

# Integration of direct air capture and biological processes for sustainable production of Methane



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## Motivation

Carbon capture and utilization (CCU) is one of the strategies proposed for mitigating dependency on fossil resources. Direct air capture (DAC) technologies are able to capture CO<sub>2</sub> directly from ambient air [1]. The captured CO<sub>2</sub> can be used as commodity for multiple purposes or as a carbon feedstock for chemical production. A particularly interesting product is methane. With CO<sub>2</sub> and H<sub>2</sub> as feedstock, biomethanation reactors are able to produce grid-quality (>95%) methane [2].

Biological CO<sub>2</sub> methanation take place in anaerobic, mild conditions [3], with pH range between 6.2-8.5 and temperature between 35-40°C (mesophilic) or 55-65°C (thermophilic), according to the following reaction,

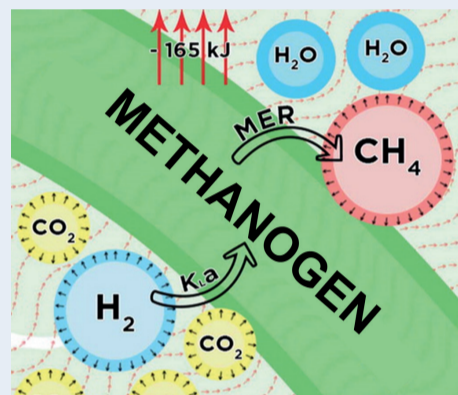
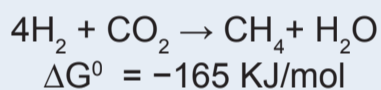


Fig.1 Biological CO<sub>2</sub> methanation [2]

This research seeks to develop an energy-efficient process to produce renewable and biomass-independent methane with CO<sub>2</sub> from atmosphere, by integrating an previously described electrochemically-assisted DAC (Fig. 2) [4] and biological CO<sub>2</sub> methanation step (Fig. 3).

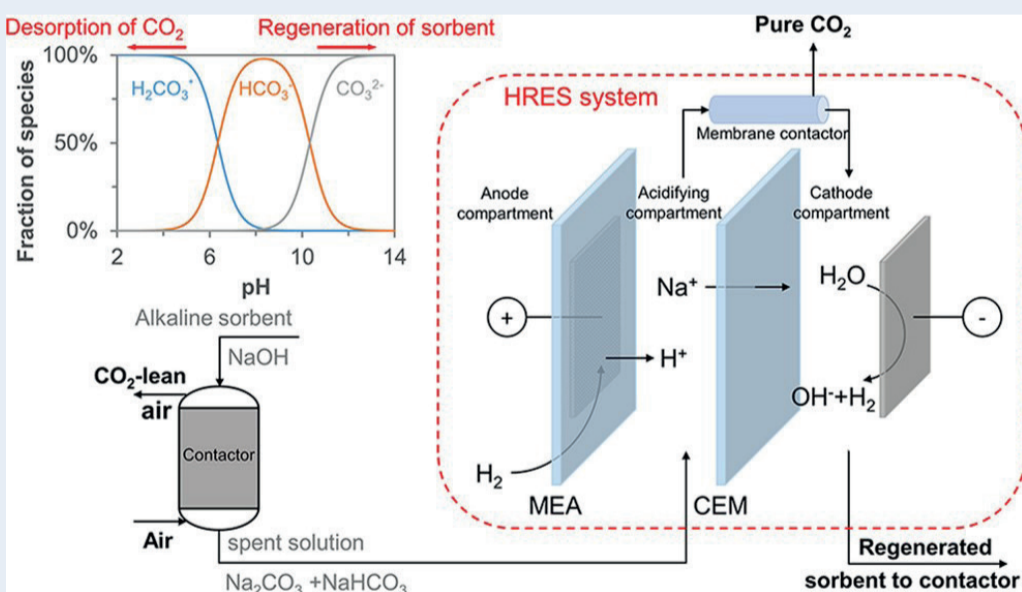


Fig.2 Principle of DAC process using a Hydrogen recycling electrochemical system (HRES) for CO<sub>2</sub> desorption.[3]

## Technological challenge

Typically the electrochemical system can be characterized as fast-responding with extreme conditions, whereas the bioreactor operates best at mild and stable conditions. To integrate the electrochemical unit with the bioreactor unit, the balance between these two systems is crucial.

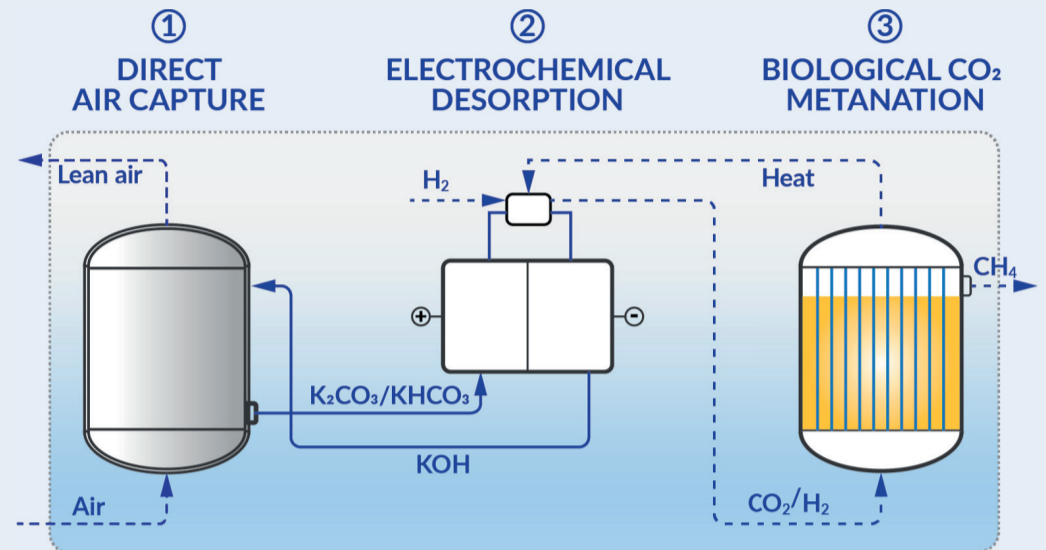


Fig.3 Schematic drawing of the integrated DAC-Biomethanation system.

Mass flows need to be explicitly tuned to sustain a stable substrate/product balance for biomethanation. Heat and pH need to be managed to keep methanogens at optimal metabolic activity. Finally, in order to reach an efficient methane production, individual mass and energy flow need to be optimised in terms of energy requirements (kJ/mol CO<sub>2</sub>), and product yield (mol CH<sub>4</sub>/m<sup>3</sup> air).

## Research goals

The research will be organized into three main objectives:

- Reach stable and tunable performance for integrated DAC with electrochemical desorption
- Optimize operating conditions and gas feeding strategy for biological CO<sub>2</sub> methanation
- System integration and overall process optimization. Concerning CO<sub>2</sub> and H<sub>2</sub> conversion efficiency, heat integration, electrical energy input, water production and losses in the system.

[1] Sanz-Pérez, E.S., et al., *Direct Capture of CO<sub>2</sub> from Ambient Air*. Chemical Reviews, 2016. **116**(19): p. 11840-11876.  
 [2] Rusmanis, D., et al., *Biological hydrogen methanation systems – an overview of design and efficiency*. Bioengineered, 2019. **10**(1): p. 604-634.  
 [3] Lecker, B., et al., *Biological hydrogen methanation – A review*. Bioresource Technology, 2017. **245**: p. 1220-1228.  
 [4] Shu, Q., et al., *Electrochemical Regeneration of Spent Alkaline Absorbent from Direct Air Capture*. Environmental Science & Technology, 2020. **54**(14): p. 8990-8998.



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