In-situ CO_2-biomethanation for biogas upgrading

Background

A significant restructuring of the global energy system is urgently required to achieve net-zero CO_2 emissions by 2050. Renewable energy must replace fossil fuels which currently account for around 80% of the global energy consumption. Ireland has a long-term ambition to reduce 80-95% of energy-related greenhouse gas emissions by 2050 as compared to 1990 levels. The Decarbonised Gas scenario, one of the modelled scenarios used to achieve net-zero emissions for heating and cooling in Ireland by 2050, relies heavily on green hydrogen and biomethane.

Ireland has potential for the development of biomethanation with a target of biogas and biomethane output in 2050 equivalent to 28% of the current gas supply. Biomethane can be used to support the Government's strategy for an energy self-sufficient Irish bioeconomy. There is an estimation that 900 new anaerobic digestion (AD) plants are required to deliver this carbon savings target [1]. This will require the industry to grow significantly as Ireland currently has only a few AD plants.

In the early- and mid-2030s timespan of the modelled scenarios of Ireland achieving a decarbonized heat supply by 2050, all suitable available bioresources are used to produce biomethane, which is injected into the grid and reconverted on demand [2]. Fig. 1 shows the resources used to produce biomethane in the balanced scenario by resource type. From the late 2030s, the remaining available resources (i.e., availability above the quantity required for grid injection) are to be shipped as containerized biomethane for delivery to off-grid commercial and public uses [2].

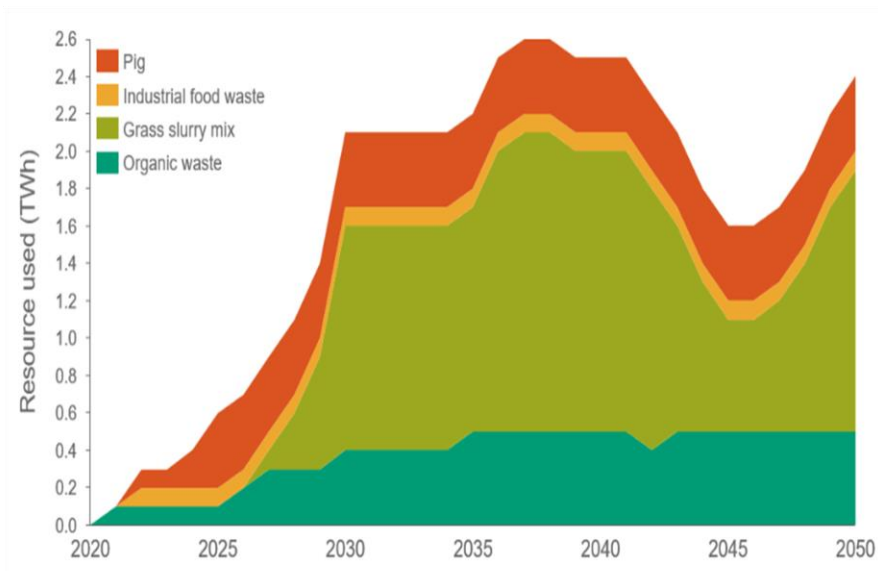

Fig. 1. Total resources used to produce biomethane for grid injection in the balanced scenario, 2020- 2050, by resource type, including for both grid injection and off-grid containerized biomethane (Source: from [3]).

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Further reading:

- IEA World Energy Balances 2020
- SEAI Energy in Ireland 2021 Report
- Implementation of bioenergy in Ireland – 2021 update

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Biomethanation approach

Biogas is produced from AD of organic matter and composed of ~50-70% methane (CH_4) and ~30-50% carbon dioxide (CO_2). It has a lower calorific value based on the CH_4 content and is mostly used to produce electricity and heat. AD of biomass for energy production also represents a significant CO_2 source, with production in Europe of around 34.2 million tons in 2015. Conventional biogas upgrading separates and discards the CO_2, resulting in the loss of this portion of the feedstock carbon, and representing a loss of resources and a release of CO_2 to the atmosphere.

The endogenous CO_2 can be combined with injected exogenous H_2 and biologically transformed into additional CH_4 by ***in-situ* biomethanation** using the capacity of the indigenous methanogens of the existing AD system for biogas upgrading. Biological methanation has been envisioned for a decade as a viable solution in the energy sector. The technology is considered a substitute for CO_2 purification and a potential low-cost Power-to-Gas technology to produce biomethane, which can be used directly as vehicle fuel or injected into the natural gas grid, thereby (i) broadening the range of applications, (ii) increasing the value of biogas, and (iii) contributing significantly to the reduction of greenhouse gas emissions and the transition from a fossil fuel-based economy to a more renewable energy-based circular economy.

While pure H_2 generated by renewable electricity sources provides an excellent fuel for biogas upgrading processes, it is only applicable to areas with abundant wind or solar energy resources. To address this challenge, a two-stage AD system can be employed (Fig. 2) in which the first reactor is a dark fermentation unit that produces biologically H_2 and volatile fatty acids (VFAs) from organic wastes. The second reactor treats the effluent from the first reactor and produces CH_4 from the VFAs, CO_2 and H_2. The latter thus functions as an upgrading stage, responsible for further conversion of CO_2 and H_2 that is produced in the first stage, to biomethane.

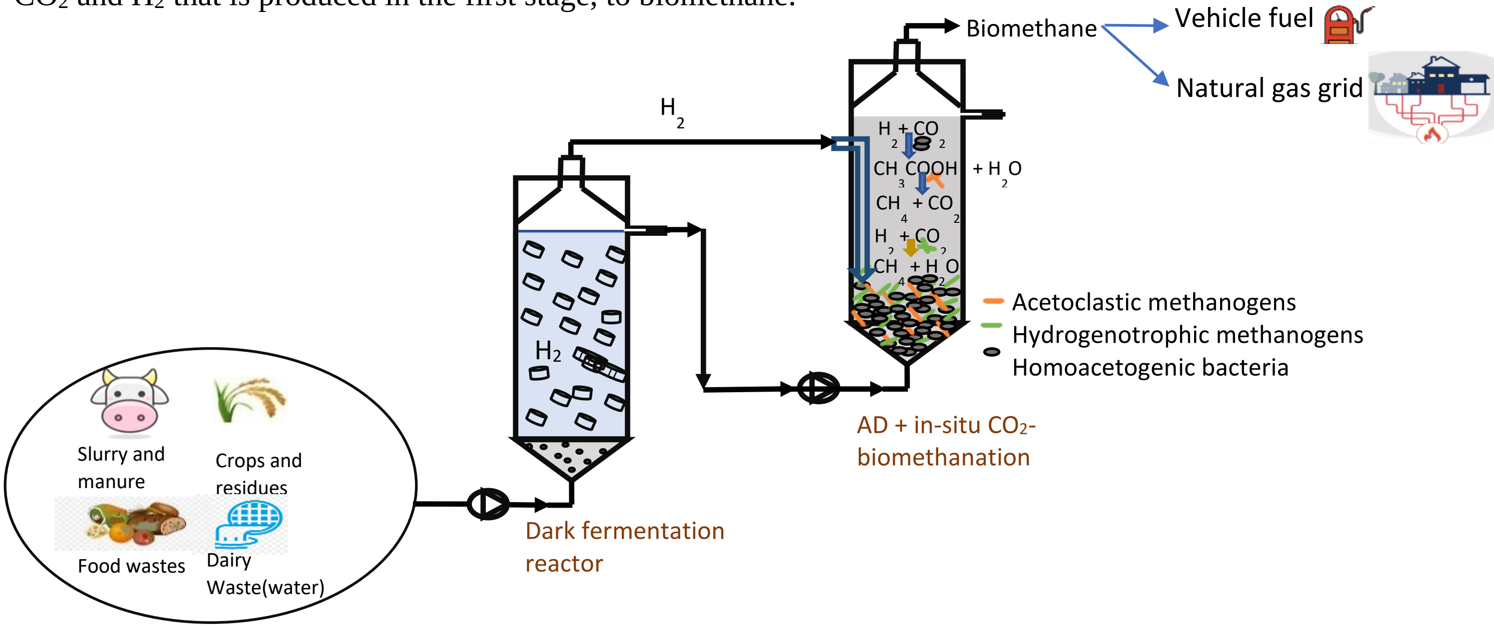

Fig. 2. Two-stage *in-situ* bioconversion of CO_2-to-CH_4 by methanogens for biogas upgrading

References

1. SEAI Economic Assessment of Biogas and Biomethane in Ireland. https://www.seai.ie/publications/Summary-Assessment-of-the-Cost-and-Benefits-of-Biogas-and-Biomeathane-in-Ireland.pdf
2. Net-zero by 2050: An exploration of decarbonisation pathways for heating and cooling in Ireland. Final report of the National Heat Study. https://www.seai.ie/data-and-insights/national-heat-study/net-zero-by-2050/
3. SEAI report on Exploring Decarbonisation Pathways for Heating and Cooling in Ireland. https://www.seai.ie/data-and-insights/national-heat-study/net-zero-by-2050/
4. IEA. *Outlook for biogas and biomethane: Prospects for organic growth*. (2020).
5. Jensen, M. B., Jensen, B., Ottosen, L. D. M. & Kofoed, M. V. W. Integrating H_2 injection and reactor mixing for low-cost H_2 gas-liquid mass transfer in full-scale in situ biomethanation. Biochem. Eng. J. 166, 107869 (2021)
6. Alfaro, N., Fdz-Polanco, M., Fdz-Polanco, F. & Díaz, I. H_2 addition through a submerged membrane for in-situ biogas upgrading in the anaerobic digestion of sewage sludge. Bioresour. Technol. 280, 1–8 (2019).