Bundesministerium
Klimaschutz, Umwelt,
Energie, Mobilität,
Innovation und Technologie

ERA-NET Bioenergy | IEA FORSCHUNGS KOOPERATION | FFG Forschung wirkt. | klima+ energie fonds

Highlights of Bioenergy Research 2020
January 24th, 2020, Messe Congress Graz, Austria

Abstract

Development of a heat integrated steam explosion pretreatment process to enhance biogas yields in anaerobic digestion of manure

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Animal manure is a promising feedstock for anaerobic digestion and is a largely untapped energy resource in Europe. In Switzerland and Sweden less than 5% of the manure is currently used for biogas production. Cattle manure solids contain about 50% lignocellulosic fibers that are recalcitrant to biological deconstruction. Consequently, only modest methane yields (25 to 40%) are achieved in anaerobic digestion. The low yields render the economic performance of anaerobic digestion plants operated with only manure unattractive for farmers and explain the current low utilization of this untapped resource. In order to improve the biomethane potential (BMP) of manure, different pretreatment methods have been investigated. Thermal pretreatments are a promising option and have been shown to be effective, especially if they include an explosive pressure release that disrupts the lignocellulosic structure and reduces the particle size. However, by the sudden pressure release, high-grade heat is dissipated and only low-grade heat of 100°C can be recovered. Together with the low solids content (< 10% w/w) a vast amount of high-pressure steam would have to be supplied to heat the manure to the desired pretreatment temperatures between 140 and 220°C. Another issue of thermal pretreatments in general is that the non-water-soluble fractions of the biomass (i.e. hemicellulose, cellulose, proteins, fats, lignin) respond differently to the pretreatment.

In this project we develop (and plan to pilot) a heat-integrated and optimized steam pretreatment process for a more efficient biogas production from cow manure with the aim to unlock the manure potential for biogas production.

During the first half of the project an elaborate optimization of the steam explosion pretreatment of cattle manure was carried out, with pretreatment temperatures and times varying between 130 and 190°C and 5 to 40 Min. The resulting biomass solids and liquids were analyzed for their chemical composition and biomethane potential (BMP). We could show that the BMP of manure liquid cannot be enhanced by a steam pretreatment. However, washed manure solids benefit from steam

pretreatment and the BMP can be increased by more than 50% for selected conditions. Furthermore, the fermentation time was reduced to less than 10 days due to a solubilization of non-water-soluble biomass fractions. We also designed, built and operated a test rig to test key elements of the envisioned pilot plant, such as heat recovery, pumpability of manure or the effect of explosive discharge. In the scope of the project also a techno-economic model was developed to evaluate the economic viability of a potential biogas plant employing a steam pretreatment unit using only dairy cow manure to produce electricity. In Switzerland where no compensatory feed-in renumeration is in place anymore such biogas plants become only economically feasible if the produced electricity is consumed on the farms and if manure of more than 300 livestock units (LSU) is available. In Sweden where an investment support and a manure-gas support are available it is economically more favorable to sell the power; such a biogas plant will be economically viable for 200 LSU. The project comprised also an assessment of environmental impacts. A qualitative LCA assessing key environmental aspects that may be impacted by the pretreatment step showed that the global warming potential is likely not affected, while it is not yet possible to draw a conclusion on the effect on global warming potential.

More information about the event, photos and presentation slides are available for download: https://nachhaltigwirtschaften.at/en/iea/events/2020/20200124-highlights-bioenergy-research.php