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BIOLOGICAL CONVERSION OF CO/CO_2 AND GREEN H_2 INTO E-BIOMETHANE: RESULTS AT BATCH AND CONTINUOUS SCALE

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SPOKE, WP AND TASK

SPOKE 8 – Circular economy in agriculture through waste valorisation and recycling
WP 8.2 – Agroenergy production from wastes to reduce energy dependence
TASK 8.2.3 – Waste gases to be upgraded to feedstock feeding innovative bio and no-bio technologies producing molecules/products

BACKGROUND

What is e-biomethane?

Biologically synthesized methane from **non-fossil** energy sources (i.e. green H_2), within the **Power to Gas** (PtG) framework

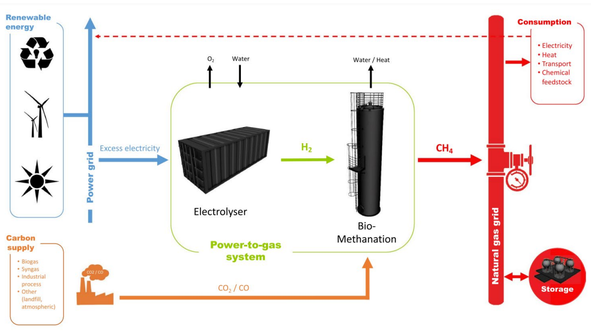


Figure 1. Ex situ biomethanation concept

Why is PtG crucial?

Promotes **circular economy** and **sector coupling** by transforming **surplus renewable energy** and **capturing CO_2**

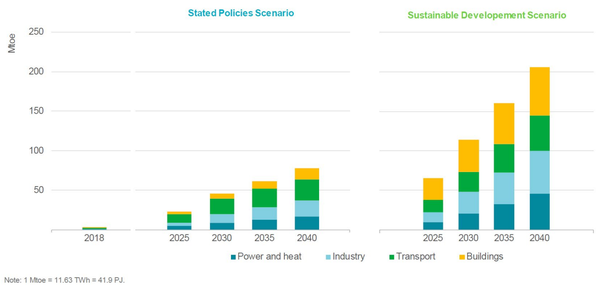


Figure 2. Global biomethane demand by sector

Who are the actual players?

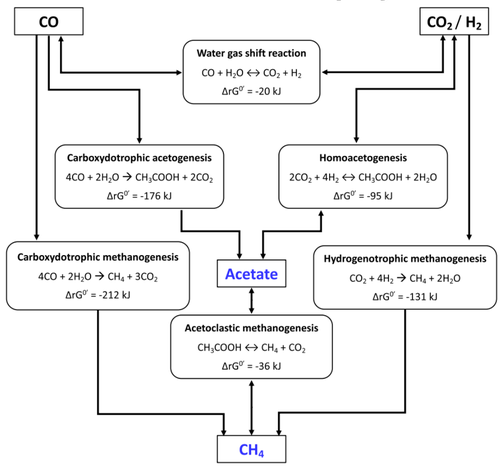


Figure 3. Anaerobic conversion pathways of CO/CO_2 to CH_4

Research goals

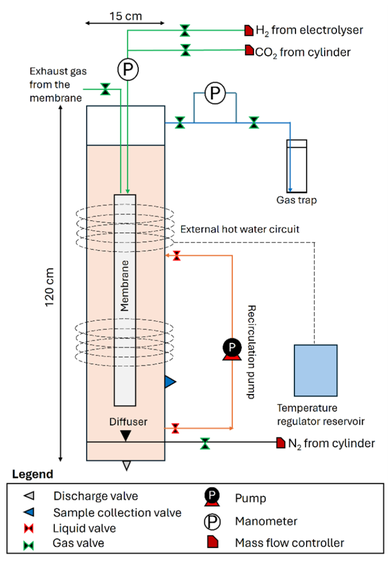
The research aims to engineer an innovative processes for **converting CO, CO_2, and green H_2 into CH_4**, based on the combination of membrane gas transfer and biofilm growth to:

- ✓ Optimize energy efficient H_2 gas-liquid mass transfer
- ✓ Optimize process rates
- ✓ Promote carbon capture and utilization
- ✓ Support the production of e-biomethane and PtG in agro-industrial environment

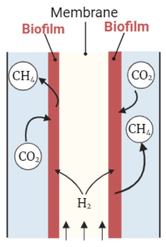
MATERIALS & METHODS

Continuous scale – CO_2

Design and operation of a pilot scale **Membrane Biofilm Reactor** (MBfR) feed with H_2 and CO_2. The **hydrogenotrophic methanogenic biofilm** grows on a hydrophobic **hollow-fiber membrane**



- **Zeelung Lab scale module**
  → H_2 and/or CO_2 transfer → Dead-end



- **Porous diffuser**
  → N_2 or CO_2 transfer

- Enriched culture of **hydrogenotrophic methanogens**

- H_2 generated by an **electrolyser**

Figure 4. Scheme of the Membrane Biofilm Reactor

Batch scale – CO

Mesophilic **carboxydotrophic** and **methanogenic specific activity tests** to optimize the CO conversion preliminary to continuous test and scale-up.

Set up of the **manometric** specific activity tests:

- **Suspended** and **granular** anaerobic sludge (5 and 2 gVS/L) **inocula**
- 6 bottles, V_{liq} = 0.5 L in duplicates (+ blanks)
- Initial Head-Space Composition:
  CO = 20%, N2 = 80% and p = 1 bar
- Magnetic stirring
- T = 37°C
- **Head-space pressure** measured continuously over time

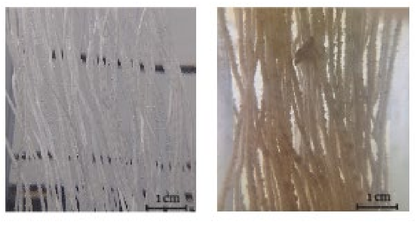
Figure 5. Specific activity tests set-up

RESULTS

1. **Optimal hydrogen gas transfer** is obtained operating in dead-end mode (ASCE Standard)

Operation mode	k_La H_2 (d^{-1})
Flow-trough	6.14
Dead-end	12.44

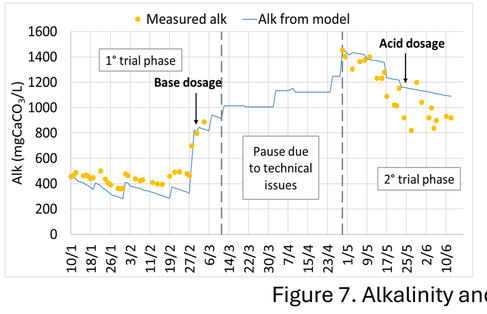
2. **Reactor inoculation**



- A biofilm is formed on the fibers **rapidly**
- **Biofilm growth** confirmed by a **67%** increase in **H_2 conversion rate** over 3 months
- Efficient **H_2 transfer** and **CH_4 conversion** rates above **80%** and **60%**

Figure 6. Clean and inoculated membrane's fibers

3. Modelling of **nutrients** and **alkalinity trends** for correct nutrients and buffer dosages



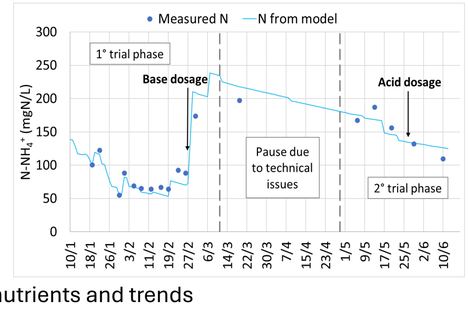


Figure 7. Alkalinity and nutrients and trends

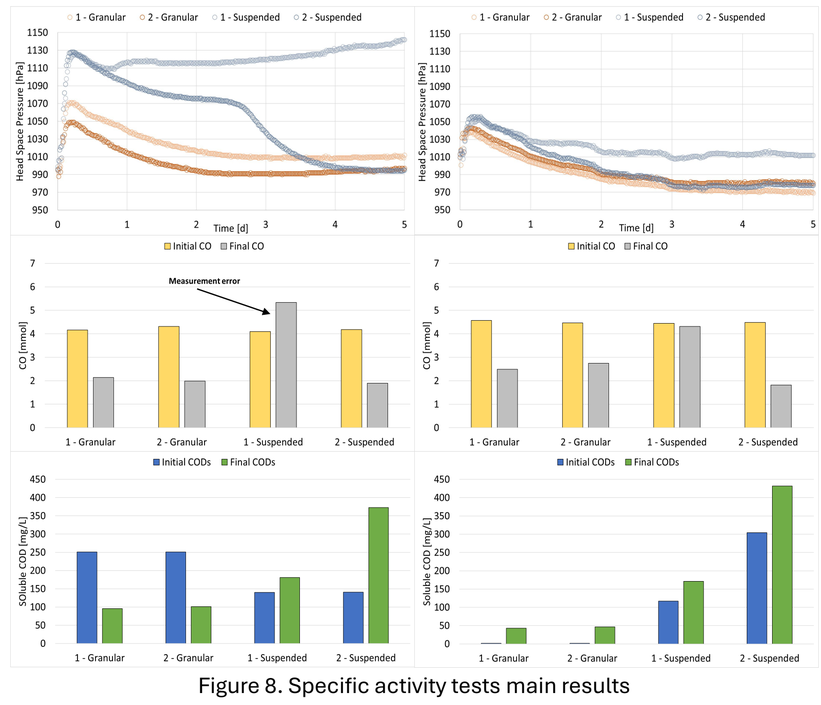


Figure 8. Specific activity tests main results

1. Head-space reduction of pressure and CO content show clear **adaptation**
2. Soluble COD trends suggest **VFA production** ☺
3. **Follow up at batch scale**: continuous monitoring of gas composition dissolved H_2 and VFA to better understand CO consumption pathways

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