2 steps.



Direct methanation of biogas is a promising opportunity to increase the flexibility of biogas plants by the creation of new marketing concepts for operators of biogas plants. Since biogas consists to approx. 25 – 45 % of carbon dioxide, the additional conversion of this CO₂ to methane can produce up to 40 – 60 % more methane (depending on the biogas composition) compared to the conventional biogas upgrading technologies. The direct methanation of biogas to biomethane could potentially eliminate the cost and energy-intensive CO₂ separation processes, which are required by the conventional biogas-upgrade technologies and increasing the CH₄ yield significantly. Above all, the method is gaining in importance because the use of hydrogen generated from renewable electricity creates a good possibility of coupling the energy sectors electricity, heat and the transport sector. Since the required Hydrogen is usually generated from surplus electricity the process is also referred as Power-to-Methane as one opportunity of the Power-to-Gas processes. The existing natural gas distribution network and the natural gas storage facilities in Europe offer an enormous storage potential for the methane provided and thus an interim storage facility for excess electricity from fluctuating renewable energy sources such as power from wind turbines and PV installations.

Growing demands from the biogas industry have motivated the authors to address the specific requirements of smaller biogas plant operators (with a raw biogas production capacity of less than 250 m³/hour) precisely to generate biomethane for feeding it into the natural gas grid in a new research project. Compared to the currently pursued power-to-gas approaches, where the carbon dioxide is separated

from the raw biogas before the catalytic conversion, the new project will supply the entire raw biogas stream to the catalytic methanation. The aim of the project is the development of an innovative multi-component system for direct catalytic methanation of the carbon dioxide contained in the raw biogas of biogas plants by reaction with hydrogen produced by using renewable sources. A schema of the project conception is shown in figure below.

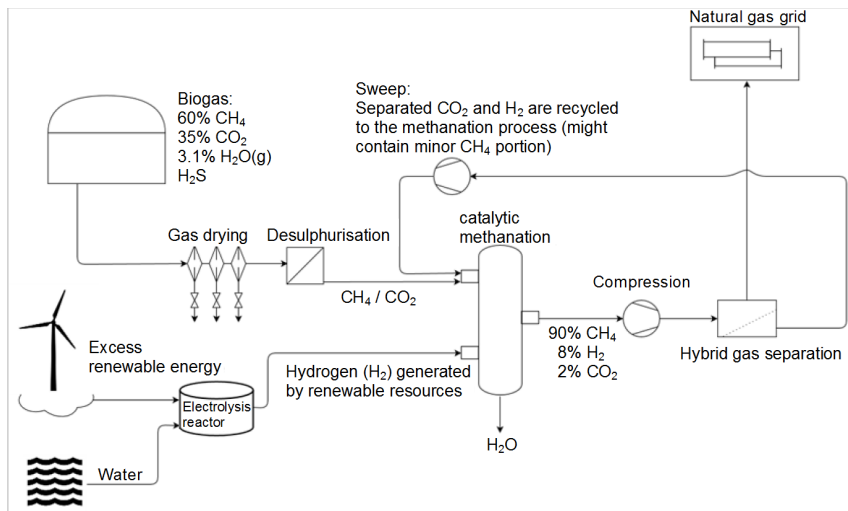


Figure 1 – Process schema of the catalytic methanation of biogas

To achieve this objective, an integrated approach of catalyst zeolite matrix, an optimal integration of gas treatment/gas separation and a customer oriented system integration is pursued. To avoid poisoning of the catalyst (zeolite supported nickel and ruthenium catalysts were used for the catalytic methanation) a comprehensive desulfurization of the biogas is required. To ensure the required low concentrations of < 5 mg/m³ (maximum hydrogen sulfide concentration according to [DVGW 2013]), the combination of adsorption in iron oxides and activated carbon seems to be a suitable method. The energy, released from the following exothermic conversion reaction can be used (and is required) to supply the heat for the biogas digester, which are mostly operated under mesophilic conditions (at approx. 36°C). Approx. 0.72 – 0.90 kWh thermal energy from the methanation of 1 m³ (raw) biogas (depending on the initial CO₂ concentration) can be used for digester heating and a heat surplus is produced which can be used for other applications or heat consumers close by the biogas plant.

Acknowledgments.

The authors acknowledge the financial support from the Institut für angewandte Forschung (IFAF Berlin) for the project “Nachgeschaltete Biogasmethanisierung mit Zeolithmatrix-Katalysatoren (KatMethCon)”. The results presented in this abstract are based on a system analysis created as part of this project.