Optimization of the biogas upgrading process with CO_2 recovery using membrane contactors at pilot scale.

J.M. Martín-Marroquín[1,2], D. Hidalgo[1,2], S. Bedate[1], F. Nieto[1,2,3]

1.- CARTIF Technology Centre, Circular Economy Area, Boecillo (Valladolid), 47151, Spain
2- ITAP, University of Valladolid, Paseo del Cauce, 59 - 47011 Valladolid, Spain
3- Mechanical Engineering Department, University of Valladolid, Paseo del Cauce, 59 - 47011 Valladolid, Spain
Keywords: biogas upgrading, membrane contactors, CO_2 recovery
Presenting author email: jesmar@cartif.es

Introduction

Biogas upgrading process using membrane contactors aims to provide solutions to the different problems raised by the growing concern for environmental problems related to high greenhouse gas (GHG) emissions from the use of fossil fuels, with the ambition of responding to the energy needs of the population from a technical and financial point of view. Demand for methane-rich biogas (renewable natural gas) and other renewable fuels is increasing worldwide as use of this product as vehicle fuel or injection into the natural gas grid become common practice. In addition, and according to previous studies, the specific GHG emissions associated with biomethane production amount to 44.6 gCO2eq/kWh, which corresponds to an overall reduction in GHG emissions of 82% compared with natural gas. These figures make biomethane a key option on the path to a sustainable and renewable energy supply.

Nowadays, there are several commercially available technologies for biogas upgrading, but due to their high investment cost, high energy consumption or use of polluting chemicals, it is difficult to decide which of them to implement on an industrial scale. This study at pilot scale seeks to develop a reliable, low-risk and low-cost biogas enrichment system based on membrane contactors, capable of efficiently treating the biogas generated in different production environments.

The novelties that these membrane contactors introduce with respect to the existing upgrading systems are the following:
- Use of a gas-liquid membrane technology that allows the CO2 to be separated from the CH4 contained in the biogas at low pressure (4 bar), thus minimizing safety problems, needed investment, and the operation and maintenance costs associated with works under high pressure, commonly associated with gas-gas membranes upgrading systems (16 bar).
- Use of low-cost technology, since the necessary infrastructure is widely spread for gasification/degassing applications in the carbonated beverage industry, thus solving the great problem of upgrading processes related to high investment costs in equipment.

Materials and Methods

The biogas upgrading pilot plant is composed of three main steps:

a) Cleaning of contaminants that are intrinsic to biogas and that can damage membrane contactors, such as xyloxanes, water vapor and hydrogen sulfide, using an activated carbon bed for the removal of xyloxanes and H2S, and a condenser with gas-water cooling for water vapor removal.
b) Biogas upgrading system made up of 5 lines, each of which has two 3M Liqui-Cell EXF-8x20 Industrial serie membrane contactor, capable of treating up to 10 m3/h of biogas, with which the pilot plant would be able to produce around 32.5 m3/h of biomethane assuming a methane concentration in the biogas feed of 65%.
c) Recovery of the CO2 absorbent solution, using the same membrane contactors and a liquid ring vacuum pump.

Distilled water, tap water and 1 M NaOH solution will be tested as CO2 absorbent liquid phase in the system. In the latter case, the CO2 cannot be desorbed, since sodium carbonate will be formed. This product, depending on the industry, could be used as a raw material in further processes, as is the case, for example, of the sugar industry.

Biogas used during the experimentation proceeds from an anaerobic digester operating with wastewater from a sugar industry located in Toro (Spain). The pilot plant is totally containerised to facilitate transport between industrial facilities for testing. The biogas cleaning equipment is located in a 20-foot container and the biogas upgrading and CO2 recovery equipment has been deployed in a 40-foot container. This pilot plant allows testing and demonstrating the efficiency of this technology in different operating scenarios and with minimal inconvenience for the biogas supplier industry.

Preliminary Results

The pilot plant (Figure 1) has been operating in parallel with distilled water, tap water and 1 M NaOH solution as liquid phase in order to compare the performance of the system with the three solvents under the same operating conditions (biogas composition, pressure and temperature). In the first month of study, it has been possible to confirm that the 1M NaOH solution is the one with the highest absorbent capacity, followed by distilled water and finally tap water, but it is necessary to continue the study over a long period, at least 1 year, to evaluate the robustness of the process (membrane degradation, solvent life cycles, operation and maintenance costs, etc.).

a) b)

Figure 1. Biogas upgrading pilot plant: a) biogas cleaning container; b) biogas upgrading and CO_2 recovery container.

Acknowledgments

The authors gratefully acknowledge support of this work by the Programme of subsidies for the implementation of R&D projects for SMEs in Castilla y León, co-financed with FEDER funds, under the responsibility of the Institute of Business Competitiveness (ICE) of Castilla y León– Spain - (project CONTACTGAS, Ref. 04/18/VA/0109).