frontiers in Environmental Science

EDITORIAL
published: 12 July 2018
doi: 10.3389/fenvs.2018.00075

Editorial: Advanced Utilization and Management of Biogas

Ioannis V. Yentekakis[1]*, *Grammatiki Goula*[1], *Pierluigi Leone*[2] and *Stylianos G. Neophytides*[3]

[1] School of Environmental Engineering, Technical University of Crete, Chania, Greece, [2] Department of Energy, Politechnico di Torino, Turin, Italy, [3] Foundation for Research and Technology Hellas, ICE-HT, Patras, Greece

Keywords: biogas upgrading and utilization, syngas, ethylene, hydrogen, fuel cells, wastewater treatment, energy efficiency

Editorial on the Research Topic

Advanced Utilization and Management of Biogas

OPEN ACCESS

Edited and reviewed by:
Miklas Scholz,
Lund University, Sweden

***Correspondence:**
Ioannis V. Yentekakis
yyentek@isc.tuc.gr

Specialty section:
This article was submitted to Wastewater Management, a section of the journal Frontiers in Environmental Science

Received: *23 May 2018*
Accepted: *26 June 2018*
Published: *12 July 2018*

Citation:
Yentekakis IV, Goula G, Leone P and Neophytides SG (2018) Editorial: Advanced Utilization and Management of Biogas. Front. Environ. Sci. 6:75. doi: 10.3389/fenvs.2018.00075

OVERVIEW

Biogas, a product of biological wastewater treatment plants, sewage facilities, and refuse landfill sites is extensively produced on a local basis and therefore represents a dispersed valuable renewable energy resource. Its current utilization, mostly for heat generation at the production sites, is inefficient and polluting, besides the worst case of detrimental venting to the atmosphere of poor-quality biogas.

Accordingly, innovative and efficient strategies for an advanced utilization of biogas for direct electrical energy generation or production of added-value chemicals are currently top research and technology challenge (Abatzoglou and Boivin, 2009; Sun et al., 2015). Such advances could lead to a substantial optimization of biogas-producing wastewater treatment plants (WWTPs), or to modern designs of eco-friendly biogas utilization plants, that will be characterized by both low operational cost and environmental damage, at the same time creating efficient energy and chemicals production systems.

Biogas composition (50–70% CH_4, 25–50% CO_2, 1–5% H_2 with minor impurities—NH_3, H_2S, siloxanes, halides) makes it advantageous for several modern processes, such as the direct dry reforming for syngas/H_2 production, and an effective feedstock for fuel cells. Its upgrading to substituted natural gas could also offer a valuable fuel for transport or grid injection (Abatzoglou and Boivin, 2009; Sun et al., 2015), and the CO_2 separated can be used as a sustainable carbon stock in renewable liquid fuel synthesis processes or other implementations (e.g., power-to-gas process, algae growing), leading to polygeneration systems. Ultimately in a holistic approach, biogas offers considerable benefits for eco-friendly electrical power generation and a sustainable carbon stock for the production of added-value chemicals; together with natural gas, biogas can be considered as a "bridge fuel" for the twenty-first century, enabling transition to a low-carbon energy economy.

THIS RESEARCH TOPIC

The present Research Topic aims to cover promising recent trends and advances in biogas utilization in the 5 high-quality papers contributed: the comprehensive reviews of Yentekakis et al., and Niakolas et al., focusing respectively on advanced utilization strategies for biogas management as an energy and chemicals production sector, on enhancing the energy efficiency of wastewater treatment plants through co-digestion and fuel cell systems, and on the development of carbon and sulfur tolerant anodes for solid oxide fuel cells (SOFCs); the Charisiou et al. and Shiratori et al. original studies, involving respectively the Ni/(ZrO_2-WO_3)-catalyzed dry reforming of biogas (DRB) toward syngas, and the production of a real biogas that then fed, without fuel processing, in an advanced-design fuel cell for electrical power generation.

Specific Findings and Highlights

Yentekakis and Goula reviewed the most innovative and efficient strategies for improving the management and utilization of biogas. After concisely reviewing state-of-the-art purification and upgrading methods, in-depth consideration was paid to the efficient and eco-friendly exploitation of biogas in the renewable energy and chemicals sectors; In respect to the former, particular emphasis was given to direct biogas SOFCs, which have currently attracted much research effort. Concerning the chemicals sector, the most promising potentially practical and environmentally benign utilization routes were reviewed and an informative process sequence network was provided. A chemical route, not previously considered for biogas utilization that can efficiently transform all the biogas content (CH_4+CO_2) to ethylene was also proposed.

Gandiglio et al. provided a comprehensive overview of the technological measures capable to increase the self-sufficiency of WWTPs, in particular for the largely diffused activated sludge-based plants. An overview of existing WWTPs in Europe classified in terms of geographical location and capacity was initially introduced. Energy consumption issues in wastewater treatment plants, pointing out the effect of the size of the system and the effluent requirements in terms of purification were discussed. Promising methods for increasing the efficiency of WWTPs were illustrated, including process optimization and energy harvesting for combined heat and power generation. Overall, it is shown that achieving energy self-sufficiency in WWTPs should include the reduction of energy consumption in secondary biological treatment, where aeration is performed, and in water pumps. Furthermore, efforts should be devoted to increase the internal energy production by both improving sludge pre-treatment and anaerobic digestion management, taking advantage of the possibility of performing co-digestion with other organic wastes. Finally, a case study of a high efficiency SOFC system fed on biogas was illustrated.

Niakolas et al. (Gandiglio et al.) reviewed the efforts regarding the development of Ni-based electrodes for SOFCs, which are tolerant to carbon and sulfur upon processing internal steam reforming at low S/C<1. Under these conditions, Au(<3wt%)- and/or Mo(<0.5wt%)-modified Ni/GDC anodes resulted in materials with high tolerance to carbon and sulfur. The atomic accumulation and dispersion of Au and Mo atoms within the Ni surface structure can induce significant modifications on Ni activity. The reforming reaction sequence is affected both by retarding the dehydrogenation of methane and by enhancing the formation of oxy-hydrogenated carbon species that lead to syngas. This bypasses the complete dehydrogenation of CH_4, avoiding carbon deposition. Critical findings are highlighted in order to stress the key differences in the electrocatalytic performance between Ni/YSZ and Ni/GDC, paying considerable attention on the role of the support.

Shiratori et al. integrated a SOFC-aided wastewater treatment process in a bench-scale unit, coupling biogas production and electrical power generation. Using biomass feedstock collected in the Mekong Delta, they report biogas production with low H_2S concentration (<50 ppm) in the biomass fermentation unit compartment, successfully utilizing, for the first time, methanogenic bacteria in the shrimp pond sludge for the digestion of bagasse and molasses. The real biogas produced was then directly fed to an innovative, paper-structured SOFC, without any fuel processing (e.g., desulfurization, pre-reforming), which offered stable power generation.

Charisiou et al. studied the dry reforming of biogas (DRB) to syngas on Ni supported on two commercially available supports (ZrO_2 and WO_3-ZrO_2), using a simulated biogas ($CH_4/CO_2 = 1.5$). A complementary characterization was performed to determine textural, structural and other physicochemical properties of the catalysts, and to reveal their impact on the DRB activity, stability and the type of carbon formed. Although Ni dispersion and reducibility characteristics were superior on Ni/WZr, its DRB performance was inferior compared to Ni/Zr. This attributed to the higher acidity of the former; acidity competes and finally overshadows the benefits induced by the other superior properties.

AUTHOR CONTRIBUTIONS

IY contributed to the conception and coordination of this Research Topic. All authors contributed to the writing, discussion, read and approved the present editorial article.

ACKNOWLEDGMENTS

IY and GG acknowledge support by the EU and Greek National Funds through the Operational Program Competitiveness, Entrepreneurship and Innovation, under the call Research-Create-Innovate (project code: T1EDK-00782). We kindly thank Field Chief Editor, Prof. Martin J. Siegert, for giving us the opportunity to organize this topic and the journal Editorial Office for the great, continuous support. Thanks to all contributed authors and reviewers for their valuable involvement on the high standards contributing papers produced that can give advances for researchers on the field, which is of significant importance in a holistic, advanced and eco-friendly approach of wastewater management in view of cyclic economy.

REFERENCES

Abatzoglou, N., and Boivin, S. (2009). A review of biogas purification process. *Biofuel Bioprod. Biorefin.* 3, 42–71. doi: 10.1002/bbb.117

Sun, Q., Li, H., Yan, J., Liu, L., Yu, Z., and Yu, X. (2015). Selection of appropriate biogas upgrading technology-a review of biogas cleaning, upgrading and utilization. *Renew. Sustain. Energ. Rev.* 51, 512–532. doi: 10.1016/j.rser.2015.06.029

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.