Transforming our understanding of methanation: One-step CO_2-conversion in Microbial Electrolysis Cells

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Electrochaea

Introduction

Power-to-Methane with biological catalysis is typically comprised of two steps – electrolysis and methanation – to convert electricity, water and carbon dioxide into renewable methane (Figure 1). Based on the rapid technology scale-up over the last decade (Figure 2) Electrochaea provides a superior solution for energy storage and for the future provision of climate neutral fuel, contributing to the mandatory reduction of the CO_2-footprint.

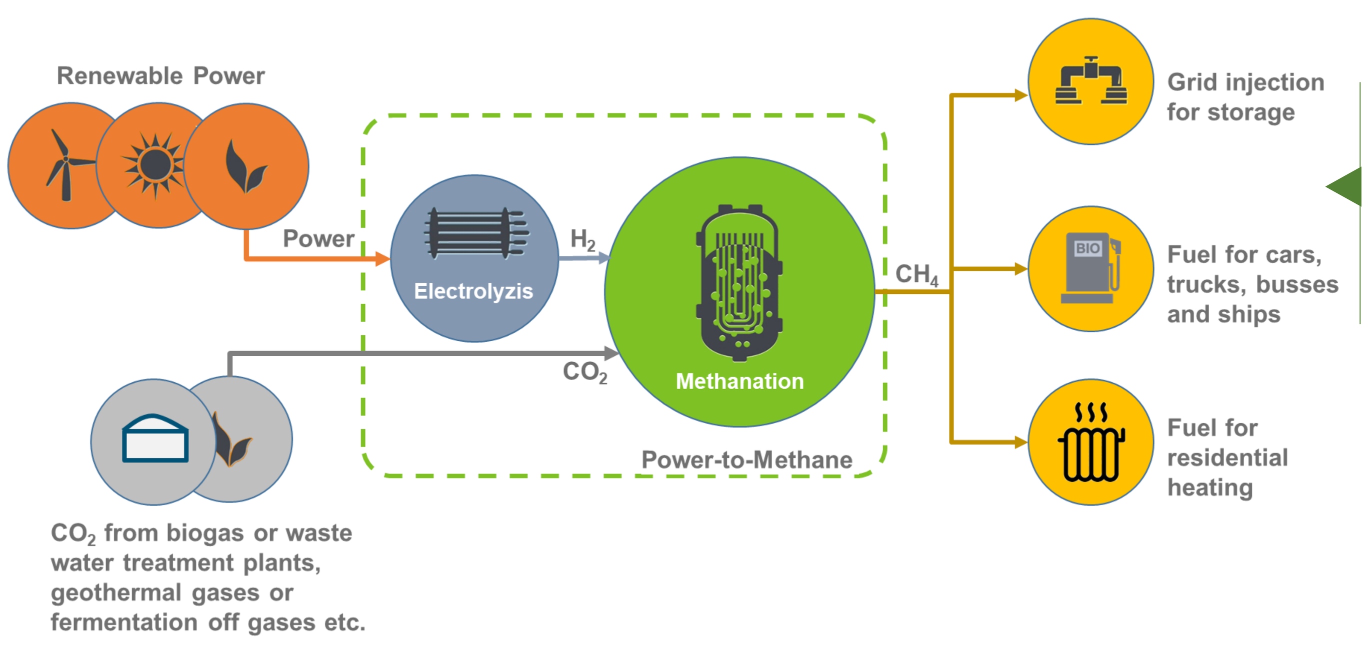

Figure 1: Power-to-methane process in 2-steps. H_2 gas is first generated from water splitting using an electrolyzer. Then it is combined with CO_2 in the biomethanation reactor (in green) where Archaea are producing methane.

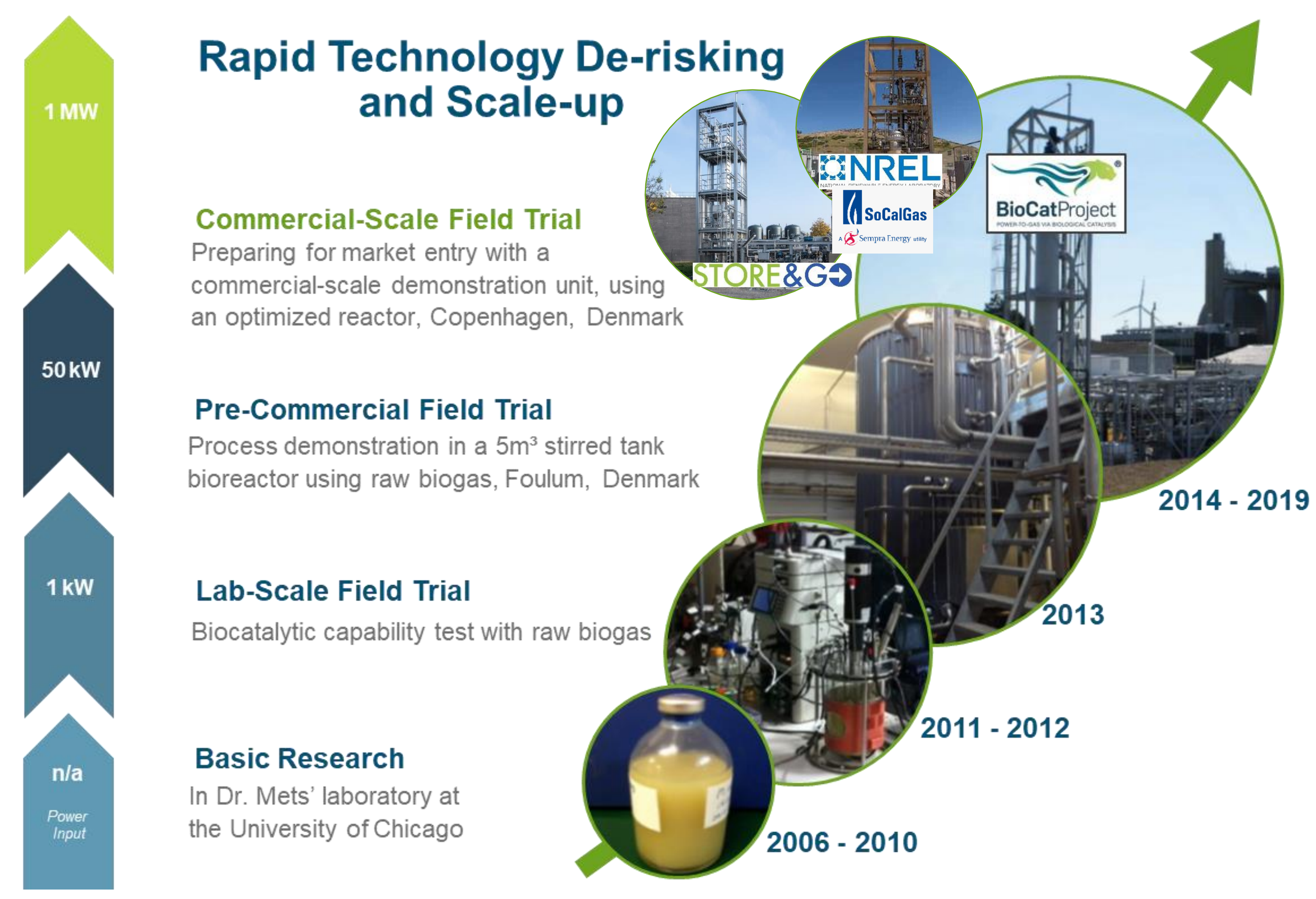

Figure 2: Electrochaea's technology scale-up from basic research to 1 MW commercial-scale field trial. The industrial-scale PtG plants are located in Denmark, Switzerland and the US (NREL, CO). The European units are injecting biomethane in the natural gas grids. The gas is also compliant with SoCalGas Rule 30.

Power-to-methane in one reactor

Electrochaea has also been developing a technology where *electrolysis* and *bio-methanation* are merged into one single reactor, a Microbial Electrolysis Cell (MEC)[1]. This transition from a 2-step to a 1-step process enables the adaptation of Electrochaea's bio-methanation technology into smaller gas producer facilities and lower electricity availabilities. The benefits of MEC as a platform reactor for biological CO_2 conversion to CH_4 (electro-biomethanogenesis) include:

- ✓ Elimination of the capital cost associated with having a separate electrolyzer and stirred bioreactor
- ✓ H_2 production in the same reactor as the microorganism converting CO_2 into CH_4, thus overcoming productivity limitations associated with low solubility and poor mass transfer of H_2 in water
- ✓ Reduced material cost due to low pressure system design

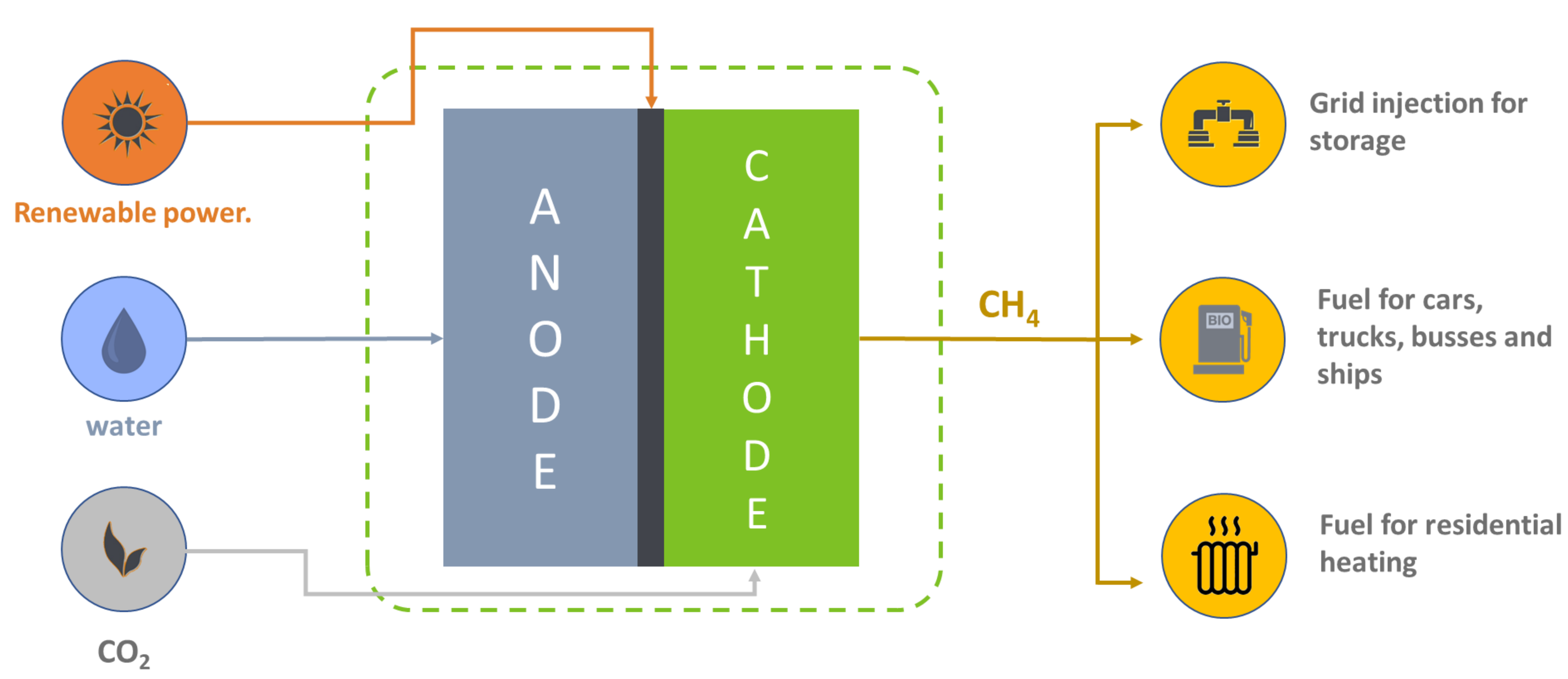

Figure 3: Scheme of Power-to-methane process in 1-step. Electrolysis and bio-methanation occur in one single reactor

MEC fundamentals

- ✓ MEC uses renewable electricity as the energy source for the production of methane from CO_2
- ✓ The system consists of two electrodes, anode and cathode, separated by a membrane
- ✓ At the anode, the water oxidation reaction takes place yielding 2 H^+ and 8 electrons
- ✓ Electrons flow through an external electrical circuit to the cathode, whereas protons migrate through the membrane to the cathode to maintain electroneutrality
- ✓ At the cathode, the protons and electrons are used to produce methane
- ✓ The reaction at the cathode is catalyzed by electrochemically active microorganisms.

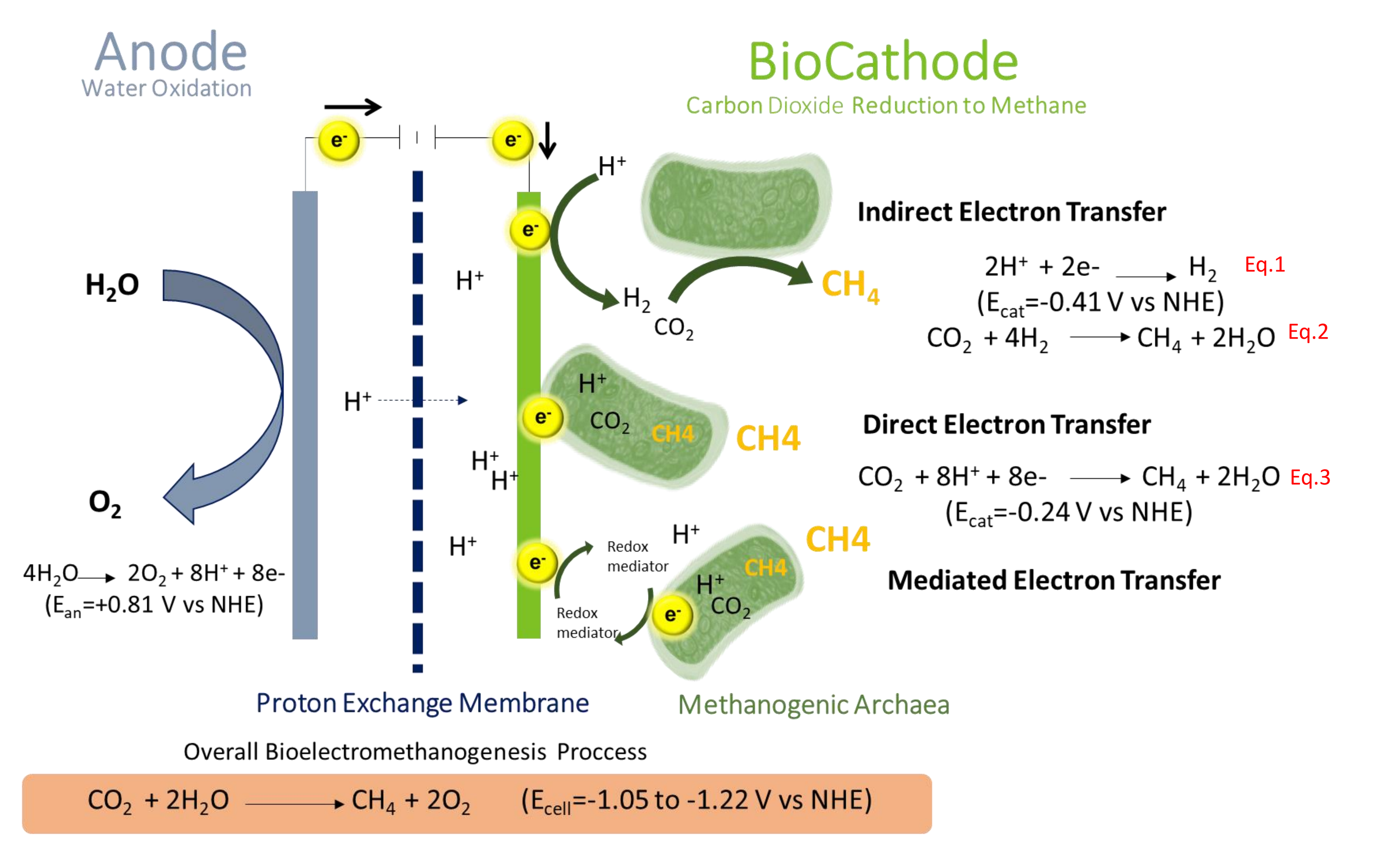

Figure 4: Scheme of a methane production MEC. CO_2 reduction to CH_4 takes place under different mecanisms at the biocathode

Results

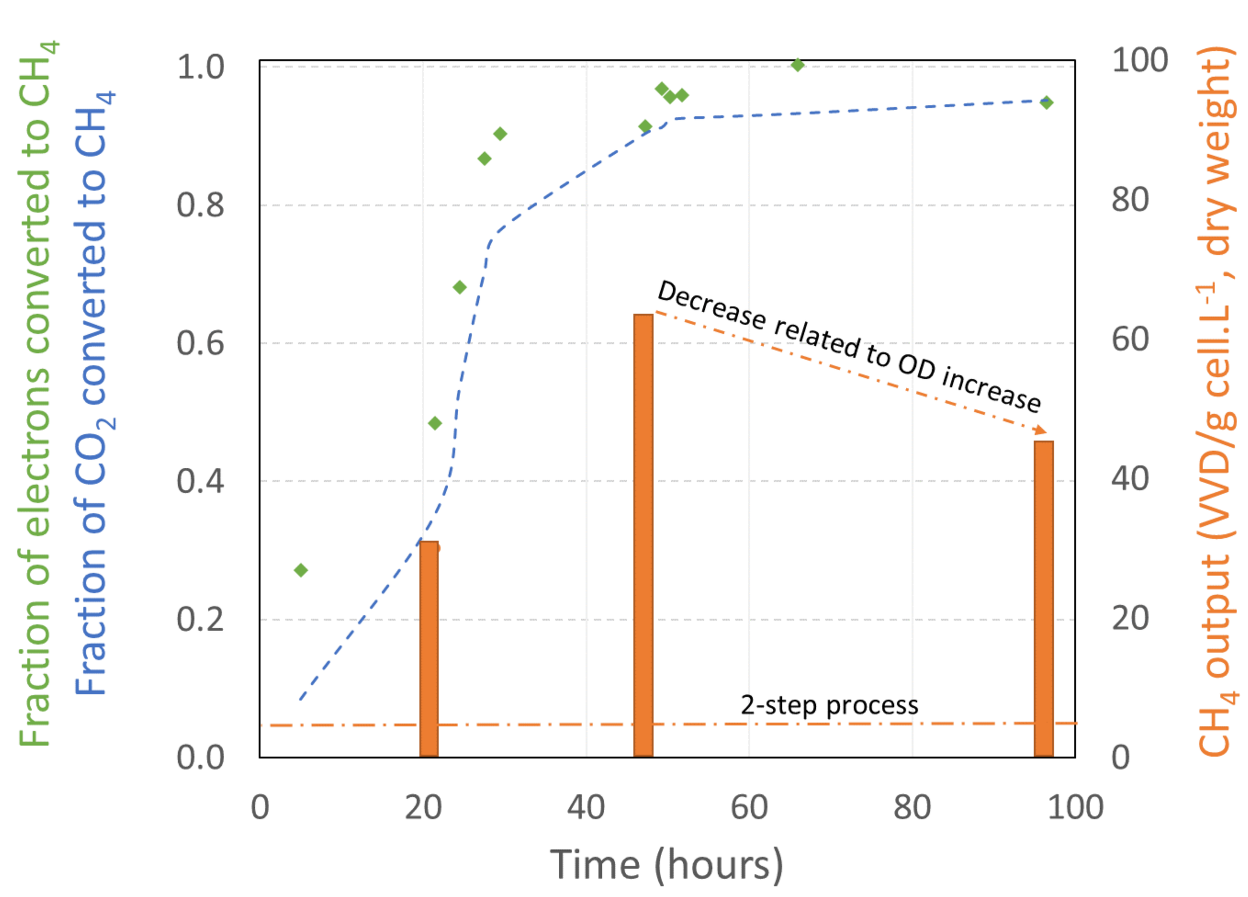

Figure 5: Bioelectrochemical performance of methane production in a Microbial Electrolysis Cell from CO_2 and electricity. Electrochaea's proprietary biocatalyst is a *Methanothermobacter thermautrophicus* strain[2] developed in in Prof. Mets Lab (University of Chicago, IL). The density of the culture placed at the biocathde duplicates during the course of the experiment.

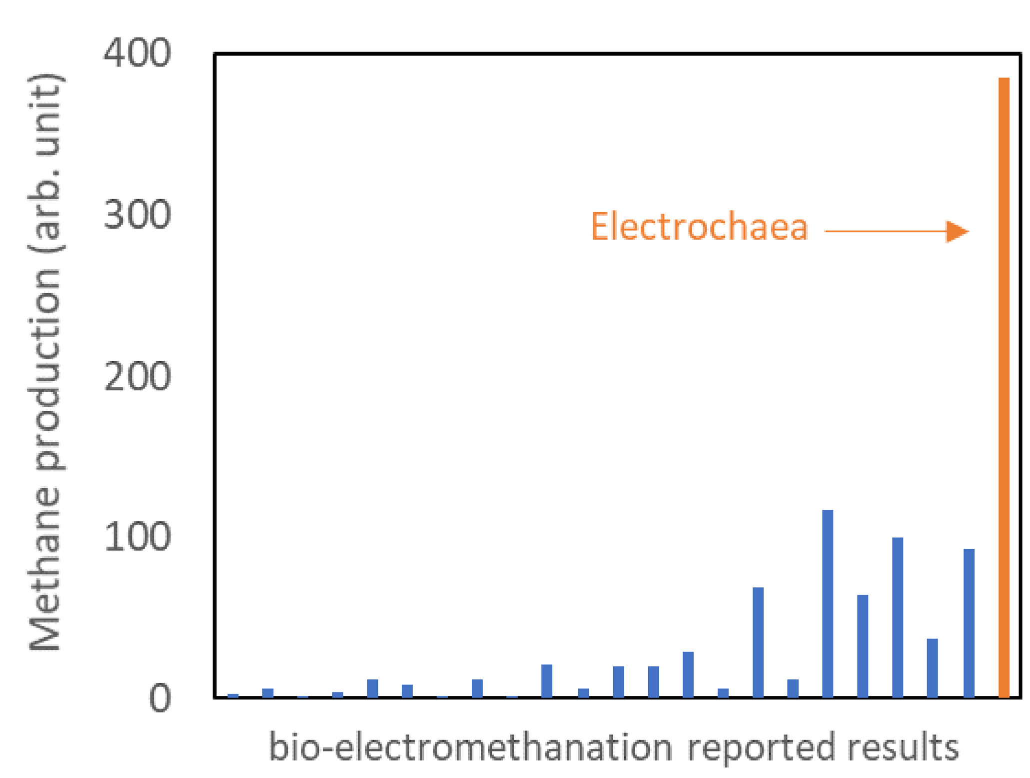

Figure 6: Relative methane production in % reported in peer reviewed articles published between 2009 and 2020[3]. The orange bar represents the relative methane production (%) achieved with the 1-step process at Electrochaea.

Conclusions

- ✓ MEC is an efficient system to convert CO_2 to methane in a **continuous process** with high conversion rates using a biocatalyst
- ✓ **High energy conversion efficiency** of electrons to methane (coulombic efficiencies above 90%)
- ✓ **High specific volumetric productivity** in comparison to the 2-step process (VVD per gram of dry cell)
- ✓ Electrochaea's proprietary **biocatalyst actively grows** in the biocathode with CO_2 as the only carbon source

1. Mets, Laurens (Chicago, IL, US) 2017 METHOD AND SYSTEM FOR CONVERTING ELECTRICITY INTO ALTERNATIVE ENERGY RESOURCES United States THE UNIVERSITY OF CHICAGO (Chicago, IL, US) 20180208884

2. Martin, M. R., Fornero, J. J., Stark, R., Mets, L., & Angenent, L. T. (2013). A single-culture bioprocess of Methanothermobacter thermautotrophicus to upgrade digester biogas by CO 2-to-CH 4 conversion with H 2. *Archaea, 2013*.

3. Zhang, Z., Song, Y., Zheng, S., Zhen, G., Lu, X., Takuro, K., ... & Bakonyi, P. (2019). Electro-conversion of carbon dioxide (CO2) to low-carbon methane by bioelectromethanogenesis process in microbial electrolysis cells: the current status and future perspective. Bioresource technology.

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