DEVELOPMENT OF BIOGAS UPGRADING PROCESSES FOR DEVELOPING AND EMERGING COUNTRIES

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INTRODUCTION

Farmers in developing and emerging countries could reduce their dependency on fossil energy sources dramatically by producing their own biogas with agricultural waste. In order to use this biogas as fuel, which is the most promising valorisation route in this case, CO_2 and other harmful impurities have to be removed[1]. Usually, farmers in these countries can afford cheap biogas upgrading plants with poor performance at the utmost. Hence, development of alternative upgrading concepts for these countries is important to broaden the usage of renewable and sustainable biogas.

FUNDAMENTALS OF THE PROBLEM

In Brazil, the chosen model region, biogas is typically produced in simple fixed-dome digesters. Investigation on real biogas data from Brazilian farmers showed that the composition of biogas produced in these simple digesters is changing strongly over time. Additionally, hazardous components like H_2S are predominant due to using manure as a major substrate. According to these results, two promising biogas upgrading concepts were developed. Both involve membrane separation technology for CO_2 removal, as this technology has low investment and operation costs, is easy in operation and thus, suitable for biogas upgrading plants in developing and emerging countries.

RESULTS AND DISCUSSION

First concept of a suitable biogas upgrading process comprises membrane based mobile upgrading plants travelling from one biogas plant to another for upgrading the raw biogas. Thereby, investment costs for single farmers are significantly reduced and thus, made affordable for them. For mobile plants various requirements like minimum space and weight demand, fast start up time or vibration resistance due to poor road conditions have to be met. Additionally, the process must be able to deal with the feed quality described above.

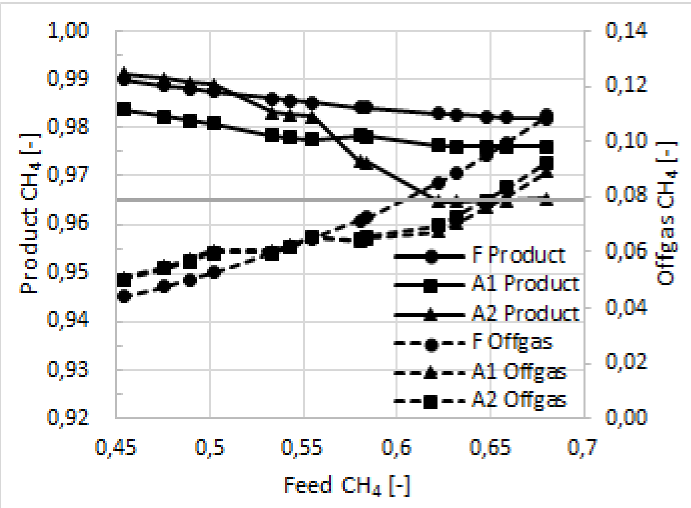

Figure 1: CH_4 concentration in product and off gas stream for different feed compositions at 10 bar. Grey line indicates the biomethane limit of 96.5 %. F = design with fixed membrane area, A1 and A2 = designs with adjustable area

Second concept is based on a hybrid CO_2 removal step for stationary biogas upgrading plants connected by pipelines with several farmers. Therefore, PSA (pressure swing adsorption) and water scrubbers, which are already available as Brazilian technology, are combined with a cheap membrane separation step. Thus, purity of the product stream will be enhanced while methane loss into the off gas will be reduced significantly.

Until yet, research was done primarily for the first concept. Investigation of different upgrading processes for CO_2 removal (scrubbers, PSA, and membrane separation) showed that membrane separation could fulfil the defined requirements at best. Additionally, two pre-treatment steps were defined for removing water and minor impurities like NH_3, H_2S, O_2 and siloxanes. Water and NH_3 are removed by cool-drying. Desulphurization and removal of O_2 and siloxanes are carried out by combining two adsorption steps using iron oxide and activated carbon as adsorbent.

Influence of feed quality and design of the membrane step on the performance was investigated by process simulation in Aspen Plus®. Simulation was carried out for the whole process with focus on the membrane separation step. A model for gas permeation was used based on the solution-diffusion model and validated in several applications[2,3,4]. Performance was investigated for designs with fixed membrane area and with membrane area adjustable to the incoming feed composition. As Figure 1 shows, performance of all designs was high enough for a broad range of incoming biogas compositions to meet the Brazilian biomethane limit of 96.5 %[5] in the product stream. At high CH_4 concentrations in the feed this criterion led to quite high CH_4 loss into the off gas when using designs with fixed membrane area. In comparison, designs with membrane area adjustable to the incoming feed composition were able to reduce the CH_4 loss into the off gas significantly at high CH_4 concentrations in the feed, while product quality remained above the biomethane limit.

CONCLUSION

Equipment for mobile biogas upgrading plants has to cover various requirements. Especially, high product quality has to be achieved for a broad range of feed compositions with the same equipment. Process simulation in Aspen Plus® showed that various designs of membrane based CO_2 removal are applicable for mobile biogas upgrading plants producing biomethane with high quality.

Further investigation of the chosen concepts will be carried out with focus on stationary biogas plants based on hybrid CO_2 removal. Therefore, performance of existing PSA and water scrubber based Brazilian biogas upgrading plants will be evaluated. Process modelling and simulation will be used for investigating and optimizing the performance of various designs for hybrid CO_2 removal.

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