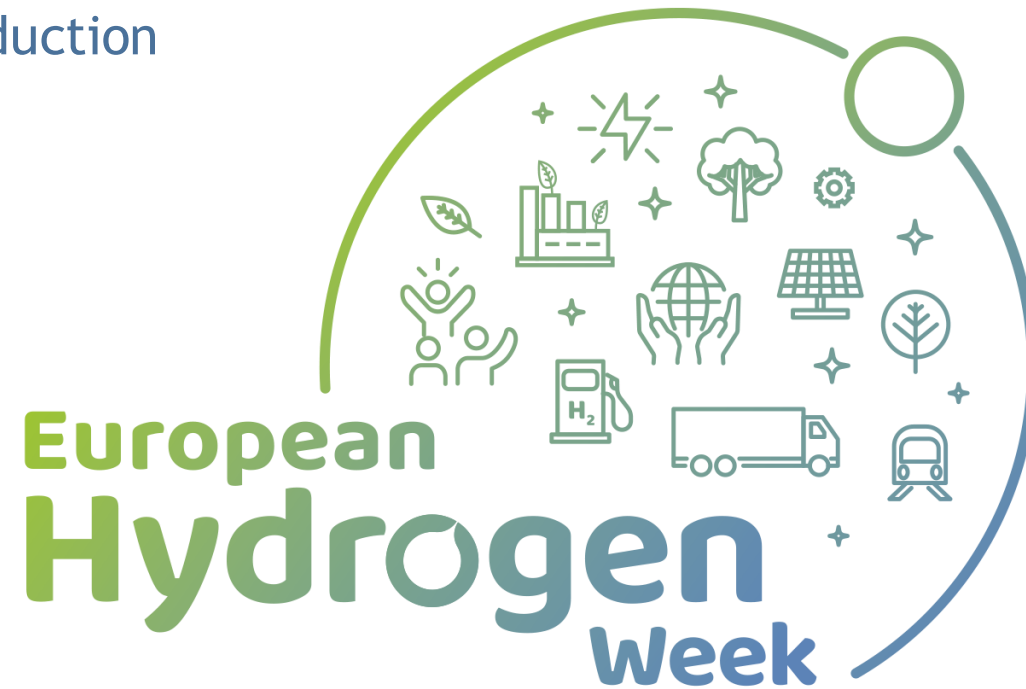


BIONICO

Biogas Membrane Reformer
for Decentralized H₂ production



Marco Binotti

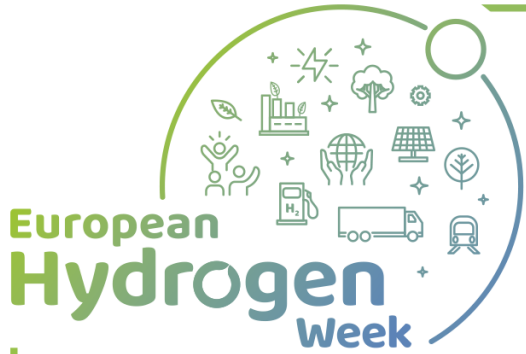
Politecnico di Milano

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marco.Binotti@polimi.it

#PRD2020
#CleanHydrogen



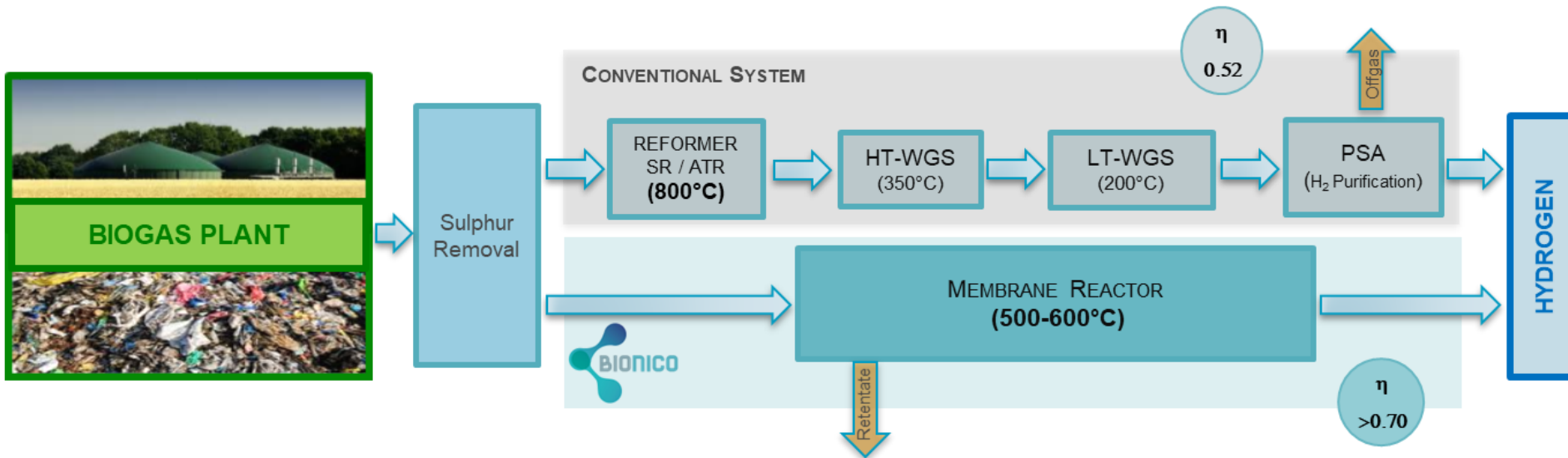


Project Overview

- Call year: 2014
- Call topic: FCH-02.2-2014 Decentralized hydrogen production from clean CO₂-containing biogas
- Project dates: 01/09/2015 - 31/12/2019
- % stage of implementation 01/11/2020: 100%
- Total project budget: 3,396,640 €
- FCH JU max. contribution: 3,147,640 €
- Other financial contribution: 249,000 €
- Partners: Politecnico di Milano, I.C.I. Caldaie SpA, JohnsonMatthey PLC, Fundacion Tecnalia Research & Innovation, TU/e Eindhoven, ENC Power LDA, Rauschert Kloster Veildorf GMBH, Quantis

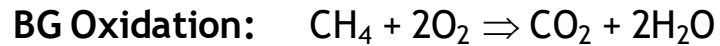
Project Summary

BIONICO aimed at developing, building and demonstrating at a real biogas plant (TRL6) a catalytic membrane reactor integrating production and separation of 100 kg/day of H₂. Direct conversion of biogas to pure hydrogen is achieved in a single step, with increased overall efficiency (up to 72%), strong decrease of volumes and auxiliary heat management units and reduction of operating temperature.

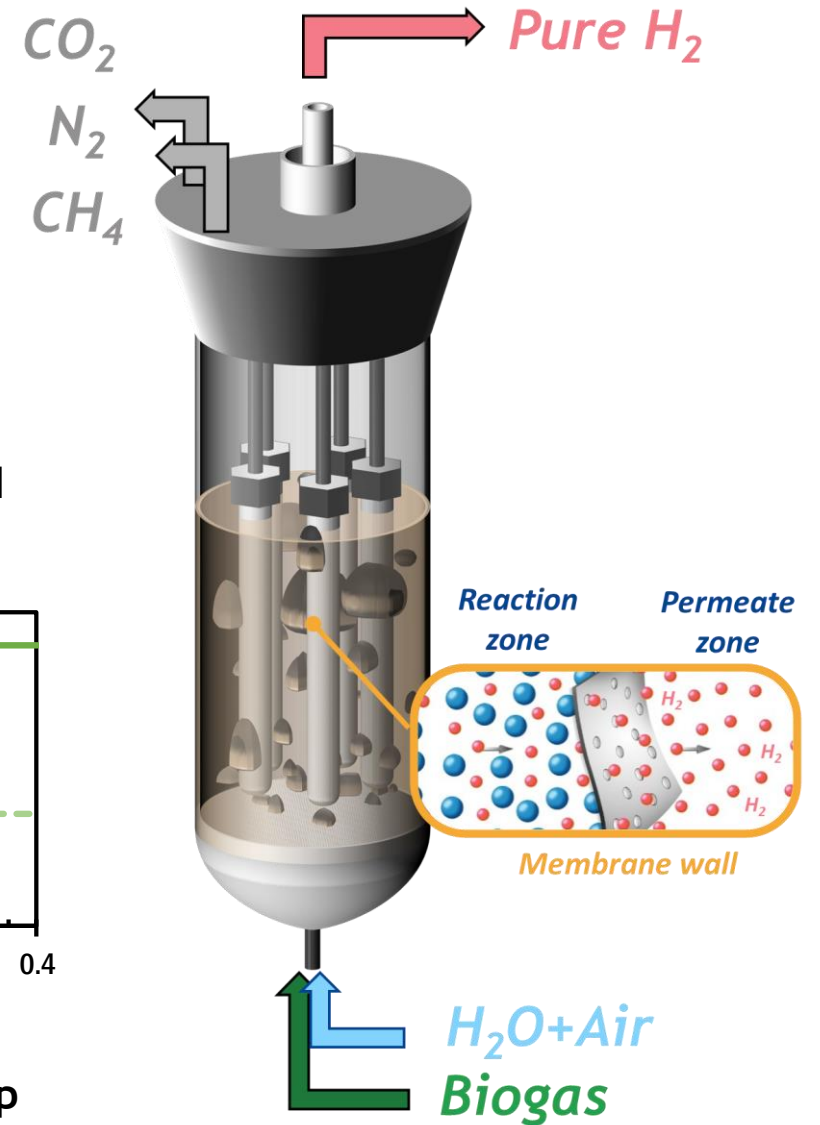
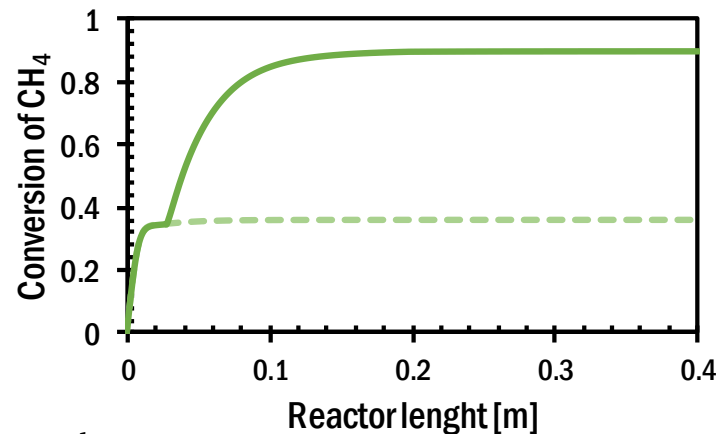


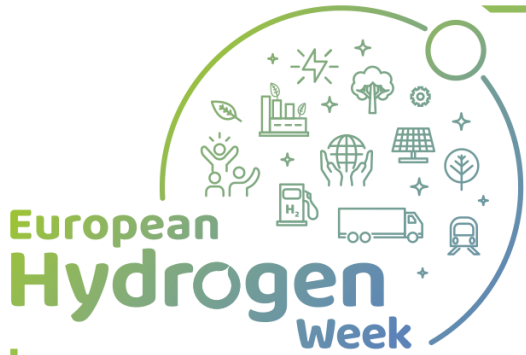
Bionico Concept

- Fuel conversion & H₂ separation take place in a single reactor thanks to membrane perm-selectivity for H₂
- The chemical **equilibrium** is **shifted** towards products (as H₂ is removed with the membranes) enhancing CH₄ conversion at lower T

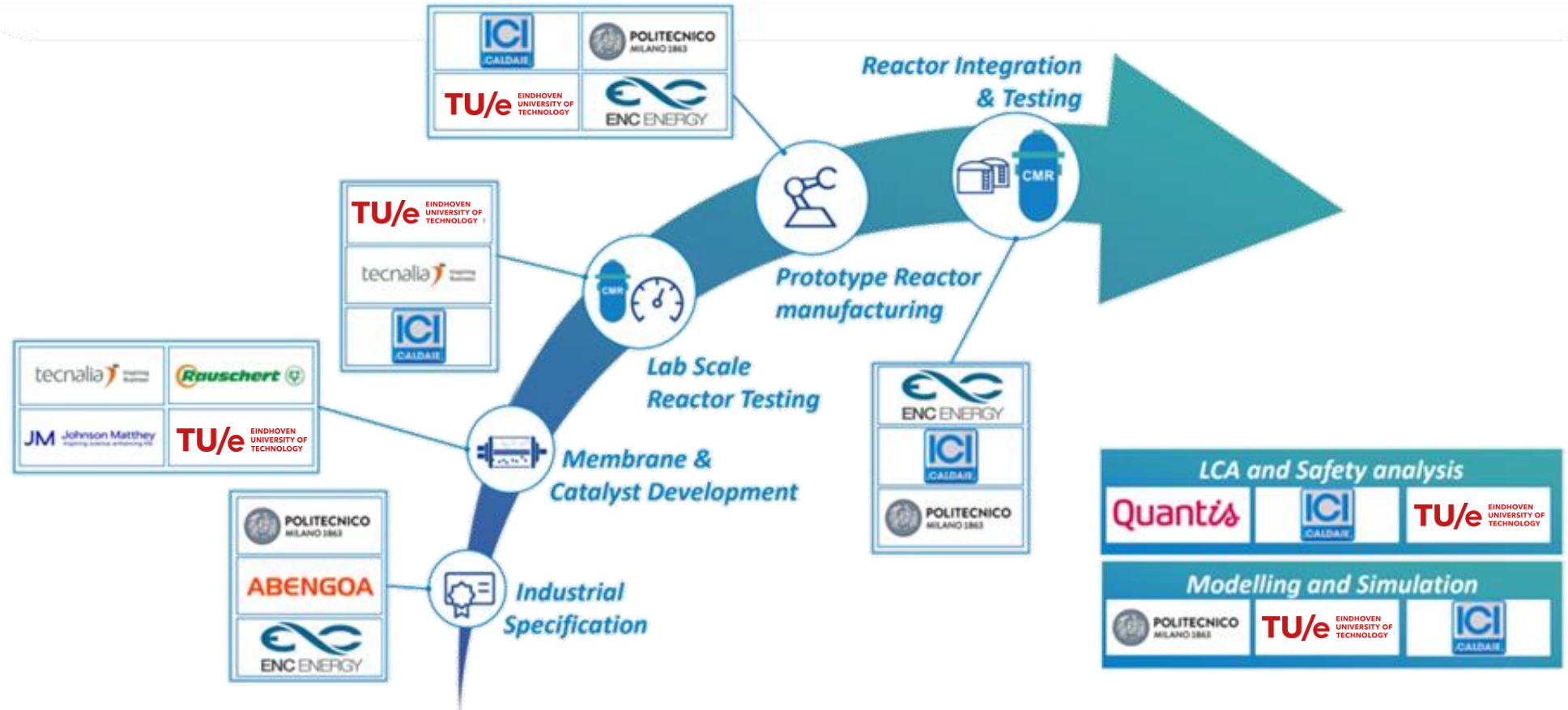


- Catalyst fluidization allows to:
 - overcome problems with T control,
 - operate with smaller particles while still maintaining very low Δp
 - overcome concentration polarization issue





Partnership Synergies



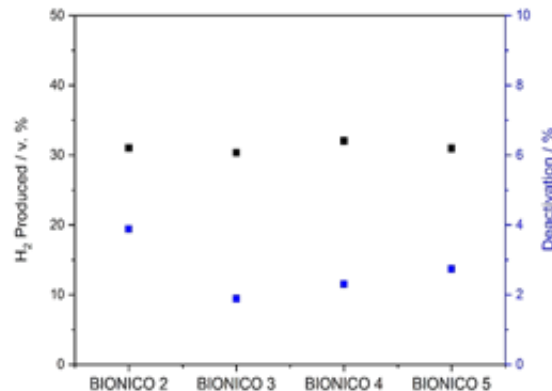
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Progress/Actions - Components development

Components developed

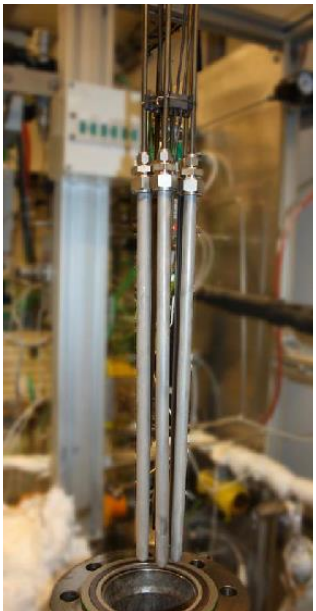
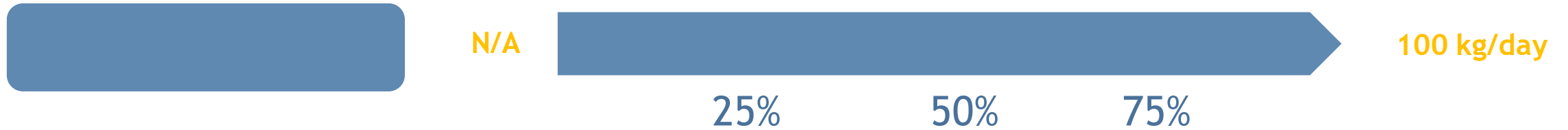
- CATALYST:** A highly active catalysts with improved coke resistance to produce H₂ from different biogas suitable fluidized bed membrane reformer was developed and scaled up.



- MEMBRANES & SUPPORTS:** Development of Pd-based membranes with porous **ceramic finger-like supports** with improved flux and selectivity, suitable for fluidized bed reactors. New membranes are longer (0.2 → 0.5 m) with larger diameter (10/4 → 14/7 mm)



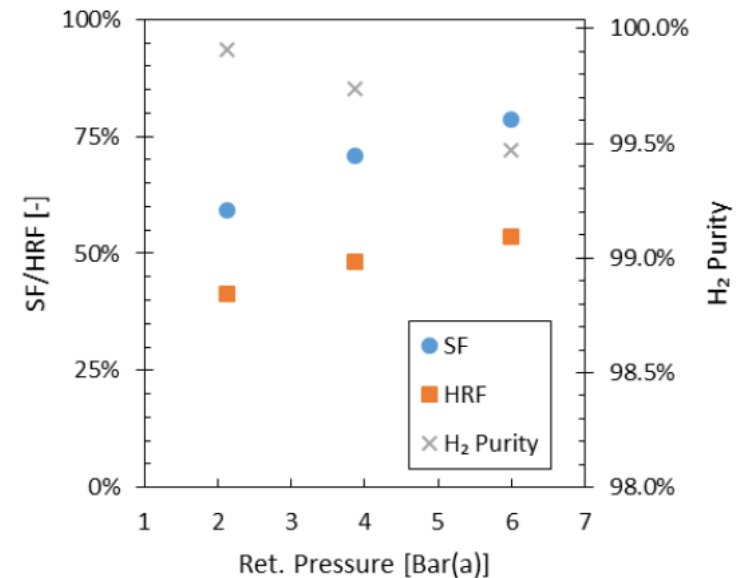
Progress/Actions - CMR Scale Up & Testing



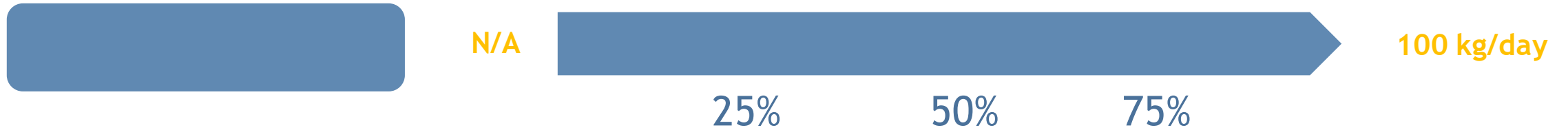
LAB SCALE REACTOR TESTING

- Integration of catalyst and membranes (1 - 5 membranes)
- Development of the reactor Phenomenological model
- Effects of Au addition on H₂S membranes resistance
- Lab scale reactor testing:

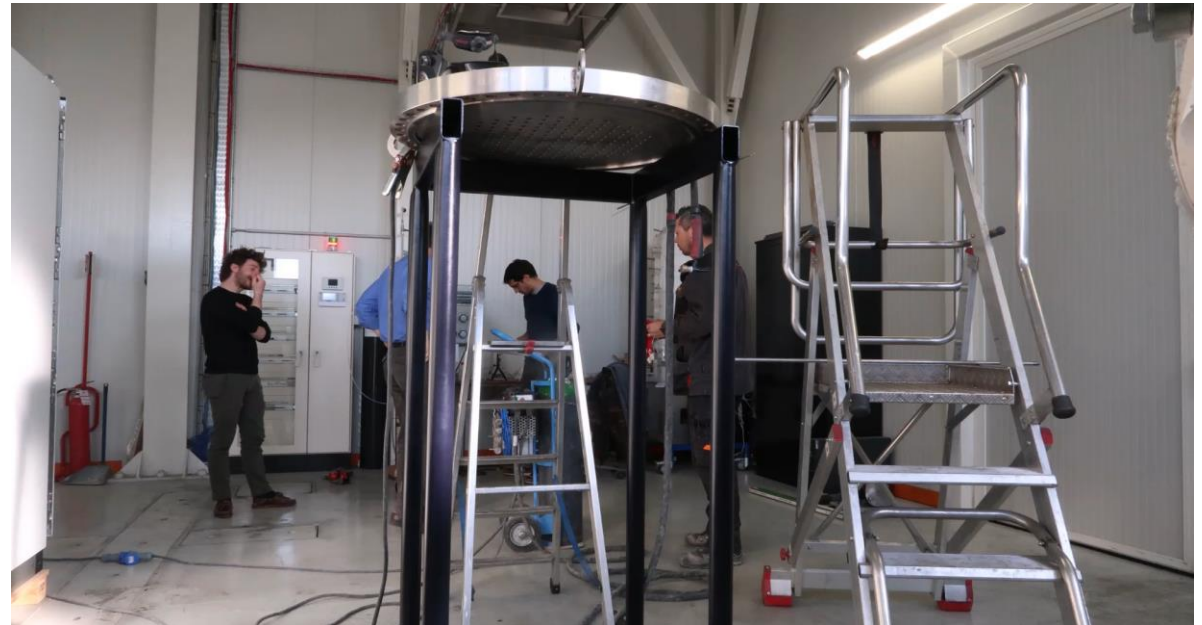
- H₂ recovery up to 55.6%
- H₂ purity of 99.65%



Progress/Actions - CMR Scale Up & Testing



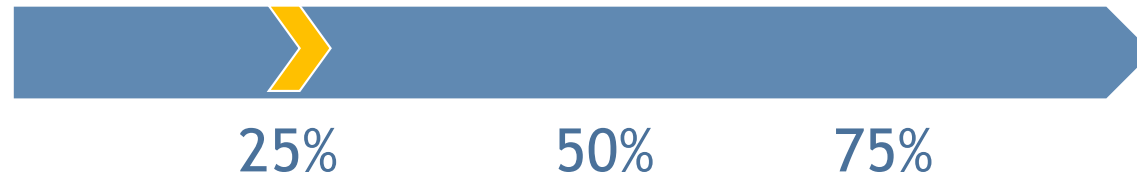
- Design and Manufacturing of a CMR for 100 kg/day of H₂ production (125 membranes) @ICI Caldaie



Progress/Actions - CMR Scale Up & Testing

28 Kg/day

N/A



100 kg/day

- Design and Manufacturing of a CMR for 100 kg/day of H₂ production (125 membranes) @ICI Caldaie
- CMR integration in the overall system (including BOP)
- Reactor testing with synthetic biogas stopped after 115h due to a severe failure of the electric system
 - **Failure NOT related to the reactor itself!!**
 - Design conditions (500°C/12bar) not achieved during operation:
 - lower H₂ mass flow rate and sys efficiency than design
 - Highly pure H₂ produced (**99.3%**)
- × Reactor testing at real Biogas plant (2500h) not performed

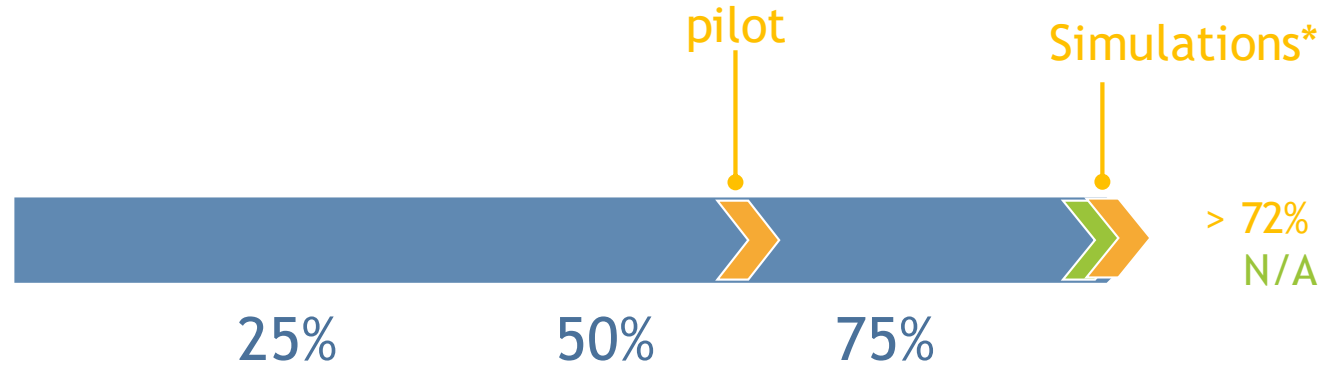


Progress/Actions - System Efficiency/H₂ cost



$\eta=73\%^*$ (39.4%)
LCOE=4.0€/kg

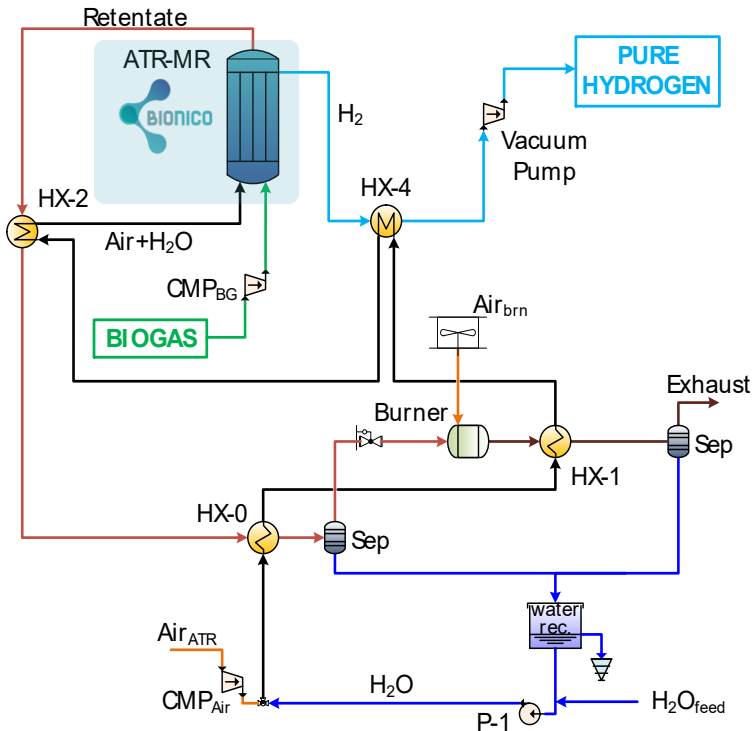
51.7%
5.0 €/kg



| | SMR+PSA | BIONICO SYSTEM (*) |
|-------------------------------------|---------|-------------------------------|
| AD Biogas feed (Nm ₃ /h) | 39.5 | 26.8 |
| AD Biogas Input (kW) | 229 | 155 |
| Sys efficiency (%LHV) | 51.7 | 73.0 @1.0 bar 66.1 @20 bar |
| H ₂ cost (€/kg) @20 bar | 4.3 | 4.0 @20 bar |

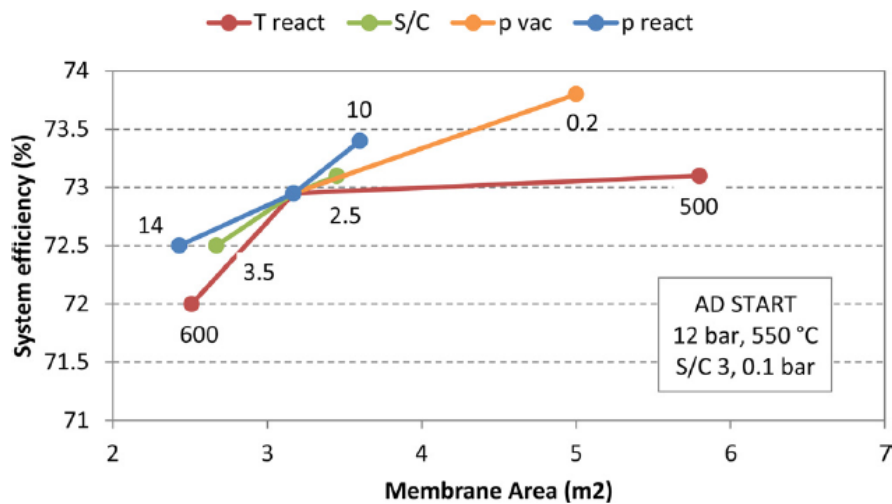
Pilot plant lower efficiency due to:

- Thermal integration not pursued (Electric resistances consumption considered)
- Design condition not achieved

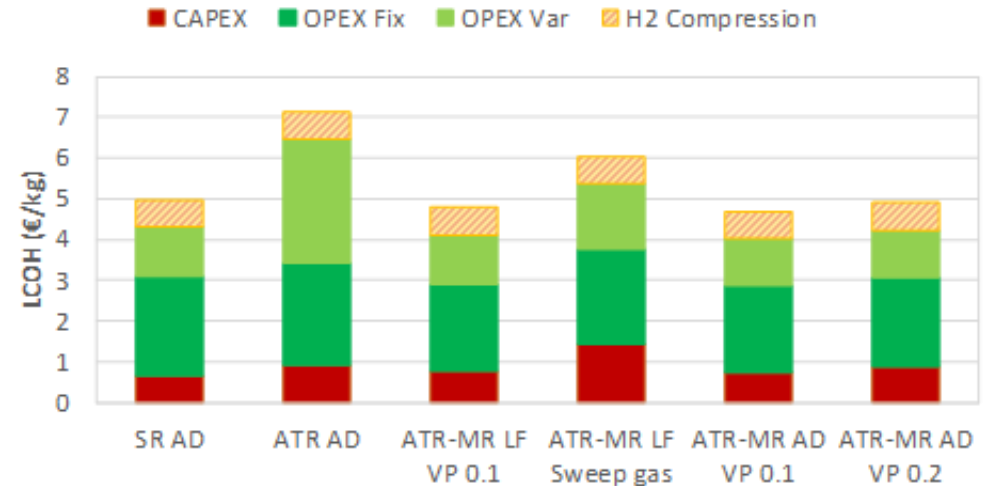


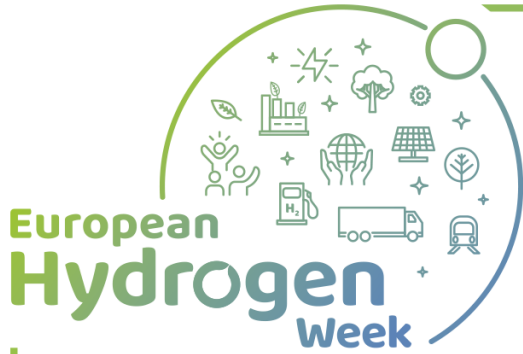
Progress/Actions - System Efficiency/H₂ cost

Sensitivity to design Parameters



LCOH





Risks, Challenges and Lessons Learned

SUPPORTS CHALLENGE

- Provide good quality of 14/7 mm OD/ID finger like ceramic supports
→ improved with experience and with the introduction of 2 characterization techniques.

MEMBRANES CHALLENGE

- Plating membranes from 10/7 mm OD/ID tubular open ends ceramic porous support to the new 14/7 mm OD/ID finger like ceramic porous supports
→ new scaled up plating technique developed
→ possibility of post-treatment to further improve membrane quality
- Membrane stability, durability and mechanical resistance
→ limited testing activity

REACTOR

- Integration of 125 membranes in a single vessel and testing
→ Successful integration
→ Testing activity stopped after 115h

Exploitation Plan/Expected Impact



Support Services for Exploitation of Research Results

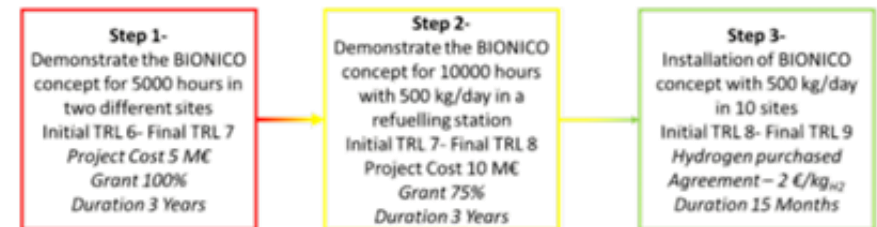
Exploitation

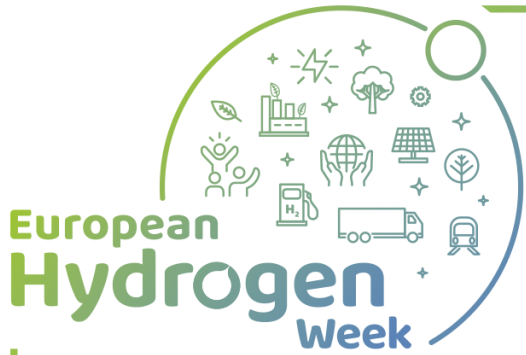
KERS identified during an INTERNAL EXPLOITATION EVENT supported by SSERR:

- Modelling tool for fluidized bed membrane reactor
- Reactor design and manufacturing
- Highly active catalysts at 600°C for biogas reforming
- Highly resistant catalysts suitable for fluidized bed reforming
- Alternative methods for valorisation of biogas and landfill gas
- Nanoporous ceramic layers coated onto ceramic supports for thin film deposition

Impact

- Key step forward for CMR technology
-> follow up [MACBETH](#) project started.
- Impact on the EU biogas market (16 Mtoe in 2016) with a new “upgrading to H₂” option.
- Competitive technology for small-medium scale decentralized green H₂ production for the EU market (4.6 Mton/y). Applications: glass/food industry, refueling stations -> *Converting 10% of the EU biogas with BIONICO would cover the H₂ demand for the EU FCEV in 2030*





Communication and Dissemination Activities

Scientific Papers

9

Conference Presentations

16

Website

+4000 users

Newsletter

9

Workshops

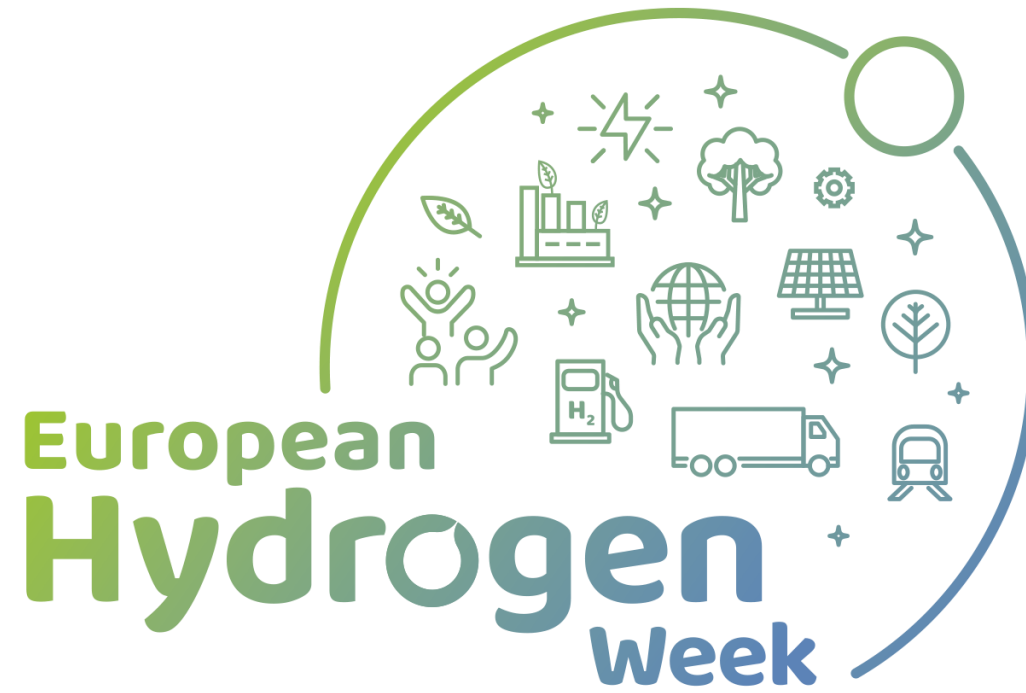
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Useful links:



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European
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Week

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