# Modelling of Material and Energy Balance of Biogas Production Process

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An increasing use of upgraded biogas as alternative fuel or as additive in natural-gas pipelines was observed in recent years. Upgrading of biogas is economically reasonable only for large biogas streams produced under optimized conditions. Therefore, an optimal design and efficient operation of large biogas plants is required. It is necessary to provide a stable process, and desirable to produce or to supply biogas just in time.

To analyse the biogas production, the material and energy balance of the process, respectively of the most important components of a biogas plant (fermenter, pump, screw, heat exchanger and combined heat and power unit) were modelled in Aspen Custom Modeller (ACM). Two different types of fermenters were investigated. The typical agricultural fermenter is rather wide, made of armoured concrete with a flexible roof as gas storage, and mostly mixed by one or more submersible motor-driven agitators. Danish fermenters are usually made of enamelled steel, are considerably higher and mixed by one central agitator. The different fermenter types differ also with respect to heat and power demand, which were compared in the analysis.

To calculate the material balance, different models were used and compared. Over the past decades several static and dynamic models were published with the goal to predict the biogas production depending on various parameters such as substrate composition, temperature or ionic equilibrium. Compared to dynamic models, static models are easy to handle; they can be applied to many problems without fundamental microbiological knowledge. Static models can be used to calculate quality and quantity of the biogas produced from different substrates depending on the composition of the substrate. However, they do not yield information about production at a specific time or about aspects related to process stability. To analyse the process behaviour dynamic models are required.

Three models of either category were selected. The dynamic models include process parameters such as temperature, ionic equilibrium, gas solubility, alkalinity and process inhibition by volatile acids, ammonia, carbon dioxide, hydrogen, and pH value. They largely differ with respect to complexity, considered degradation steps and the used kinetic microbial growth model. The static models consider only the composition of the input substrate.

Thermophysical properties of biogas and of input and output substrates were calculated depending on their composition. To check the calculated properties, the heat capacity, upper heating value and density of manure, energy crops and digestate were experimentally determined.

To validate the static and dynamic models and the corresponding ACM algorithms, they were compared with each other, with laboratory data and with data of a large-scale biogas plant. The developed ACM algorithms are tools for designers and operators of biogas plants, which can be used to design new plants, to select adequate substrates and substrate mixtures, to compare sub-processes and configurations, to carry out parameter studies aiming at an optimisation of biogas plants or to analyse the process behaviour, e.g., start-up processes or load changes. The presentation will give an overview of the used models and will show results of first studies; shortcomings of current models and options for further developments will be discussed as well.