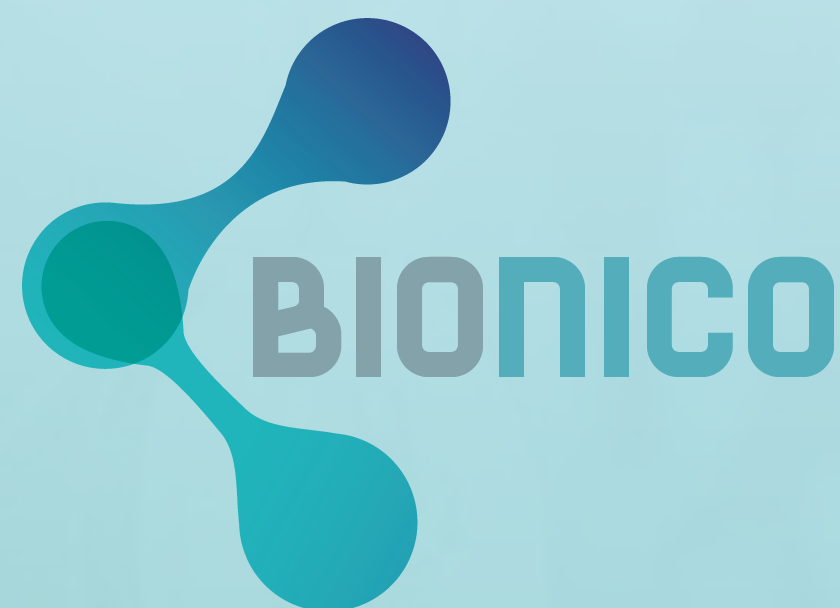




FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

BIONICO

**Biogas membrane reformer for
decentralized H₂ production**



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Programme Review Days 2019

Brussels, 19-20 November 2019

PROJECT OVERVIEW



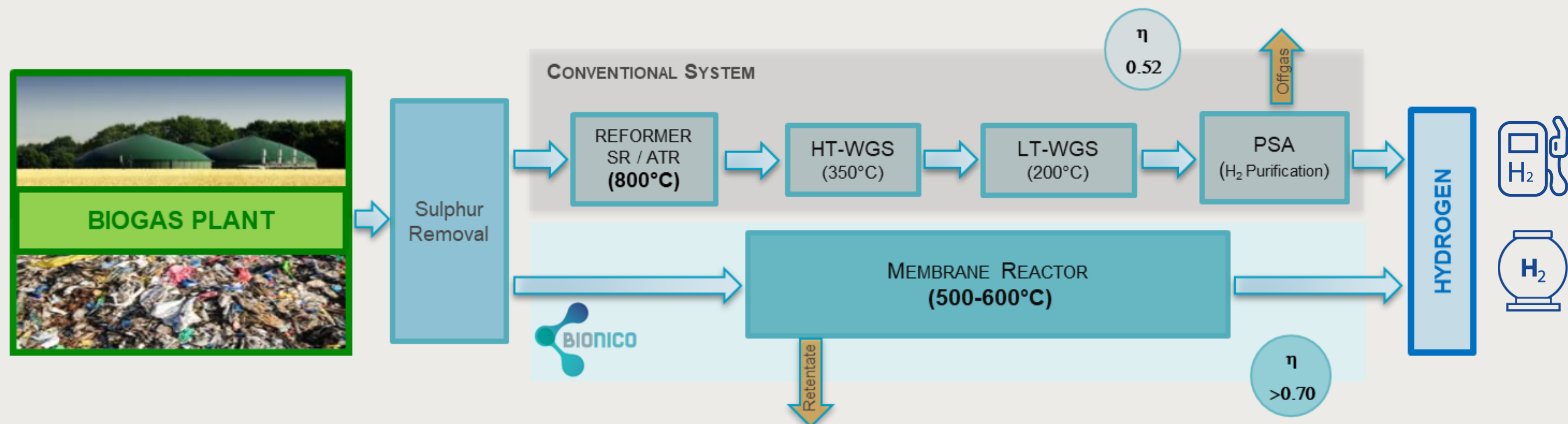
- **Call year:** 2014
- **Call topic:** FCH-02.2-2014 Decentralized hydrogen production from clean CO2-containing biogas
- **Project dates:** 01/09/2015 – 31/12/2019
- **% stage of implementation 01/11/2019:** 80 %
- **Total project budget:** 3,396,640 €
- **FCH JU max. contribution:** 3,147,640 €
- **Other financial contribution:** 249,000 €
- **Partners:** Politecnico di Milano, I.C.I. Caldaie SpA, Fundacion Tecnalia Research & Innovation, TU/e Eindhoven, ENC Power LDA, Rauschert Kloster Veildorf GMBH, Quantis



PROJECT SUMMARY

BIONICO - Biogas membrane reformer for decentralized H₂ production

BIONICO will develop, build and demonstrate 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.



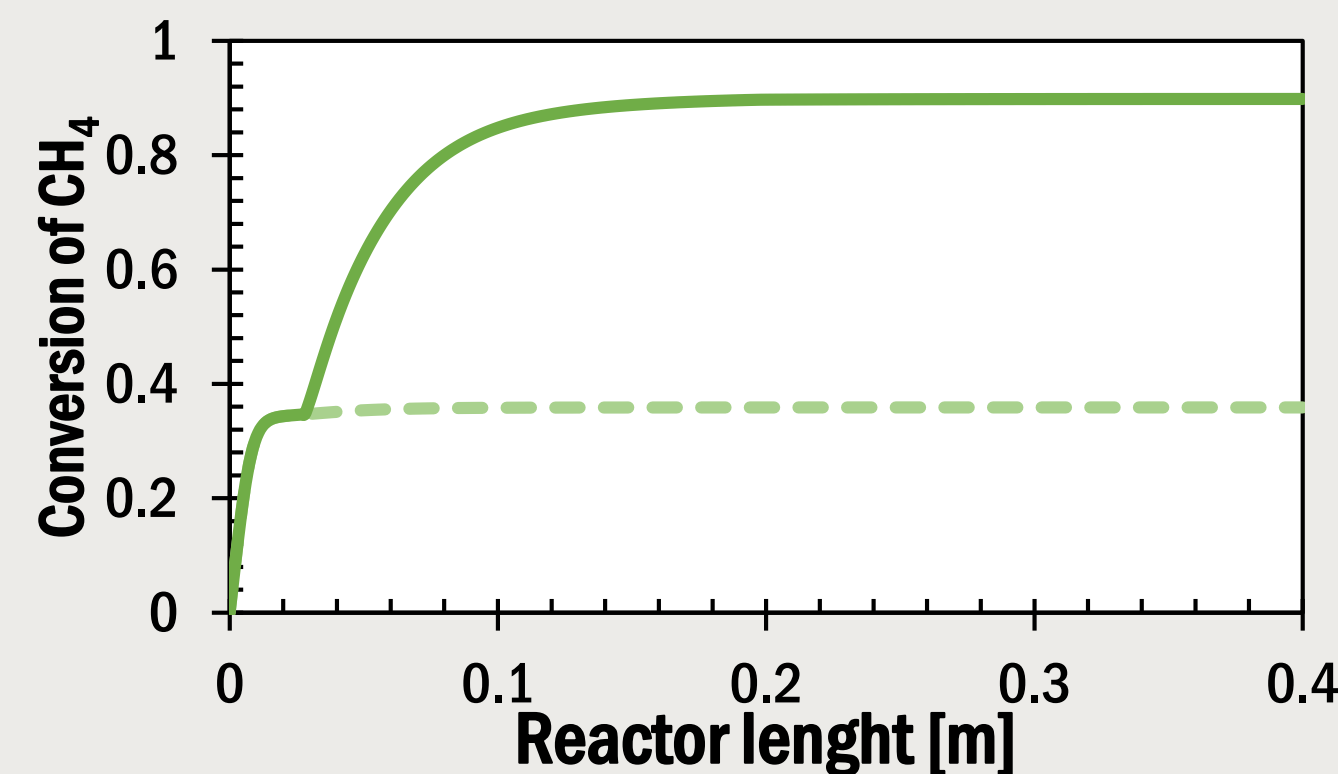
Fluidized Bed catalytic Membrane Reactor

- **Fuel conversion** and **H₂ separation** take place in a **single reactor** thanks to a 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**

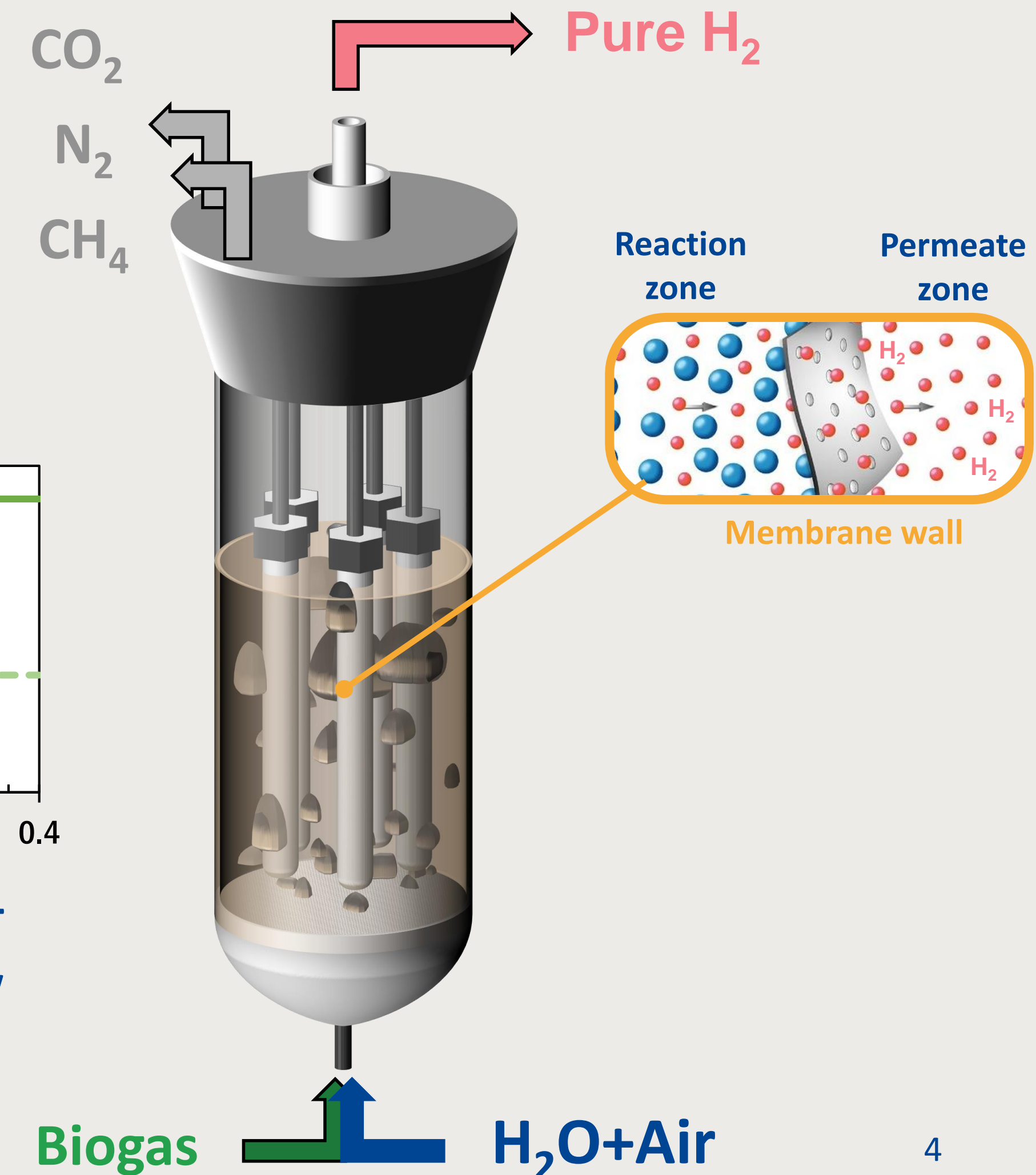
BG Oxidation: $\text{CH}_4 + 2\text{O}_2 \Rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$

BG Reforming: $\text{CH}_4 + \text{H}_2\text{O} \Leftrightarrow \text{CO} + 3\text{H}_2$

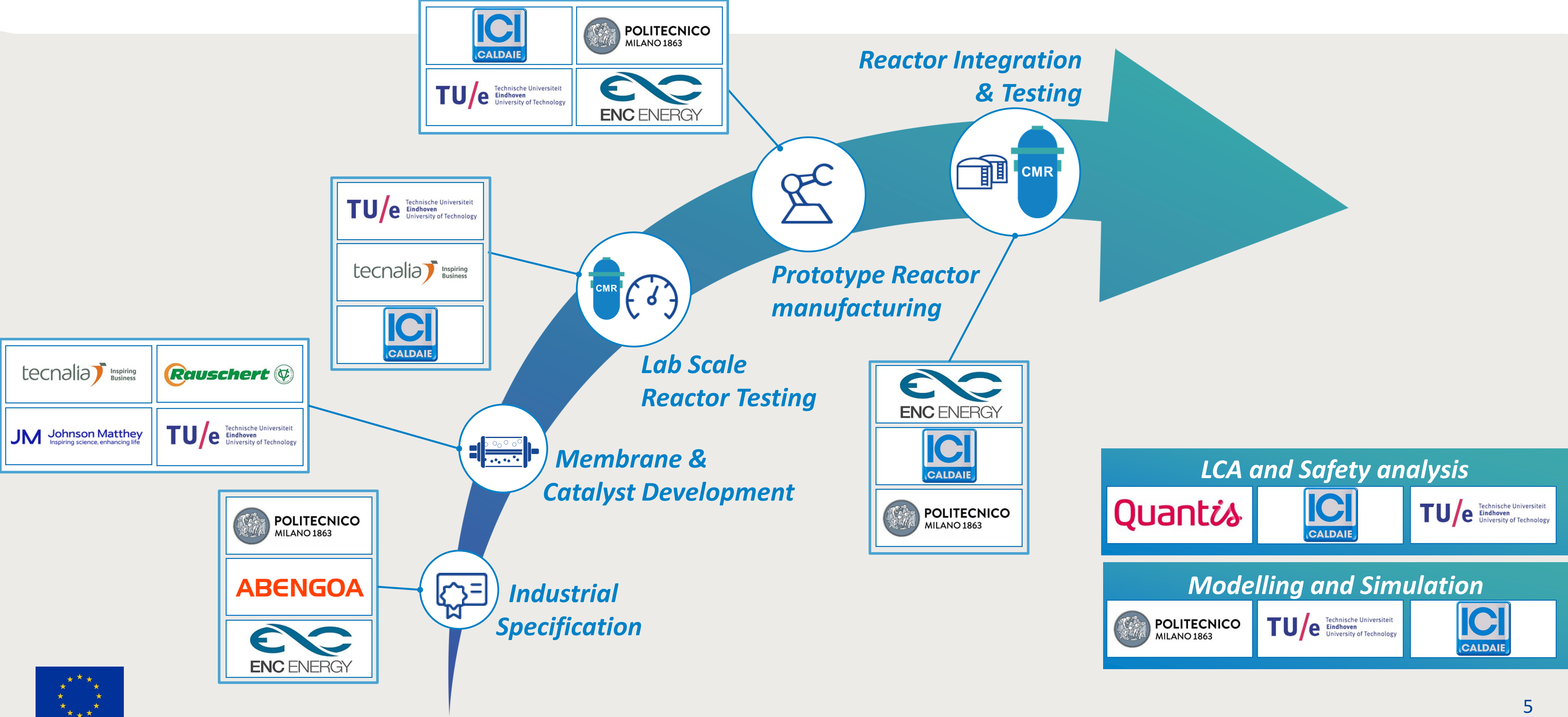
WGS: $\text{CO} + \text{H}_2\text{O} \Leftrightarrow \text{CO}_2 + \text{H}_2$



- The **fluidization** of the catalyst allows to: i) **overcome problems with T control**, ii) to **operate with smaller particles** while still maintaining very low Δp and iii) to **overcome any concentration polarization issue**



PARTNERSHIP SYNERGIES



PROJECT PROGRESS/ACTIONS – Components development

COMPONENTS DEVELOPED

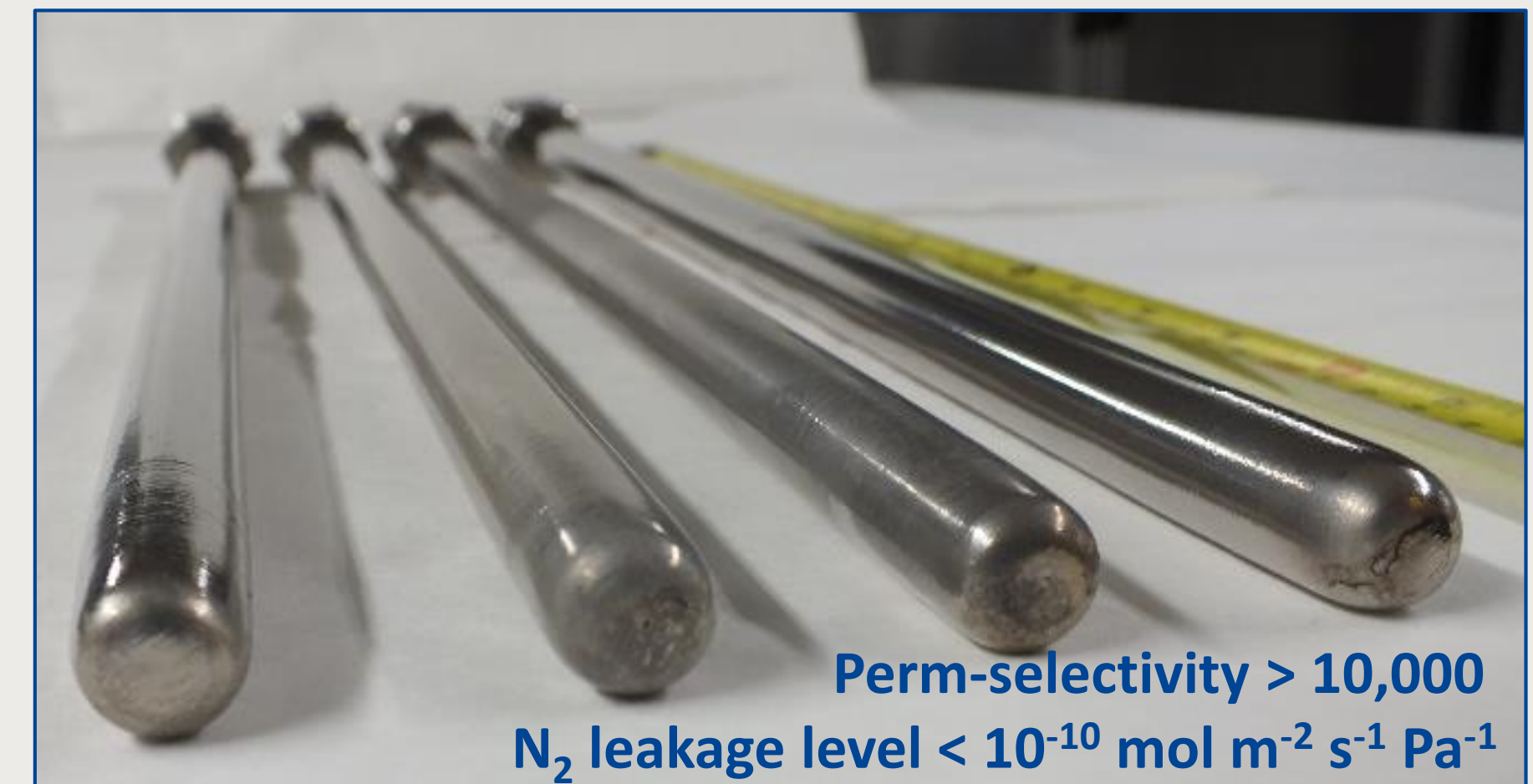
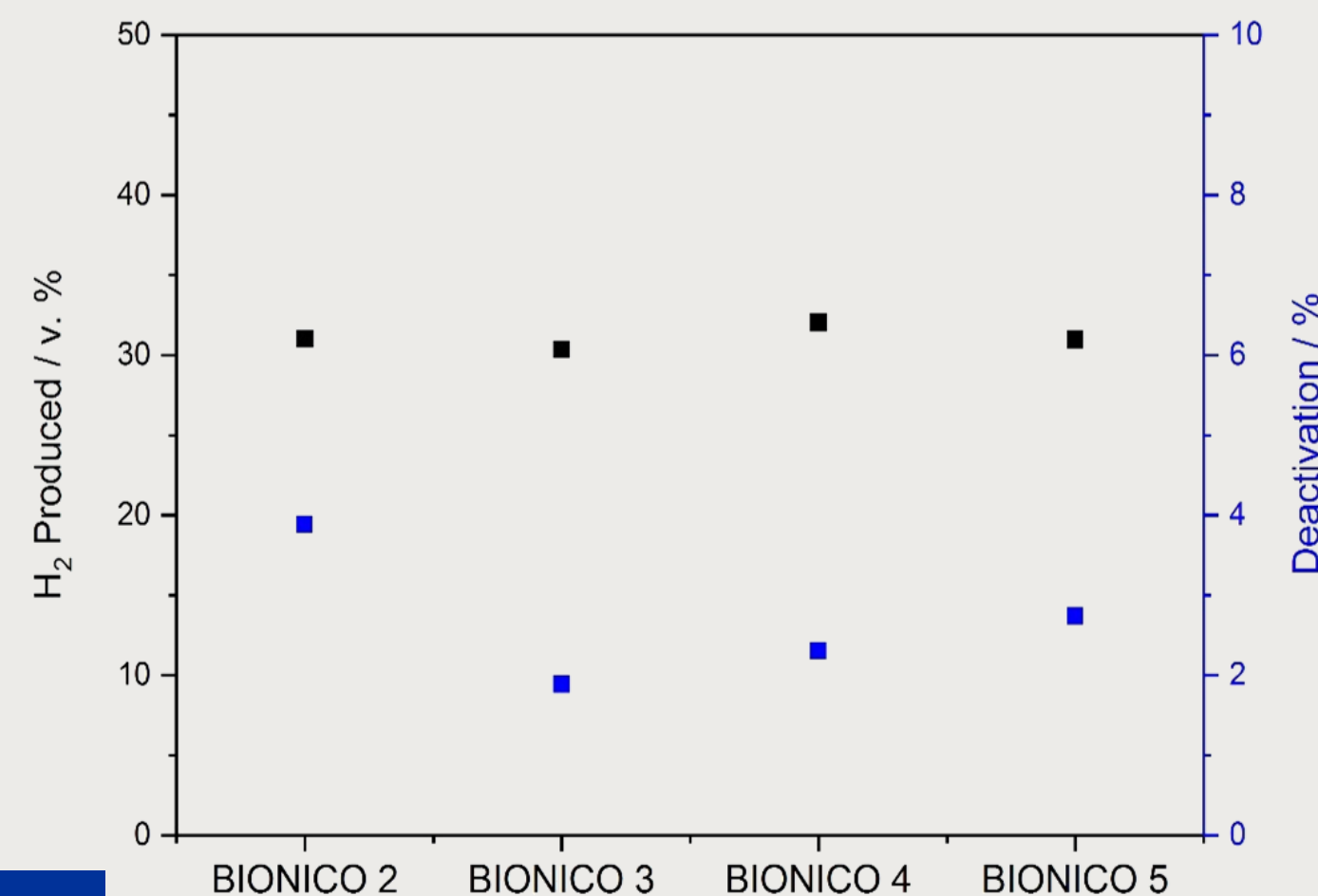
25%

50%

75%

Novel catalyst
Novel membranes
Novel supports

- **CATALYST:** A highly active catalysts with improved coke resistance to produce H_2 from diverse biogas mixtures suitable for use in a fluidized bed membrane reforming reactor 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 ($\sim 0.5m$) with larger diameter (14/7 mm)

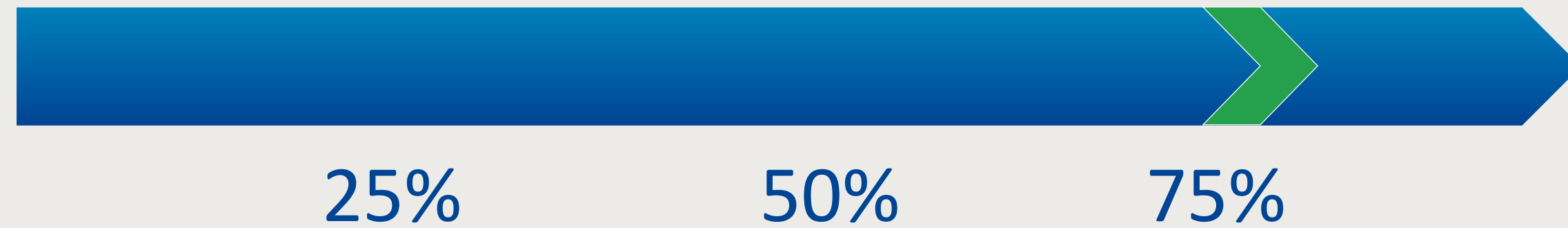


PROJECT PROGRESS/ACTIONS – Membrane Reactor Scale up & Testing

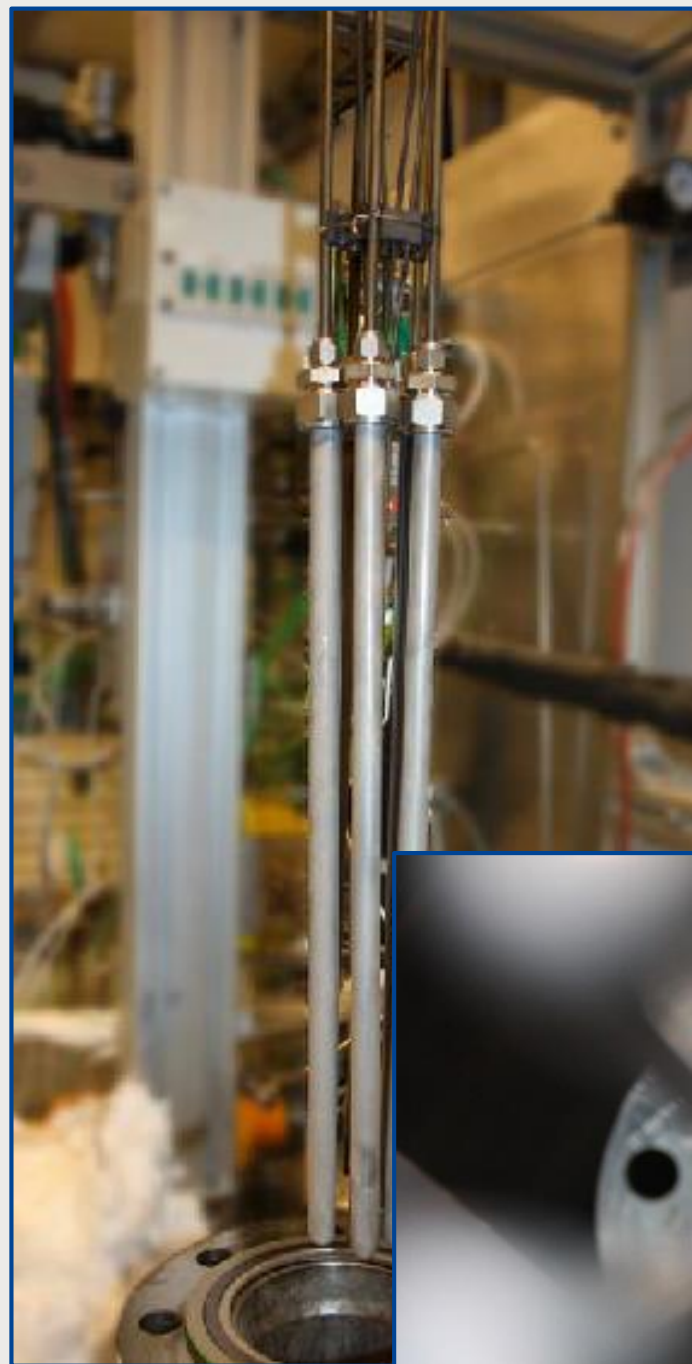


Reactor ready to start

N/A

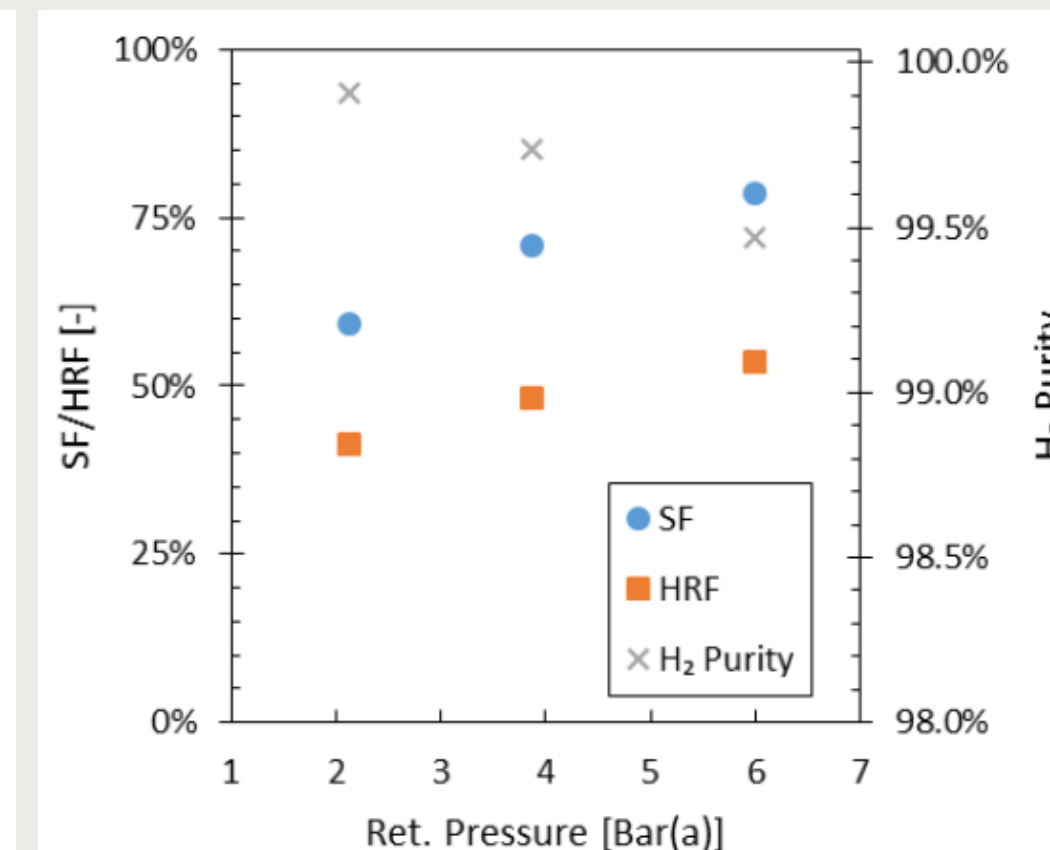
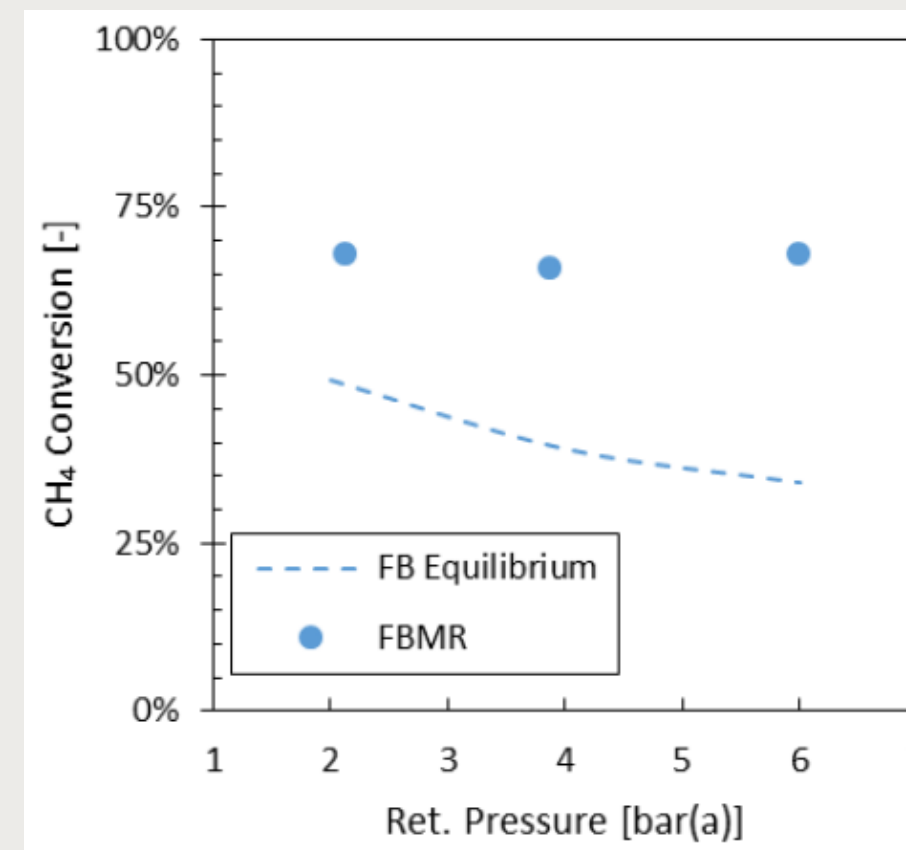
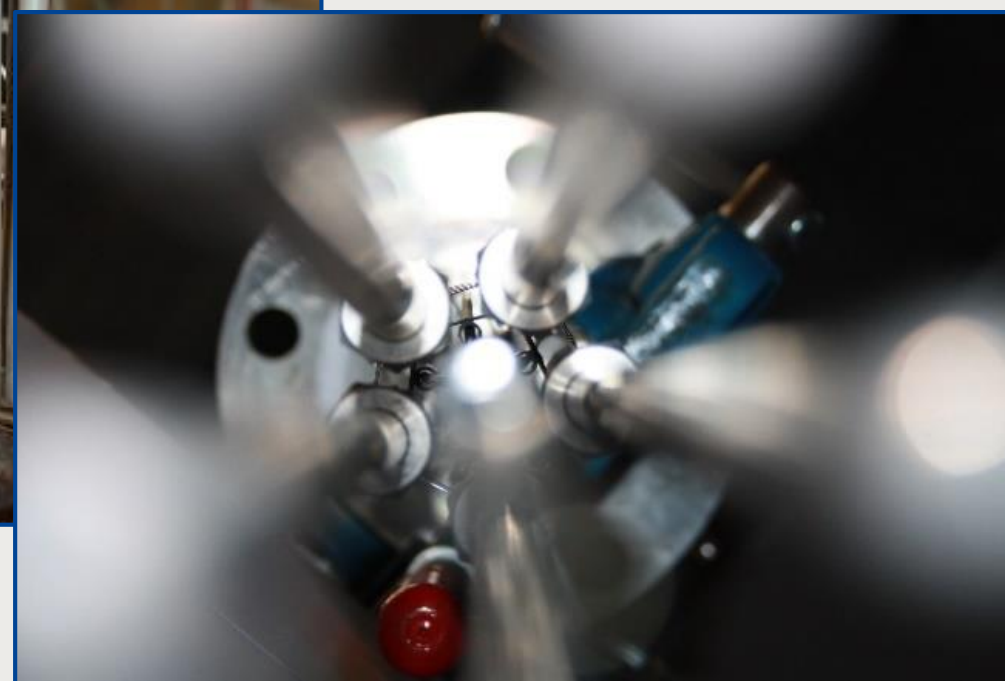


100 kg/day



LAB SCALE REACTOR TESTING

- Integration of catalyst and membranes (1 membrane, 5 membranes)
- Development of the Phenomenological model of the reactor
- Effects of Au addition on H₂S membranes resistance
- Lab scale reactor testing (CH₄ conversion, H₂ purity, etc.)



$$X_{CH_4} = \frac{(F_{CH_4,in} - F_{CH_4,out})}{F_{CH_4,in}}$$

$$SF = \frac{F_{H_2,Perm.}}{(F_{H_2,Perm.} + F_{H_2,ret.})}$$

$$HRF = SF \frac{(F_{H_2,Perm.} + F_{H_2,Ret.})}{(4 \cdot F_{CH_4,in} - 2 \cdot F_{O_2,in})}$$



PROJECT PROGRESS/ACTIONS – Membrane Reactor Scale up & Testing



Reactor ready to start

N/A

100 kg/day

25%

50%

75%



PILOT SCALE REACTOR

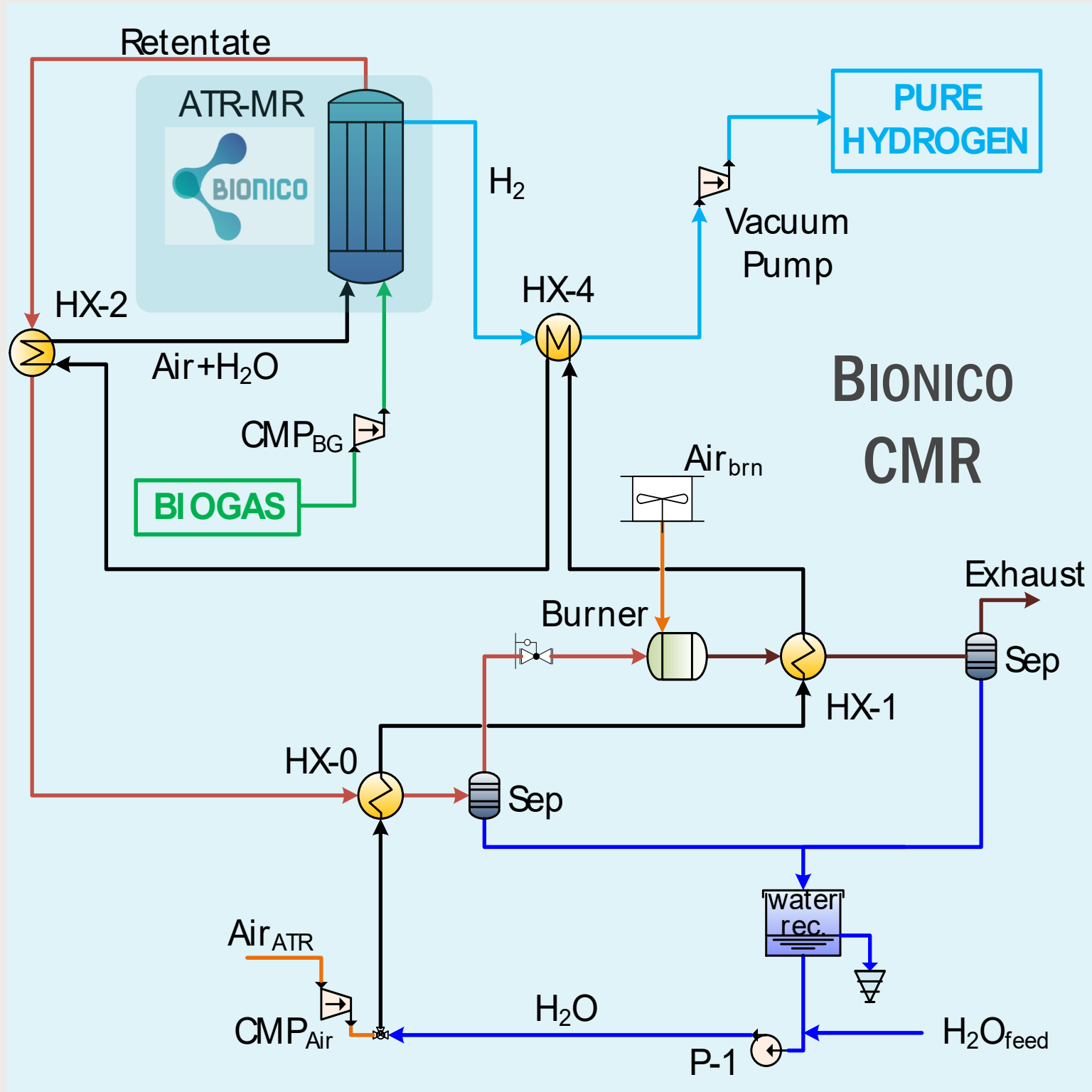
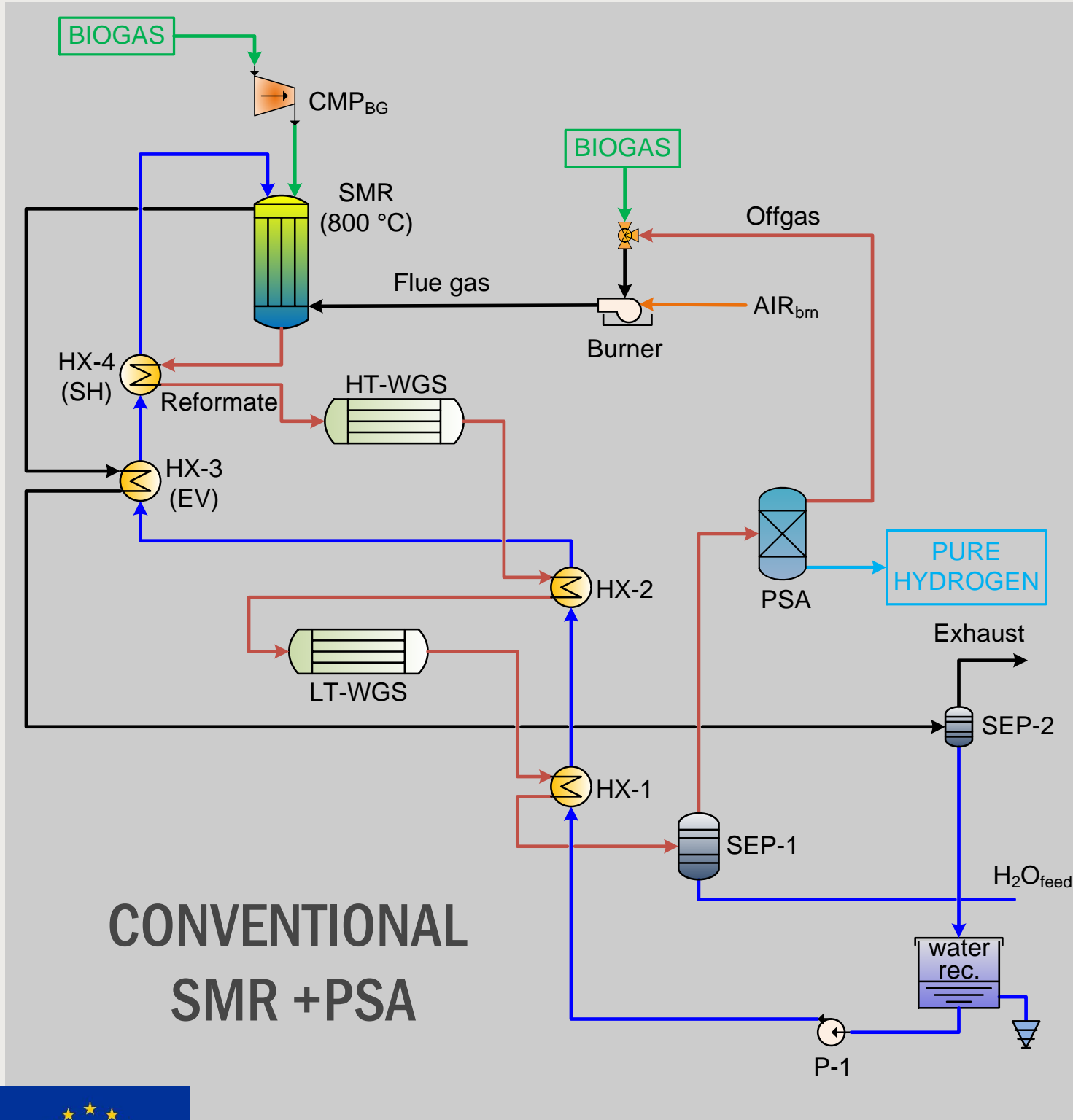
- Reactor design and manufacturing
- Integration of catalyst and membranes (125 membranes)
- BOP design and manufacturing
- System installation
- Reactor testing with synthetic biogas (ONGOING)
- Reactor testing at real biogas plant



PROJECT PROGRESS/ACTIONS – Membrane Reactor Scale up & Testing



PROJECT PROGRESS/ACTIONS – System Efficiency/H₂ cost

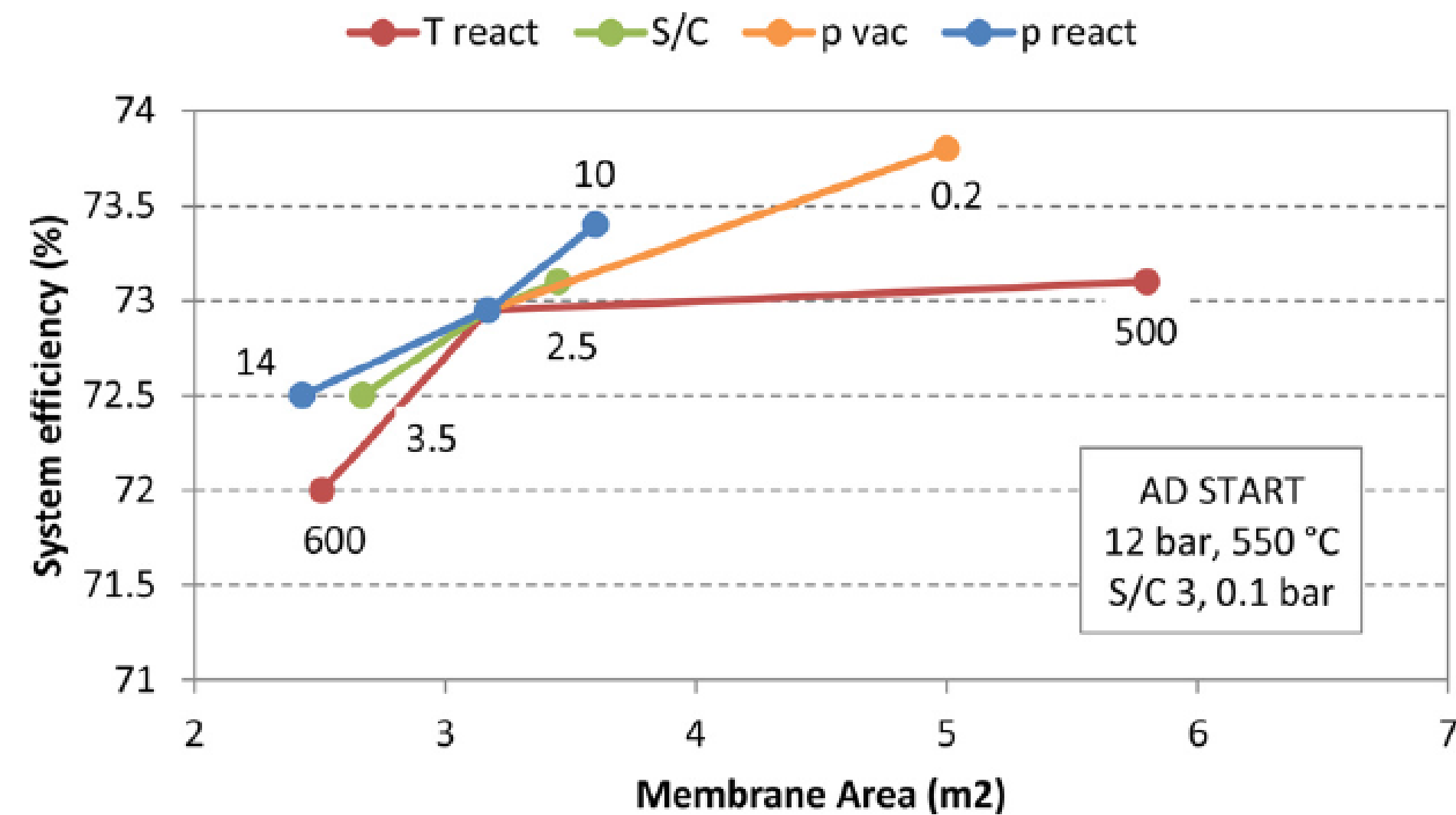


- Energy results obtained from simulations based on experimental reactor results
- Economic results based on literature costs

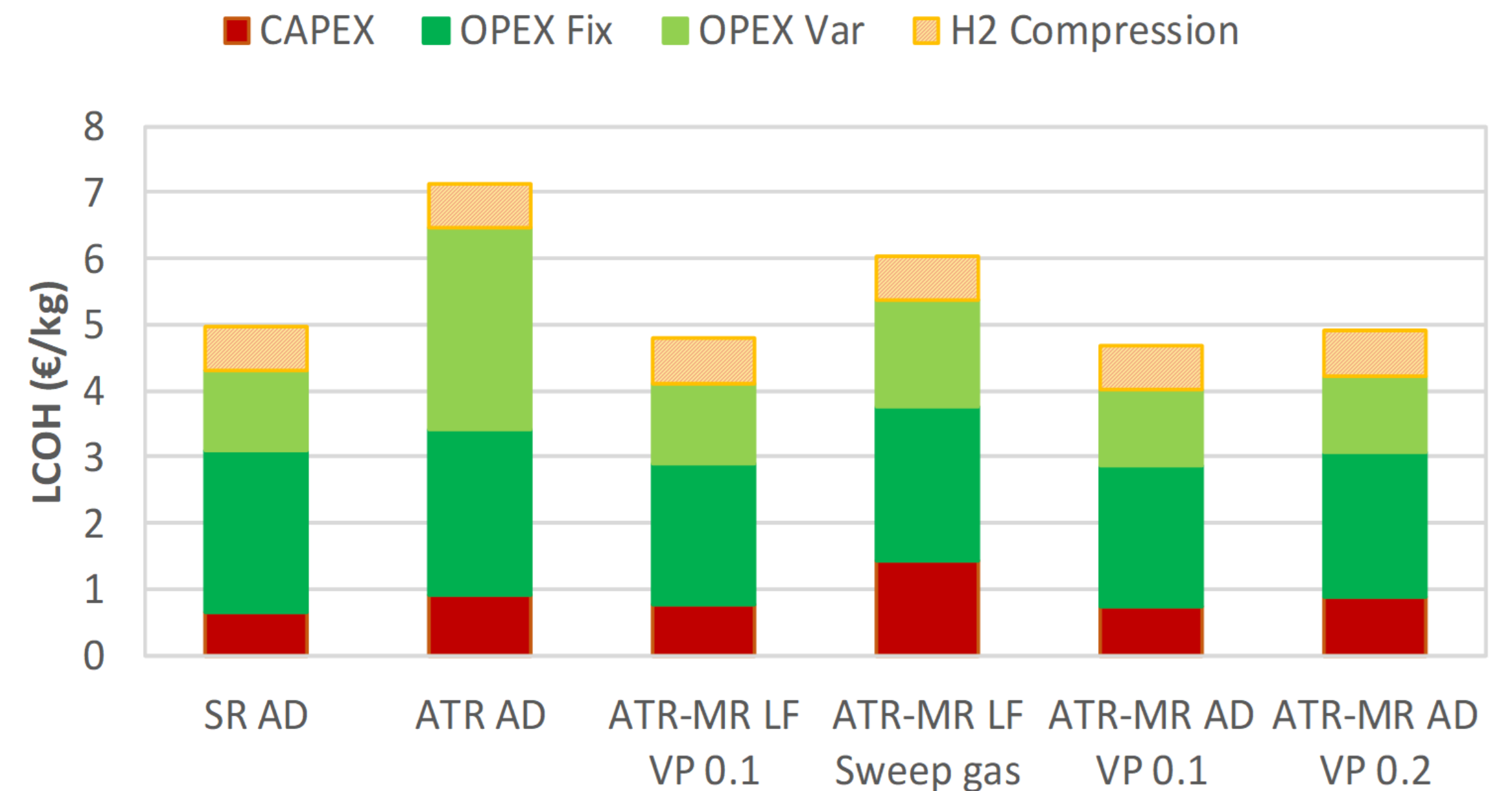
	units	SR	BIONICO
AD Biogas feed	Nm ³ /h	39.5	26.8
AD Biogas Input	kW	229	155
Sys efficiency	% _{LHV}	51.7	73.0 @1.0 bar 66.1 @20 bar
H ₂ cost @ 20 bar	€/kg	5.0	4.0

PROJECT PROGRESS/ACTIONS – System Efficiency/H₂ cost

Sensitivity to design parameters



LCOH



Risks and Challenges



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
 - to be verified after 3000h of testing on field

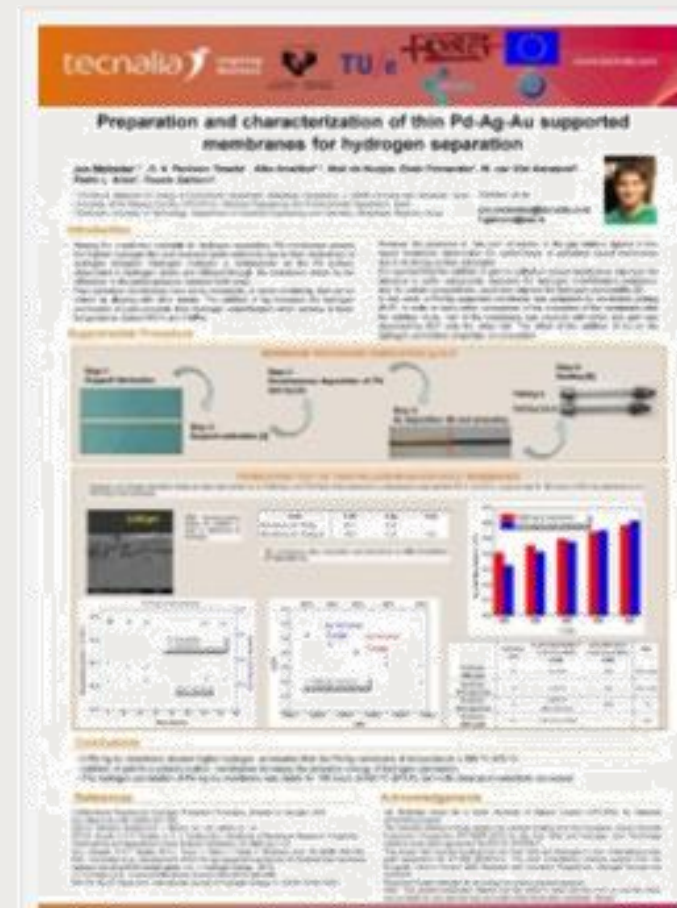
REACTOR

- Integration of 125 membranes in a single vessel and shipping it to the plant
 - Successful integration of a complex system at larger scale with respect to previous projects
 - Shipping phase still critical. 500h of testing at manufacturer site have been scheduled before shipping.

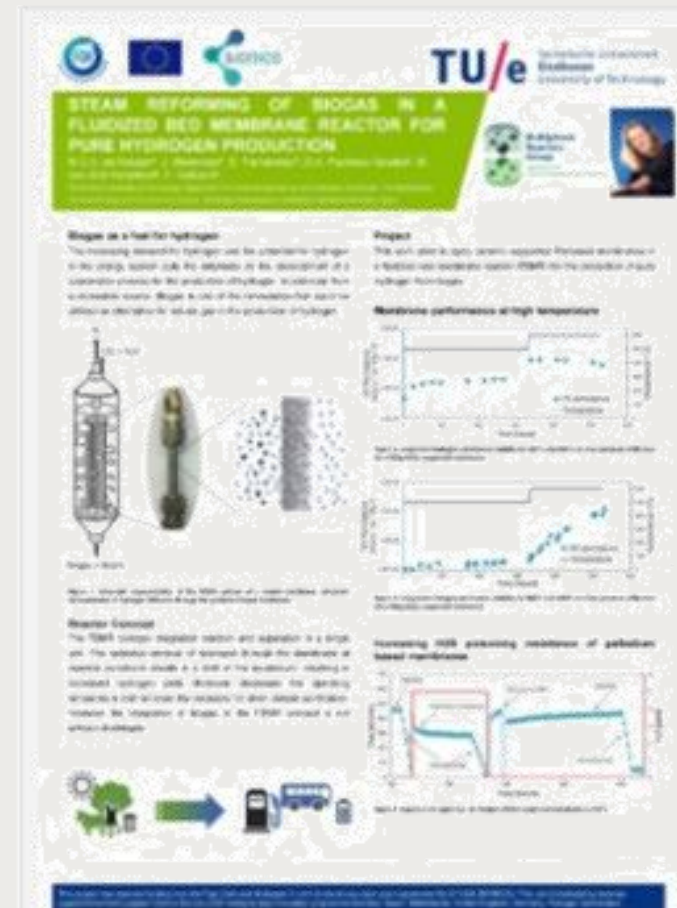


Communication and Dissemination Activities

- Project website (+3700 single users) updated till now : www.bioniconproject.eu
- 8 Newsletter prepared and distributed during the project to lifetime to about 100 recipients
- 9 papers published during the project lifetime
- 16 presentations and 9 posters presented at international conferences



EMS summer school 2016



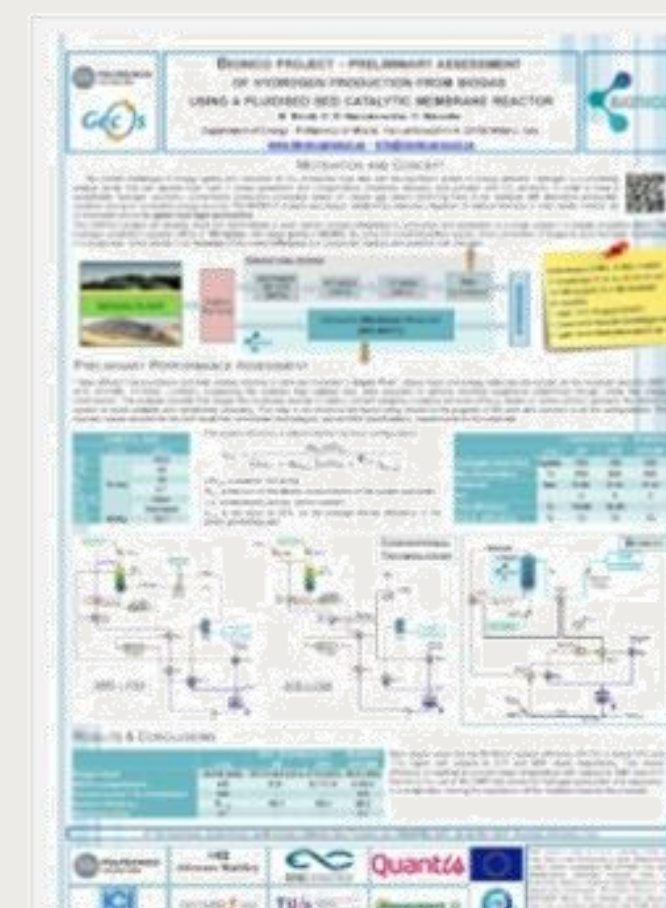
Dutch Mem. Society 2016



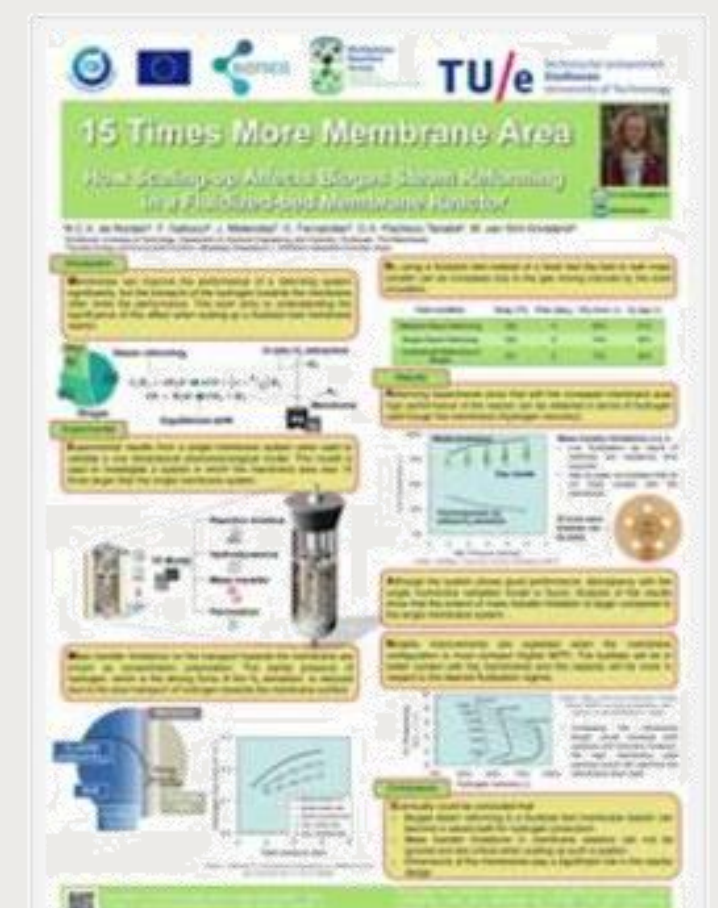
EBA 2016



MR4PI workshop 2017








REGATEC 2017



ICIM 2018

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- 9 papers published during the project lifetime
- 16 presentations and 9 posters presented at international conferences
- 2 dissemination videos (+3400 views)   + timelapse video on the reactor construction 
- Linkedin group on Membrane Reactor Technology 
- Project on ResearchGate 



Communication and Dissemination Activities

- Press-release and magazine articles
- 1 international workshop on Membrane Reactor for Process Intensification (MR4PI) with 4 other projects (~90 participants)
- 1 workshop in ICI Caldaie for Italian stakeholders (~15 participants)



EXPLOITATION PLAN/EXPECTED IMPACT



Exploitation

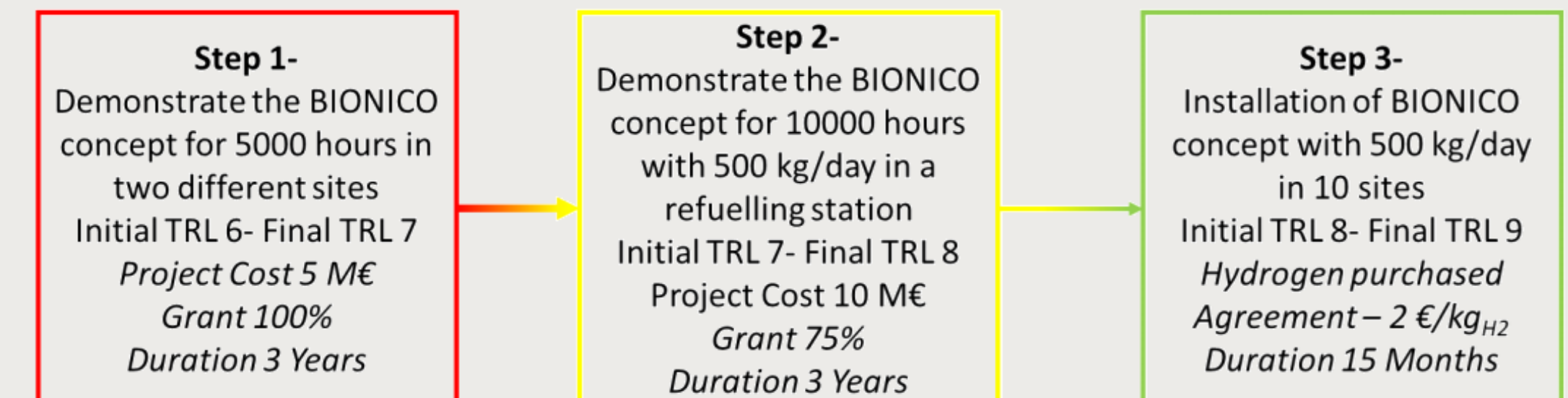


KERS identified during an INTERNAL EXPLOITATION EVENT supported by SSERR:

- 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 Catalytic Membrane Reactor technology → follow up project to be 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 to feed 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*

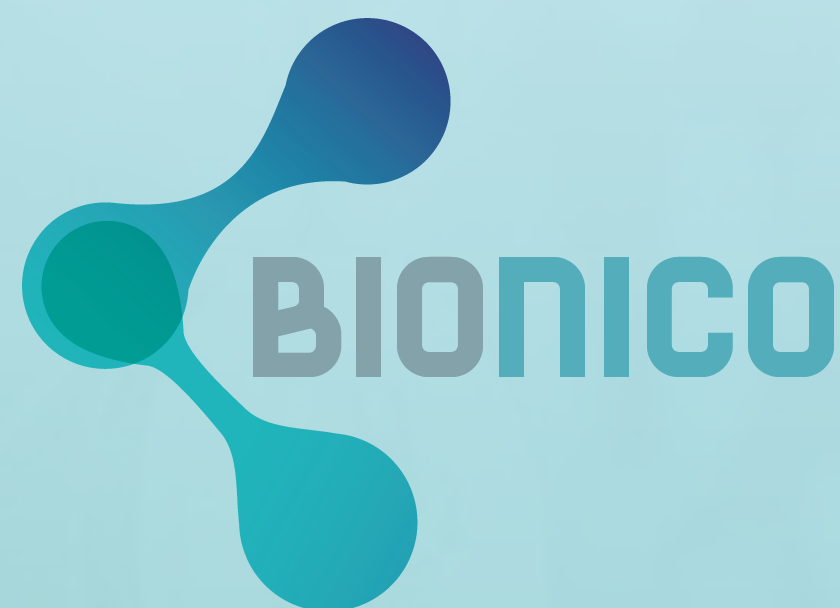




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