A glance at commercial biogas upgrading technologies

C. Nikolaidou[1], M. Gaspari[1], P.G. Kougias[1]
[1]Soil and Water Resources Institute, Hellenic Agricultural Organization DIMITRA, Thermi, 57001, Greece
Keywords: biogas upgrading, biomethane, methane purification, carbon dioxide removal
Presenting author email: c.nikolaidou@swri.gr

Nowadays, the need for transition to sustainable forms of energy is more pressing than ever. The conventional energy sources such as fossil fuels are finite and becoming increasingly scarce, and their extraction and usage greatly contribute to global warming and environmental deterioration. This climate change has been recognized as one of the greatest challenges that humanity faces. In response, several national and international initiatives have been taken, such as the Paris agreement, which represents a global effort to mitigate the devastating effects of climate change (United Nations, 2015). To achieve the goals of the agreement, there is an imperative need to decrease carbon dioxide emissions and shift towards sustainable solutions. In particular, European Union set more ambitious targets for mitigating climate change recommending 70% of electricity be derived from renewable sources by the year 2030 (European Environmental Agency Briefing No 32/2020).

Anaerobic digestion is key player in the emerging market for renewable energy since it combines renewable energy generation and organic waste management (Kougias & Angelidaki, 2018). Anaerobic digestion is a complex biological process, mediated by various groups of microorganisms, mainly bacteria and archaea, that form syntrophic relationships and through different metabolic pathways produce biogas as final product (Campanaro et al., 2018). Biogas typically contains 60% methane and 40% carbon dioxide although the composition varies depending on the influent feedstock and operational conditions. It is challenging to find the right technology or combination of technologies that will allow biogas to be upgraded from these modest methane levels up to 99% methane and be similar to natural gas in quality. The upgraded biogas, known as biomethane, is characterized by a high market value due to its wider applicability in sectors such as industry, transportation, electricity and heating as it can replace the use of natural gas. Throughout Europe, the number of biogas plants that install upgrading process technologies is constantly rising (EBA, 2021). There are numerous commercially available technologies for converting biogas into biomethane, including membrane separation, water scrubbing, water scrubbing, chemical scrubbing and pressure swing adsorption. Fig. 1 shows the upgrading technologies used in Europe in 2020 according to European Biogas Association (EBA, 2021).

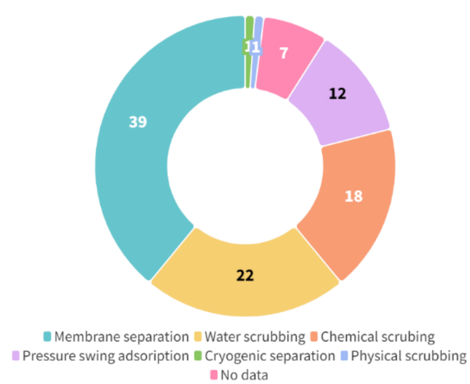

Figure 1. Use of biogas upgrading technologies (%), Europe 2020 (EBA, 2020)

Membrane-based upgrading systems rely on the selective flow of individual gas constituents across a semi-permeable membrane (Kapoor et al., 2019). The permeability properties of the membranes determine if the separation will be gas to gas or gas to liquid (Awe et al., 2017). In biogas upgrading systems, membranes permit CO_2, H_2S, H_2O and O_2 to pass while retaining CH_4 and N_2, achieving high purity of biomethane (Scholz et al., 2013). Commercial membranes based on polyimide and cellulose acetate proved to be the most suitable for biogas separation and enrichment among the different kinds of membranes tested (Sun et al., 2013). Although this technology is established and has been used for many years to upgrade biogas, recent advances in membrane manufacturing spurred by nanotechnology have increased membrane selectivity factors and, as a result, interest in their application (Muñoz et al., 2015).

Water scrubbing technology is another commercially used technology for methane purification. It is a technique for removing CO_2 that is based on the higher solubility of CO_2 to water (26 times higher at 25ºC) compared to that of CH_4 (Sinnott & Towler, 2019). Compressed biogas is inserted in a packed scrubber column and water fills in this tank in a countercurrent flow. Since CH_4 and CO_2 are soluble in different ways, the CO_2 is dissolved into the water, while the CH_4 remains in the gas phase, allowing the separation of CO_2 found in biogas from the methane (Andriani et al., 2014). Even though H_2S has a higher solubility than CO_2 and it could be removed along with CO_2, pre-separation of H_2S is normally necessary due to corrosion issues that may arise by dissolved H_2S (Sun et al., 2013). CH_4 purity varies between 80-99% and it depends on the volume of N_2 and O_2 which cannot be separated from CH_4 in this technique (Sun et al., 2013).

During chemical scrubbing, amine (mono-, di- or tri-ethanolamine) or alkali solutions (sodium, potassium, and calcium hydroxides) are used to bind the CO_2 of biogas (Andriani et al., 2014). Biogas is provided in the absorption column and the solution is provided in a countercurrent flow (Kapoor et al., 2019). Similarly to water scrubbing, prior removal of H_2S is required to prevent amine poisoning (Muñoz et al., 2015). Chemical solvent selectively reacts with CO_2 in this process, resulting in methane recovery exceeding 99% (Awe et al., 2017).

As the press to shift towards environmentally friendly power generation methods, biogas and biogas upgrade are enticing options for the cover of energy demands. Technologies for upgrading biogas are well-developed and able to generate high quality biomethane that is appropriate to be utilized in vehicles and grid injection, meeting a part of the energy requirements. Additionally, emerging biological technologies (chemoautotrophic and photosynthetic) have attracted the interest of many researches worldwide. A key benefit of these technologies is that they convert CO_2 into other forms of energy or products with special benefits. However, such methods are still on the low to mid level of the technological maturity spectrum.

Acknowledgments

This research was carried out as part of the project «BioUpgrade» (Project code: KMP6- 0192823) under the framework of the Action «Investment Plans of Innovation» of the Operational Program «Central Macedonia 2014-2020», that is co-funded by the European Regional Development Fund and Greece.

Bibliography

Awe, O. W., Zhao, Y., Nzihou, A., Minh, D. P., & Lyczko, N. (2017). A review of biogas utilisation, purification and upgrading technologies. *Waste and Biomass Valorization*, *8*, 267-283.

Campanaro, S., Treu, L., Kougias, P. G., Luo, G., & Angelidaki, I. (2018). Metagenomic binning reveals the functional roles of core abundant microorganisms in twelve full-scale biogas plants. *Water Research*, *140*, 123–134.

European Biogas Association, 2021. EBA Statistical Report 2021

Kapoor, R., Ghosh, P., Kumar, M., & Vijay, V. K. (2019). Evaluation of biogas upgrading technologies and future perspectives: a review. *Environmental Science and Pollution Research*, *26*, 11631-11661.

Kougias, P. G., & Angelidaki, I. (2018). Biogas and its opportunities — A review Keywords. *Frontiers in Environmental Science*, *12*(June 2018), 1–22.

Muñoz, R., Meier, L., Diaz, I., & Jeison, D. (2015). A review on the state-of-the-art of physical/chemical and biological technologies for biogas upgrading. *Reviews in Environmental Science and Bio/Technology*, *14*, 727-759.

Scholz, M., Melin, T., & Wessling, M. (2013). Transforming biogas into biomethane using membrane technology. *Renewable and Sustainable Energy Reviews*, *17*, 199-212.

Sinnott, R., & Towler, G. (2019). *Chemical engineering design: SI Edition*. Butterworth-Heinemann.

Sun, Q., Li, H., Yan, J., Liu, L., Yu, Z., & Yu, X. (2015). Selection of appropriate biogas upgrading technology-a review of biogas cleaning, upgrading and utilisation. *Renewable and Sustainable Energy Reviews*, *51*, 521-532.

United Nations Framework Convention on Climate Change (2015). *Paris Agreement Under the United Nations Framework Convention on Climate Change.*