Producing renewable methane – demonstration of CCU from biomass

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Abstract

Producing renewable methane can contribute in several ways to the mitigation of greenhouse gas. During biomass processing – either via anaerobic digestion of green wastes, sewage sludge etc. or by gasification of lignocellulosic biomass and subsequent gas cleaning – a significant amount of the biogenic carbon is released as CO₂ within the existing process chains. This biogenic CO₂ is typically available without major additional costs or efficiency losses for CCS or further synthesis of chemicals (CCU) thus replacing fossil CO₂. Renewable methane is one of the potential synthesis products from CO₂ (besides methanol, Fischer-Tropsch-Diesel and other hydrocarbons). It can be used as a green energy carrier as long as the hydrogen for the synthesis is produced by electrolysis powered from renewable energy resources like wind, hydropower or photovoltaics in Power-to-Gas applications.

A techno-economic assessment of several concepts for CCU within Power-to-Gas applications was conducted, considering producing renewable methane by the upgrading of biogas. For the direct methanation of biogas, a plant size of 200 m³ of biogas per hour was considered, corresponding to the output of a midsize green waste/sewage sludge digestion system. Various catalytic methanation processes were analysed with respect to how residual hydrogen (after the methanation synthesis step) can be separated or converted. On the basis of this study, the concept of fluidized-bed methanation with a downstream hydrogen membrane was chosen for a demonstration unit, as this concept promises to be most flexible in the operation of a commercial plant. Among the different Power-to-Methane pathways, upgrading of biogas is the most promising approach for the near future, because it has the lowest technical and financial hurdles to overcome due to the high methane content in biogas. This is especially true for technologies without prior separation of methane and carbon dioxide. Such a process applying catalytic fluidized bed methanation was validated in a long-term test campaign at a green waste/sewage sludge digestion site outside Zurich, Switzerland. By way of "direct methanation of biogas" (no separation of CO₂ from the raw biogas), the CH₄ yield from the same amount of biogas is considerably increased. This concept was proven in a test facility operated on biogas from a sewage treatment plant as well as a bio-waste digestion plant in Switzerland.

The demonstration unit COSYMA was built at PSI in 2016 and commissioned at the Energy System Integration platform of the Paul Scherrer Institut where a first series of scientific methanation tests were performed. In a subproject, sorbent based gas cleaning was reviewed. Promising sorbent materials were selected and tested in the laboratory and integrated into the demonstration unit COSYMA to protect the nickel based methanation catalyst from poisoning by sulphur compounds present in the biogas.
In spring 2017 the container-based demonstration unit was installed at the site in Zurich close to an existing biogas upgrading plant and connected to the biogas and natural gas grids. Until August 2017, the 1’100 hour long-duration experimental campaign was successfully conducted with a single catalyst charge. The predicted gas quality of synthesized methane was reached and the gas was injected into the natural gas grid. These experimental results of fluidized bed methanation and biogas cleaning can now be scaled up from the COSYMA scale to that of an industrial plant. The scale-up of fluidized bed methanation has already been demonstrated successfully by PSI with a previous version of COSYMA used for long duration tests at TRL 5 for biomethane production from wood gasification derived producer gas (reaching a chemical efficiency of > 61%) and subsequent up-scaling to a TRL 7 plant (1 MW scale, EU-project BioSNG) at a site in Güssing, Austria.

With a hydrogen-separation membrane integrated into the COSYMA unit, the ability to produce synthetic natural gas with more than 96% CH₄ (i.e. nearly full conversion of CO₂) and less than 2% H₂ could be demonstrated, which allows unlimited injection into the natural gas grid.