CARMA·H2

CARMA-H2

Waste reimagined. Energy reborn.

Co-funded by the European Union

Clean Hydrogen Partnership

Hydrogen Innovation Webinar – 28.05.2025

Clean hydrogen from local waste

CARMA-H2 is a four-year EU-funded project demonstrating a circular, decentralised route to hydrogen production. At its core lies the bioPMR (Protonic Membrane Reformer), which will convert biogas from organic waste into pressurised hydrogen while producing a food-grade CO_2 stream.

The technology will be validated at a wastewater treatment plant in Navarra, Spain, supporting local energy systems and advancing Europe's green transition.

Key figures & consortium

Project name: Carbon-negative pressurised hydrogen production from waste using an energy-efficient protonic membrane reformer (CARMA-H2)

Project coordinator: AIN: Asociación de la Industria Navarra

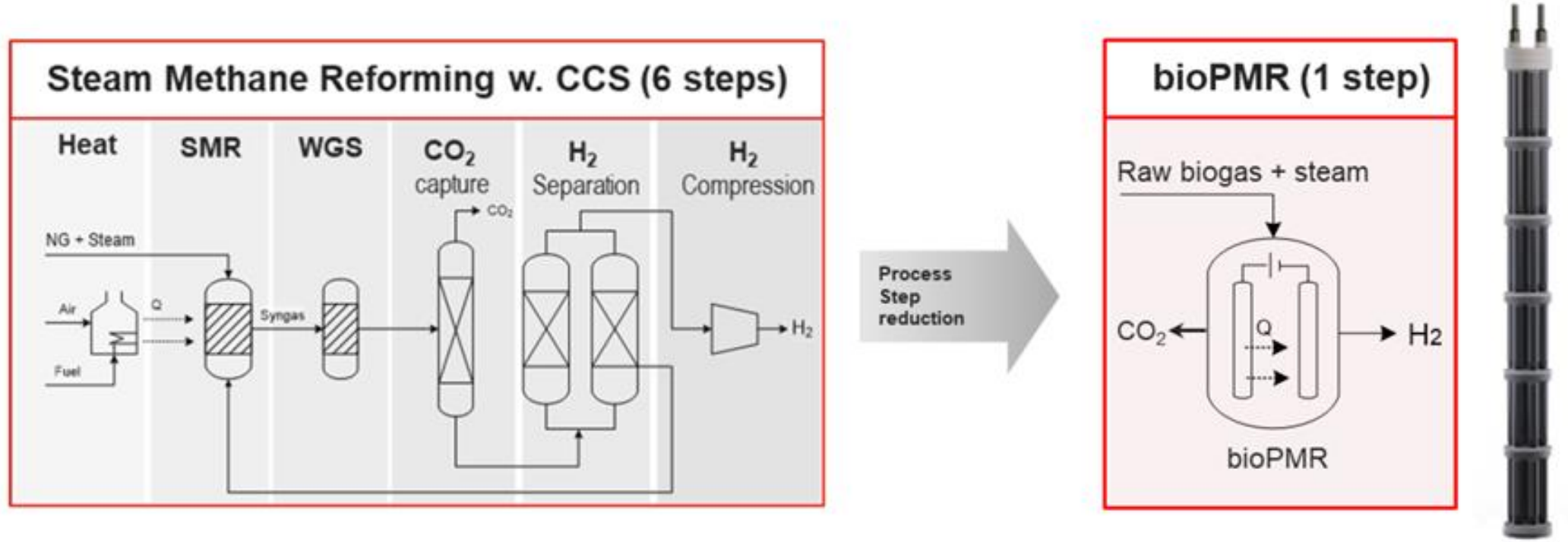
Number of partners: 12 partners, from 5 European countries

Total EU budget: €9,954,419

Duration: 48 months. From 01/10/24 to 30/09/28

PROTONIC MEMBRANE REFORMER (bioPMR)

The bioPMR technology, developed by CoorsTek Membrane Science, is able to combine the traditional 6 steps of SMR with CCS in one single reactor



bioPMR - FUNDAMENTALS

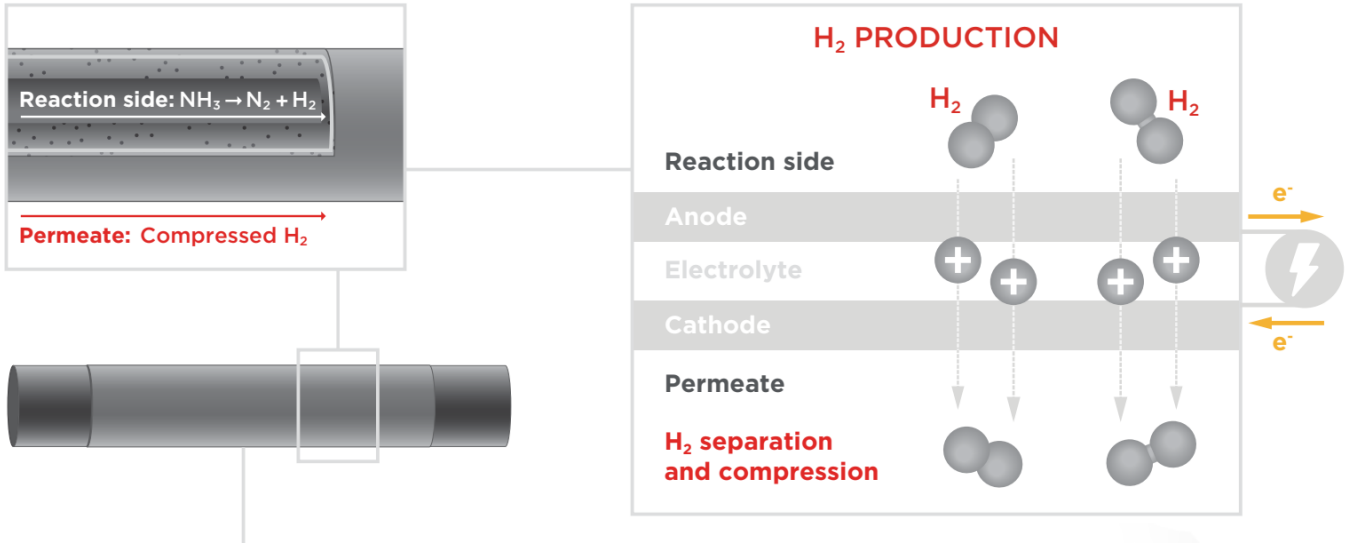
Proton ceramic membranes are the core of bioPMR

PURE HYDROGEN

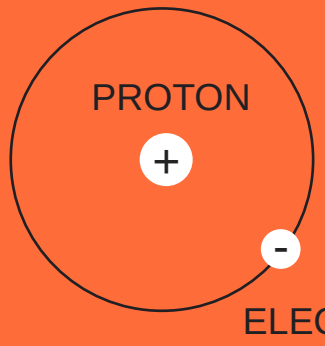
ENERGY EFFICIENT

SCALABLE

SINGLE-STEP SOLUTION



HYDROGEN



PROTON CERAMIC MEMBRANES operate at elevated temperatures between 400°C and 800°C by breaking hydrogen into its sub-atomic particles (PROTONS and ELECTRONS) and then transporting protons across a solid dense ceramic electrolyte

PROTON CERAMIC MEMBRANES offer unique opportunities for more efficient hydrogen production

bioPMR - FUNDAMENTALS

nature energy ARTICLES
https://doi.org/10.1038/s41560-017-0029-4

Thermo-electrochemical production of compressed hydrogen from methane with near-zero energy loss

Harald Malerød-Fjeld[1], Daniel Clark[1,2], Irene Yuste-Tirados[1], Raquel Zanón[3], David Catalán-Martinez[3], Dustin Beeaff[1], Selene H. Morejudo[1], Per K. Vestre[1], Truls Norby[2], Reidar Haugsrud[2], José M. Serra[3*] and Christian Kjølseth[1*]

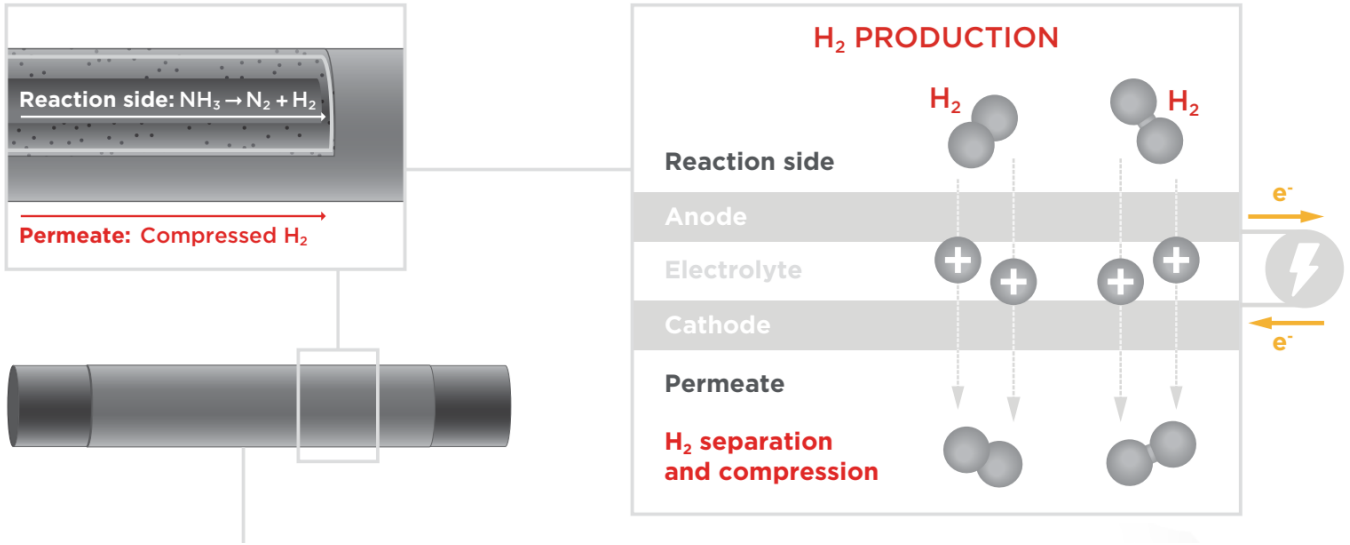
Extraction of H_2 through the proton conductive layer

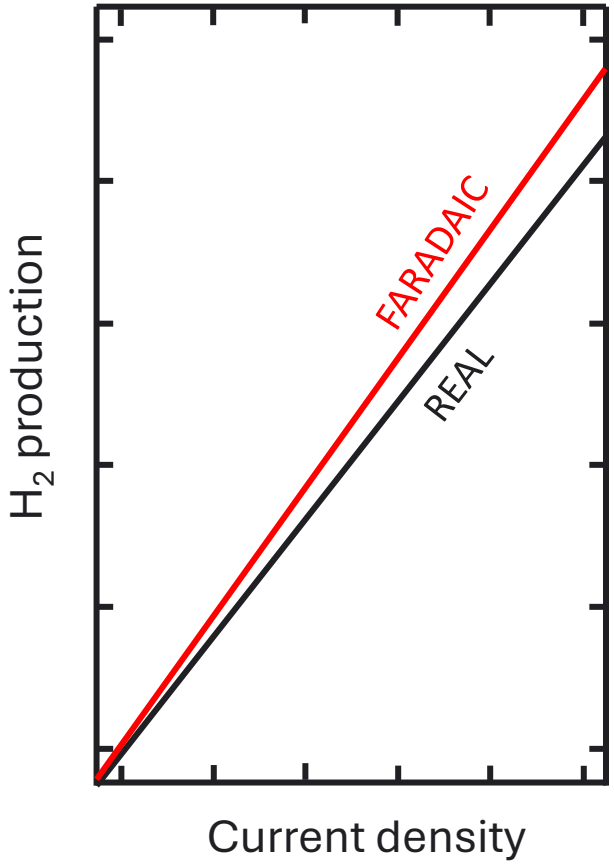
PURE HYDROGEN

ENERGY EFFICIENT

SCALABLE

SINGLE-STEP SOLUTION





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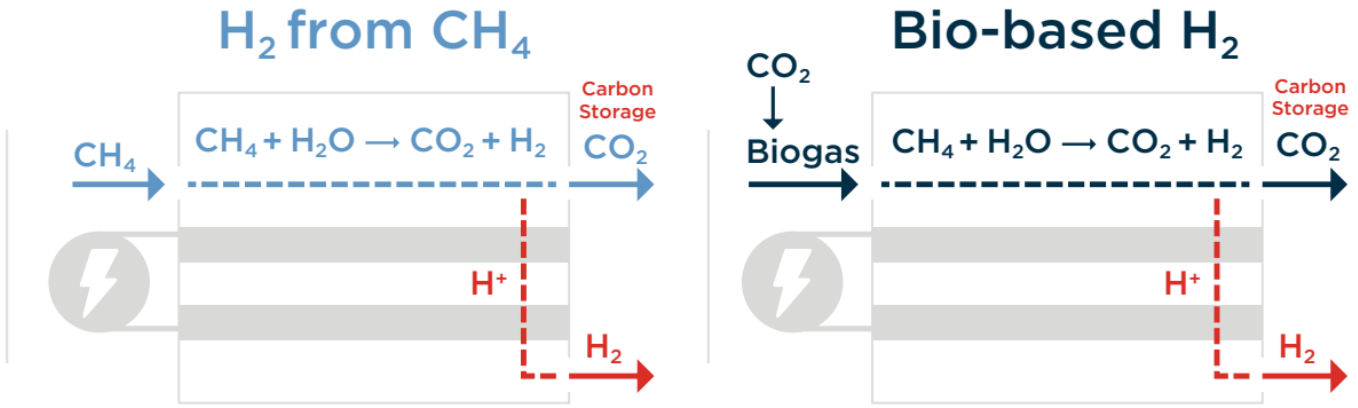
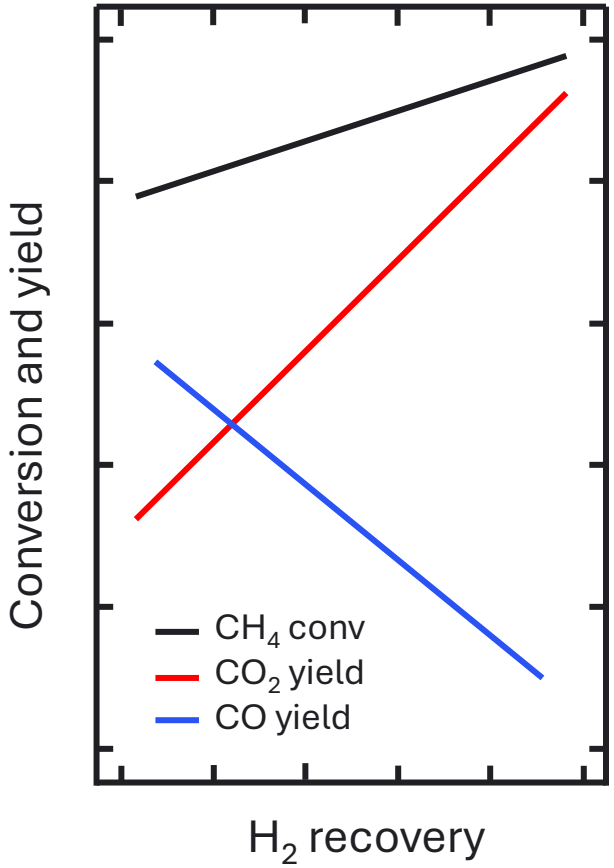
Shift of thermodynamic equilibrium towards full conversion of CH_4



$$CH_4 + H_2O = 3\,H_2 + CO$$

$$CO + H_2O = H_2 + CO_2$$



bioPMR - FUNDAMENTALS

PMR: a near-zero energy loss system

For more info about the near-zero energy loss concept, please check our paper at this link: https://www.nature.com/articles/s41560-017-0029-4

nature energy

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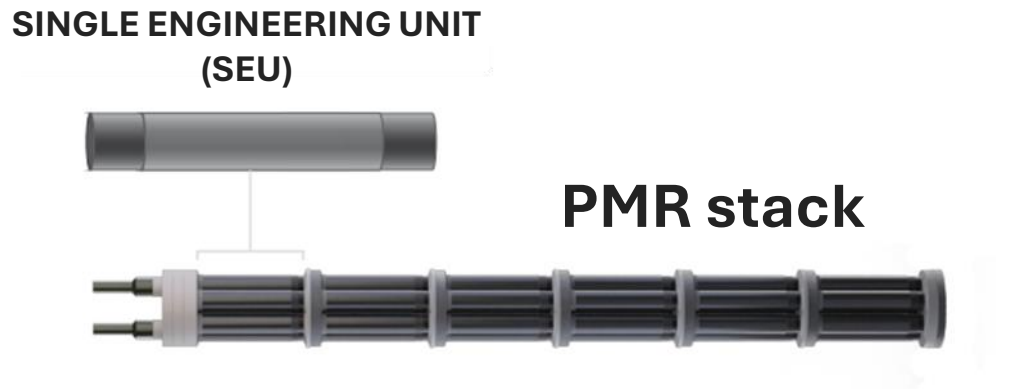
Conventional production of hydrogen requires large industrial plants to minimize energy losses and capital costs associated with steam reforming, water-gas shift, product separation and compression. Here we present a protonic membrane reformer (PMR) that produces high-purity hydrogen from steam methane reforming in a single-stage process with near-zero energy loss. We use a $BaZrO_3$-based proton-conducting electrolyte deposited as a dense film on a porous Ni composite electrode with dual function as a reforming catalyst. At 800 °C, we achieve full methane conversion by removing 99% of the formed hydrogen, which is simultaneously compressed electrochemically up to 50 bar. A thermally balanced operation regime is achieved by coupling several thermo-chemical processes. Modelling of a small-scale (10 kg H_2 day^{-1}) hydrogen plant reveals an overall energy efficiency of >87%. The results suggest that future declining electricity prices could make PMRs a competitive alternative for industrial-scale hydrogen plants integrating CO_2 capture.

bioPMR STACK – UPSCALING

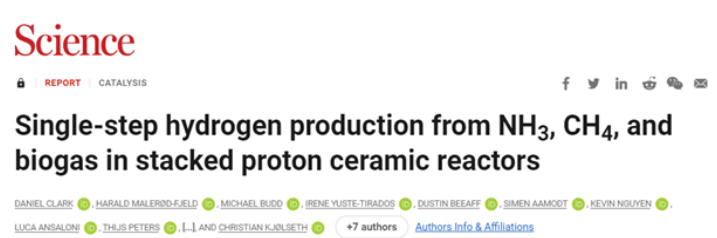
STACK FEATURES

- Series of six barrels (six SEU per barrel connected in parellel)
- U-bend type of gas flow
- Interconnects: Ni-based glass-ceramic composite
- Microthermal heat integration



For more info about stack development and microthermal integration, please check our paper at this link: https://www.science.org/doi/10.1126/science.abj3951

bioPMR STACK – OPERATION


Science

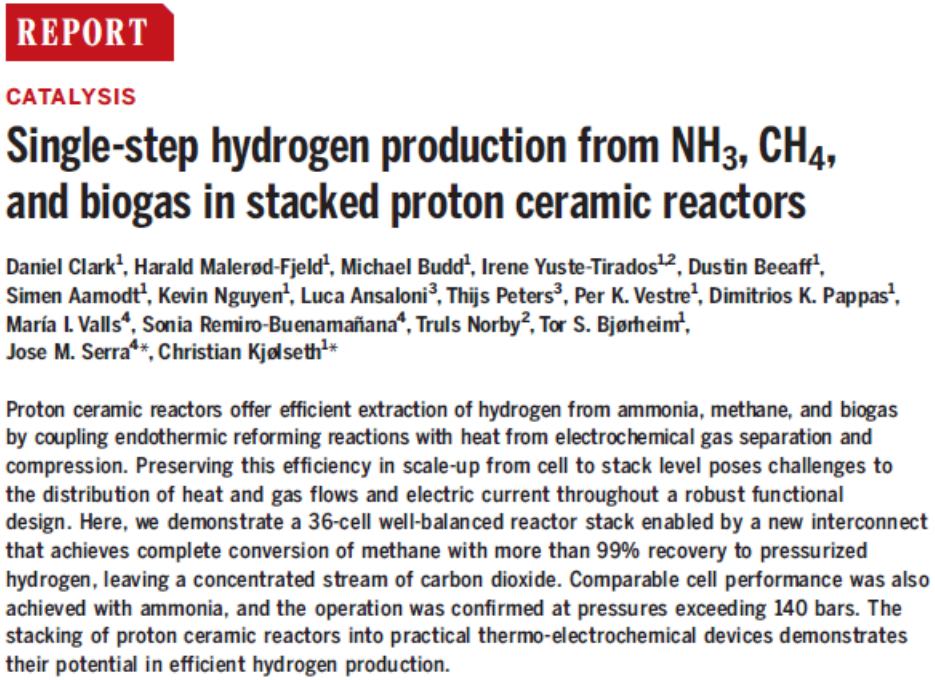
REPORT | CATALYSIS

Single-step hydrogen production from NH_3, CH_4, and biogas in stacked proton ceramic reactors

DANIEL CLARK, HARALD MALERØD-FJELD, MICHAEL BUDD, IRENE YUSTE-TIRADOS, DUSTIN BEEAFF, SIMEN AAMODT, KEVIN NGUYEN, LUCA ANSALONI, THIJS PETERS, [...] AND CHRISTIAN KJØLSETH +7 authors Authors Info & Affiliations

By increasing H_2 recovery, full CH_4 conversion is achieved
CO is also consumed, leading to high CO_2 yield

For more info about CH4 conversion and CO2 yield from the bioPMR, please check our paper at this link: https://www.science.org/doi/10.1126/science.abj3951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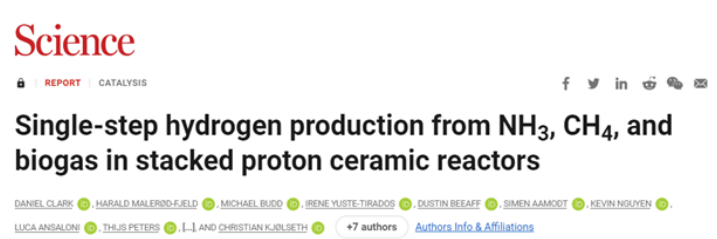
Proton ceramic reactors offer efficient extraction of hydrogen from ammonia, methane, and biogas by coupling endothermic reforming reactions with heat from electrochemical gas separation and compression. Preserving this efficiency in scale-up from cell to stack level poses challenges to the distribution of heat and gas flows and electric current throughout a robust functional design. Here, we demonstrate a 36-cell well-balanced reactor stack enabled by a new interconnect that achieves complete conversion of methane with more than 99% recovery to pressurized hydrogen, leaving a concentrated stream of carbon dioxide. Comparable cell performance was also achieved with ammonia, and the operation was confirmed at pressures exceeding 140 bars. The stacking of proton ceramic reactors into practical thermo-electrochemical devices demonstrates their potential in efficient hydrogen production.

bioPMR STACK – OPERATION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High CO_2 purity (> 95%) can be achieved
By means of electricity, H_2 can be compressed on the permeate side

For more info about CO2 purity and electrochemical H2 compression, please check our paper at this link:
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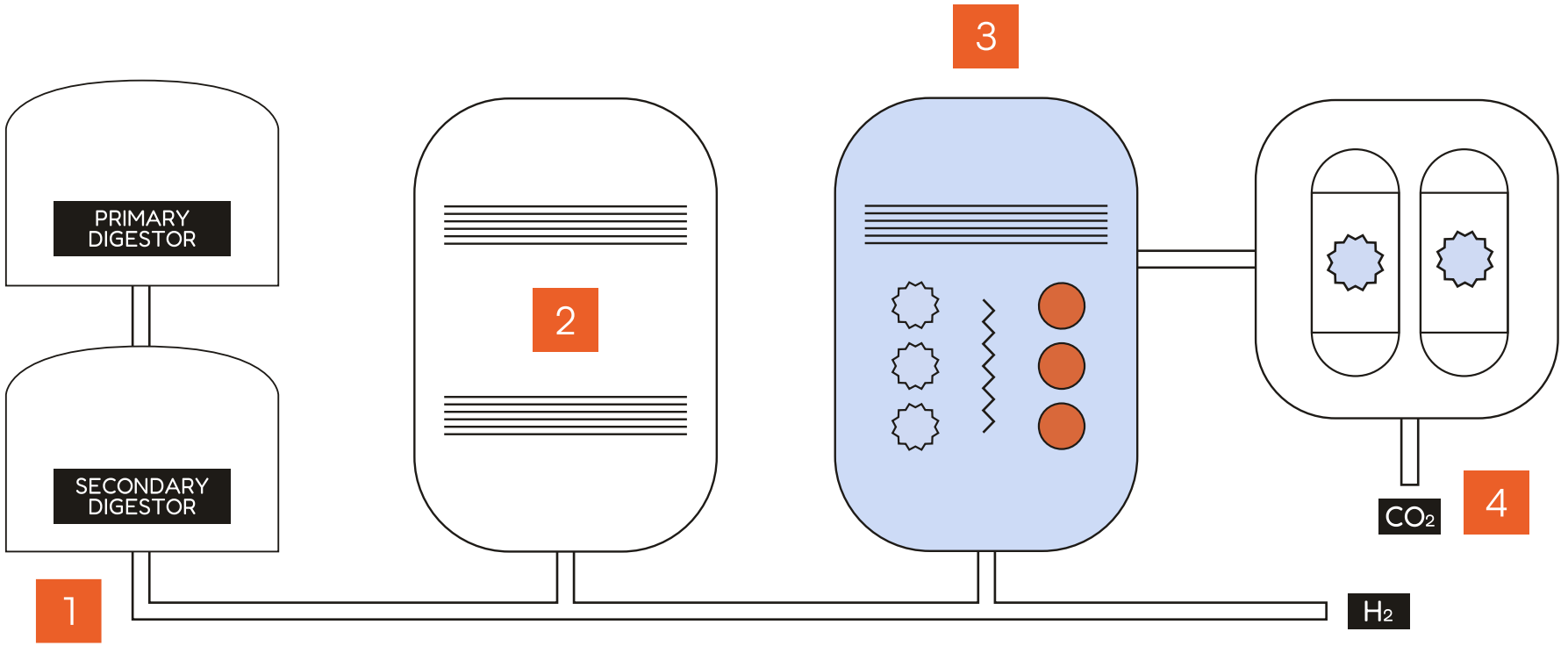
Testing site

CARMA-H2 demonstrates bioPMR technology at the **Arazuri wastewater treatment plant** in Navarra, Spain, through a full-scale pilot that includes:

- Operation of two bioPMR units for at least **4,000 hours**.
- Production of **500 kg of hydrogen per day**, for energy and mobility applications.
- Generation of **4,000 kg of food-grade CO_2 daily**, ready for use.

Pilot structure



1. Biogas production

Organic waste from wastewater is transformed into biogas through anaerobic digestion.

2. Biogas pre-treatment

The raw biogas is compressed and cleaned of unwanted impurities.

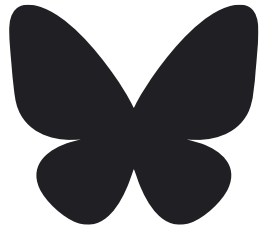
3. bioPMR modules

The purified biogas is transformed into hydrogen and food-grade quality CO_2.

4. CO_2 liquefaction

CO_2 is liquefied for storage or reuse, completing the net-zero cycle.

Stay in the loop!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Thank you!

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