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Integration of biogas plants in the building materials industry

Markus Ellersdorfer*, Christian Weiβ

Institute of Process Technology and Industrial Environmental Protection, University of Leoben, Franz-Josef-Straße 18, 8700 Leoben, Austria

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ABSTRACT

The paper quantifies the synergy-effects of an areal combination of biogas-plants with plants of the building materials industry (e.g. cement works) from the energetic and economical point of view. Therefore an overall process model based on energy and mass flow balances is developed to determine the effects of a combination of both plants in terms of energetic efficiency, investment and operating costs, greenhouse gas emission reduction and overall energy production costs. The results and the calculation procedure for a combination of biogas plants with cement works are presented in detail. The main benefits of this combination are the utilisation of low temperature excess heat sources from cement works for fermenter heating and the direct thermal utilisation of unprocessed biogas as a valuable, CO_2-neutral fuel for combustion processes for instance clinker burning. Due to the combination, the energetic efficiency of the biogas plant, defined as utilisable energy output in relation to the energy content of the produced biogas, significantly increases from 63.0% to 83.8%. Concurrently the energy production costs are reduced, turning biogas into a competitive source of energy without the need for federal sponsorship. Calculations show, that production costs in combined plants for plant sizes larger than 90 m^3_{STP}/h biogas are even lower than the actual market prize of natural gas.

1. Introduction

The anaerobic fermentation of biogenic material presents a state-of-the-art technology in treatment of waste and agricultural residues. During the years 2000–2004 the local biogas market in Austria underwent a boom mainly because of extensive governmental funding. During this time, biogas technology developed from waste treatment to the systematic production of CO_2-neutral electricity respectively biomethane. Recently, the biogas production in Austria remains more or less static [1]. The reasons for this recession in the growth of the biogas market are on the one hand increasing substrate costs, on the other hand inevitable expenses for biogas utilization. Significant energy demands due to extensive processing needs for biomethane significantly decrease energy yields. Electricity generation in combined heat and power plants (CHPs) suffers mainly from a lack of reasonable excess heat utilisation concepts. According to a survey conducted by Tragner et al. in the year 2008 48% of Austrias' biogas-plant owners declared to operate beyond the point of profitability. Over 60% of the owners would not invest in biogas plants again [2].

Nevertheless, biogas presents a valuable, CO_2-neutral fuel, which can substitute conventional fossil fuels like natural gas or fuel oil. Especially energy intensive industry sectors are continuously trying to reduce their CO_2-emissions by the utilization of renewable fuels. In view of the actual problems of the biogas market in Austria, the areal combination of biogas plants with plants of the building materials industry like cement works, lime or refractory producers would present an opportunity to enable profitable biogas-production with concurrent benefits for the building materials industry.

The average calorific value of biogas with 21 MJ/m^3 (60% methane) is sufficient to be directly used as fuel in burning processes. For example in lime and magnesia production, natural gas is commonly used [3a] and can be substituted by biogas. In cement works, primary fuel combustion in the rotary kiln and secondary combustion in the precalciner for clinker burning can be adjusted to work with natural gas as well as biogas instead of fuel oil or coal, which are actually prevalent fuels due to economic reasons. The demands in terms of gas composition for direct burning are not that strict as for CHP plants or injection in natural gas supply systems. Compression of the gas to the pipeline pressure (30–80 bar) is not necessary. Hence, raw biogas can be directly used as a renewable fuel without processing steps like desulphurisation and CO_2-removal. H_2S in the biogas is oxidised to SO_2 during combustion, which reacts to alkalisulphates with

* Corresponding author. Tel.: +43 38424025006; fax: +43 38424025002.
E-mail address: markus.ellersdorfer@unileoben.ac.at (M. Ellersdorfer).

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Nomenclature

m^3_{STP}/h	volumetric flow rate (standard temperature and pressure, IUPAC)
kWh	energy (general)
kWh_{el}	electrical energy
kWh_{th}	thermal energy
€, ct	European currency

the clinker in the preheating and calcining system [4]. Furthermore, high temperature processes in the building materials industry are a source of waste heat at various temperature levels. The use of this energy for heating a mesophillic (~35 °C) or thermophillic (~55 °C) biogas fermenter allows the utilisation of excess heat at temperature levels beyond 100 °C, which is actually discussed as an important issue in the building materials industry. Another benefit is the possibility to recover ammonia from biogas digestate for example by air or steam stripping processes. Ammonia acts as a fertiliser but the output of digestate on agricultural areas is strictly regulated by law and limited to certain times of the year. Another possibility to utilize ammonia independent from agricultural legislature is as NO_x-reducing agent for DeNOx-applications in waste gas treatment. Therefore, aqueous ammonia containing solutions are injected in off-gas streams at certain temperatures to form nitrogen and water by reducing NO_x [3b].

To overcome the drawbacks of common stand-alone biogas production plants, the current investigation proposes a procedural integration of biogas-plants within plants of the building materials industry, using the example of a combination with cement works (cf. Fig. 1).

In this paper, the proposed combination is evaluated by means of a process and economic feasibility model as well as energy and mass flow evaluations to show, that a biogas-plant combined with a plant of the building materials industry (cement works) has advantages in regard to energetic efficiency, CO_2-savings, energy production costs and plant feasibility. The calculation is based on free adjustable input parameters like biogas plant size and other site-specific conditions for example the amount of available excess heat sources. At the beginning, these evaluations are made for a combination of biogas plants and cement works. This plant configuration is referred to as “combined biogas plant”, which is compared to an equally scaled biogas plant with electricity generation via CHP (“conventional biogas plant”). The overall model configuration as well as the results for a biogas plant with 250 m^3_{STP}/h biogas production rate are presented in detail in the following chapters.

The basic scenario of biogas integration in the cement production is furthermore extended to develop a calculation model which is easily adoptable to any plant location of the building materials industry to quantify the benefits of an integration of a biogas plant in other production processes (lime, brick and refractories). The goal is to provide a tool for the identification of potential plant

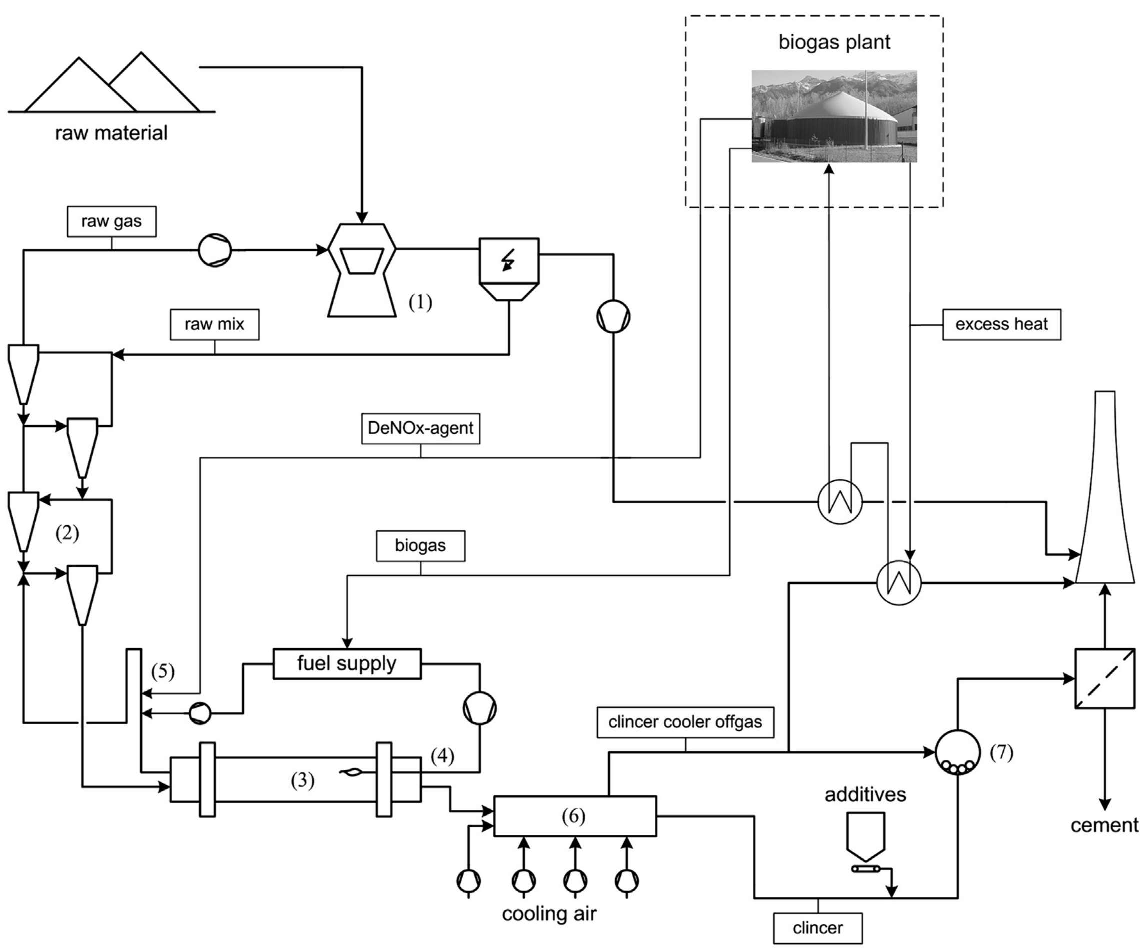

Fig. 1. Process flowchart of a combined biogas and cement plant; (1) raw mill, (2) cyclone preheating system, (3) rotary kiln, (4) primary (main) firing, (5) precalciner & secondary firing, (6) clincer cooler, (7) cement mill.