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Methanogenesis
A microbial alternative to catalytic methanation

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Motivation

Methanogenesis is a microbiological alternative to catalytic methanation, although not as well developed. While its potential had already been discovered in the 1970s, the hydrogen required for the reaction remains a limiting factor in biological systems. With 'Power-to-Gas' and the opportunity to produce hydrogen from renewable energy, biological methanation is regaining attractiveness as an environmentally-friendly alternative to catalytic methanation [1].

Methanation by microorganism

Reaction

$$CO_2 + 4\,H_2 \rightleftharpoons CH_4 + 2\,H_2O \qquad \left(\Delta G^0 = -131\,\frac{kJ}{mol}\right)$$

Microorganism

Methanogenic archaea

- Pseudonym: *Methanogens*
- Domain: *Archaea*
- Phylum: *Euryarchoaeota*

Methanogens are obligate anaerobes, which usually live in wet, anoxic (oxygen-free) environments such as sediments and muds of various aquatic habits or in the rumen of animals. In industrial processes they are used in biogas and waste water treatment plants for the anaerobic digestion of organic matter.

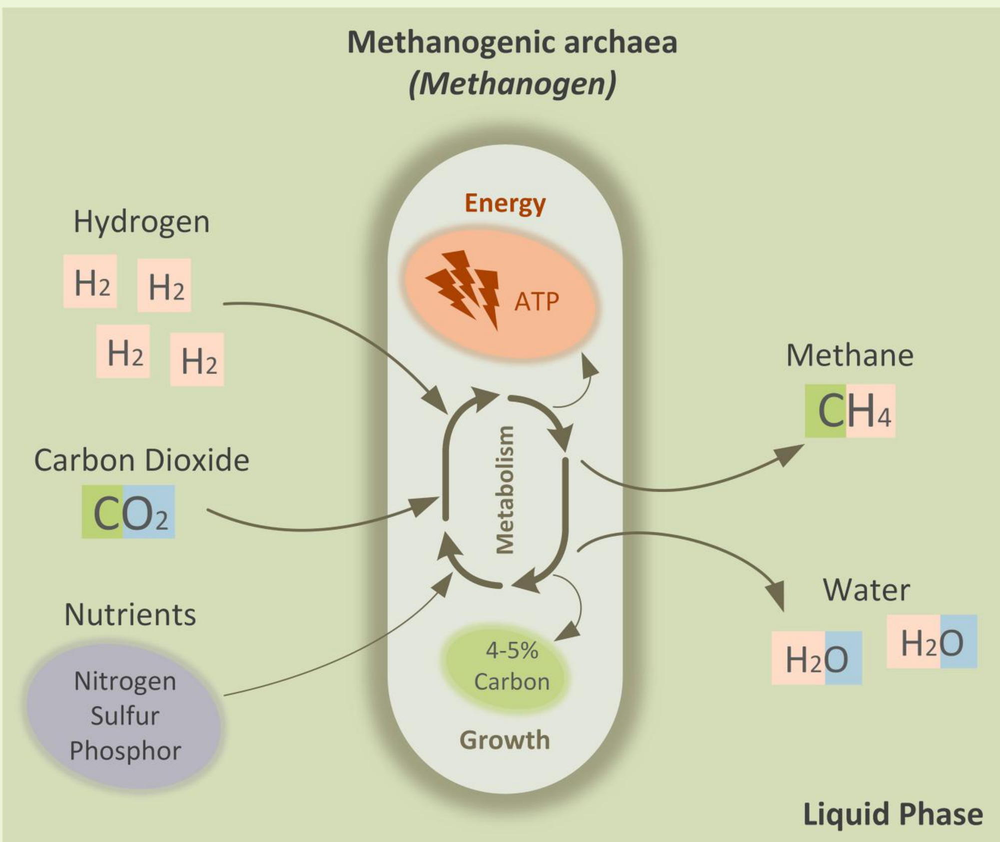

***Fig. 1** Principle of biological methanation by methanogenic archaea*

Metabolism and selectivity

Methanogens reduce carbon dioxide by means of a variety of co-enzymes. The reaction is exergonic. The microorganisms use the energy released for the synthesis of molecular energy in the form of ATP – an intercellular energy carrier in cells.

At least 1 mole ATP is obtained per mole of methane. However, for cell growth much more energy is required. Only about 4 – 5% of the carbon dioxide is used for cell growth itself. The rest is used for metabolism and maintenance of important vital functions. Accordingly, a high selectivity of carbon dioxide to methane of about 95% results from biological methanation, varying slightly depending on the methanogenic species.

Process design, reactors and challenges

Main process characteristics

- ✓ Low temperature (35 – 65°C)
- ✓ Low pressure (≥ 1 bara)
- ✓ Non-sensitive to impurities such as sulfur, siloxanes
- ✓ High selectivity to methane
- – Low reaction rate

Process variants

- <u>*Ex-situ biological methanation*</u>
  → in separate bioreactor
- <u>*In-situ biological methanation*</u>
  → inside fermenter of anaerobic digestion

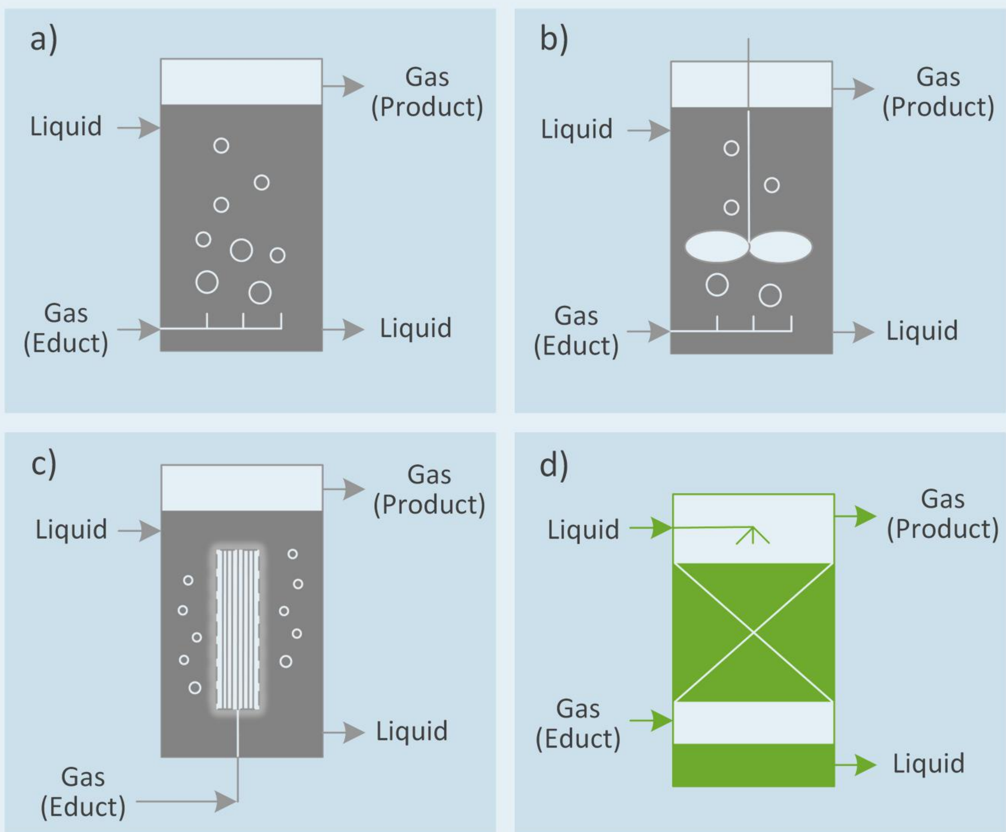

***Fig. 2** Bioreactor types investigated for ex-situ biological methanation*

Common reactor types for *ex-situ* variant

- – Bubble column reactor
- – Stirred-tank reactor
- – Membrane reactor

} Conventional bioreactors, with significant mass transfer limitation

- ✓ Trickle bed reactor → Good mass transfer, but less studied for reaction

Main issues to be solved

- Mass transfer limitation
- Process control of hydrogen addition
- Methane yield
- Heat production during reaction
- Adaptation of microorganisms to reactor conditions

Our research activities

Current activities and projects

- Cultivation of methanogenic archaea (pure and mixed cultures) under selected conditions
  # TRL 2 – 3
- Feasibility studies for integration of biological methanation into existing plants
  # TRL 6 – 9
- NRP 70 project 'Renewable Methane for Transport and Mobility'
  # TRL 2 – 3
- Setting-up of a pilot plant for ex-situ biological methanation in a trickle-bed reactor at the ZHAW
  # TRL 4 – 5

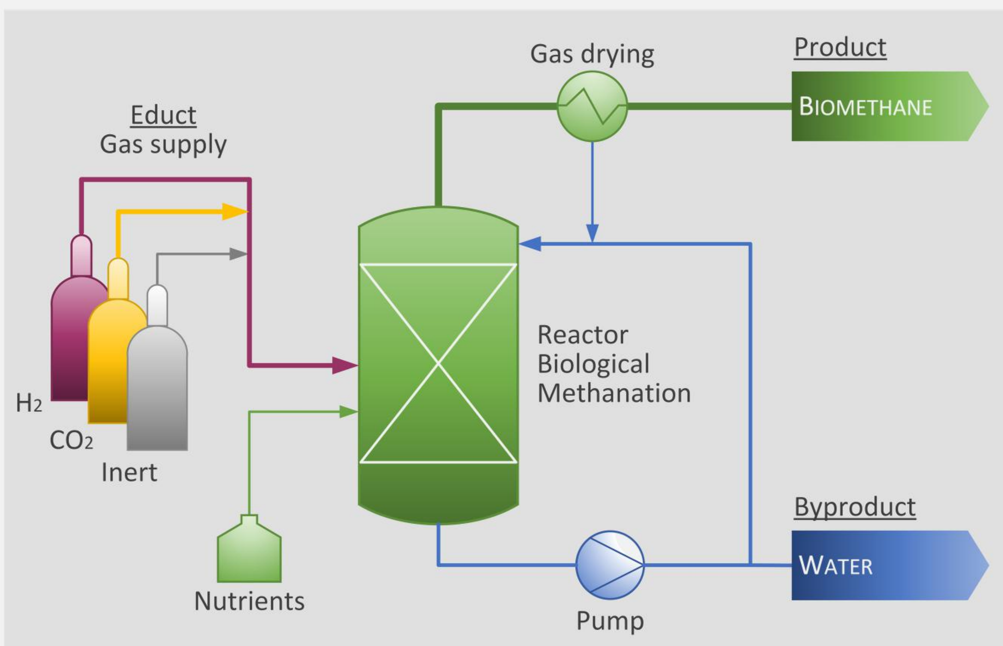

***Fig. 3** Process flow diagram of biological methanation pilot plant at ZHAW*

Roadmap 2016 – 2020

- Commissioning of ex-situ biological methanation pilot plant
- Long-duration testing and optimisation of process conditions
- Development of reactor models validated by experiments
- Techno-economic analysis (e.g. biological vs. catalytic methanation)
- Scale-up: supporting the design and commissioning of a demo plant integrated into existing biogas or WWT plant

Reference [1] Krautwald J., Baier U. «*Biologische Methanisierung - Methanogenese als mikrobiologische Alternative zur katalytischen Methanisierung*», Aqua & Gas 2016, N° 7/8, 18-23

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