BIONICO

BIOGAS MEMBRANE REFORMER FOR DECENTRALIZED H_2 PRODUCTION

Call: H2020-JTI-FCH-2014-1 Topic: FCH-02.2-2014 Decentralized hydrogen production from clean CO_2-containing biogas

SUMMARY

BIONICO **aims** at developing a **novel reactor** configuration at a **larger scale** to produce **H_2** from **biogas** production power plant based on:

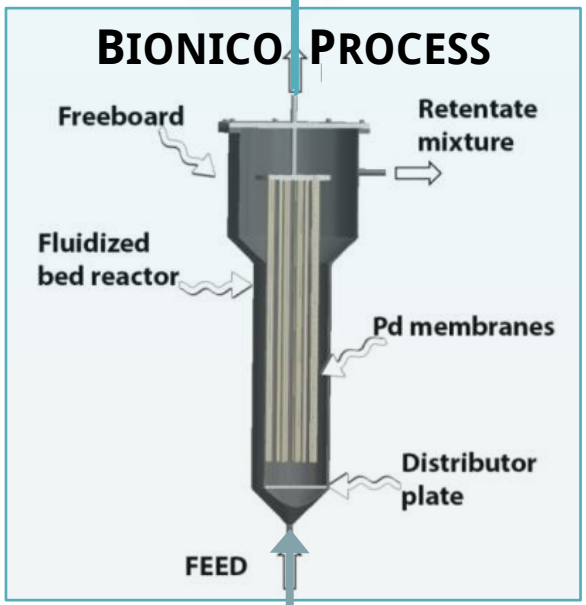
- Design, develop and test a **new concept** reactor integrating hydrogen **production** and **purification** on a **single unit**
- Design, develop and testing of a **catalytic membrane reactor** for the production of highly-purity hydrogen from biogas, scaling up new H_2 selective **membranes** and **catalyst** production
- Develop a **flexible system** (including the advance control and BoP components) capable of producing pure hydrogen from **biogas of different compositions** in a unique reactor system.

The main idea of BIONICO is to design and demonstrate an **efficient biogas-to-hydrogen conversion system** at real plant conditions (in the ENC Landfill plant at Chamusca, Santarém, Portugal) using process intensification.

CONCEPT

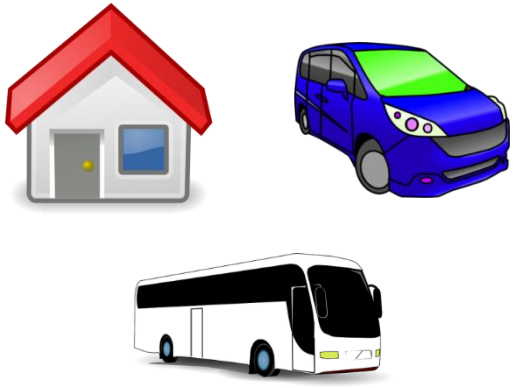
Raw Biogas

Sulfur Removal

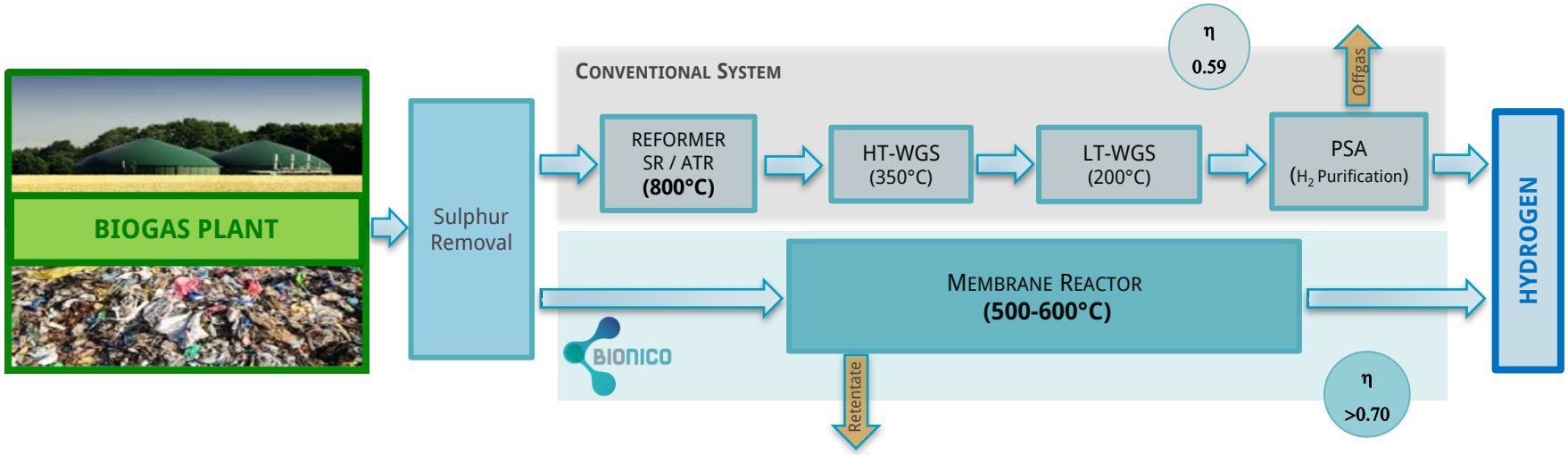


Pure H_2

End Users



WHY BIONICO?



Two reference cases (based on SR and ATR) are identified to benchmark the performance of the BIONICO concept

Reference Case Results			
	units	SR	ATR
Biogas feed	Nm^3/h	35.7+14.6	47.0
Total Biogas Input	kW	221	207
System efficiency	$\%_{LHV}$	59.2	55.4
Hydrogen delivery pressure	bar	13.3	13.3
Equipment costs	€*h/Nm^3	14520	12342
Hydrogen production cost	€/Nm^3	0.408	0.398

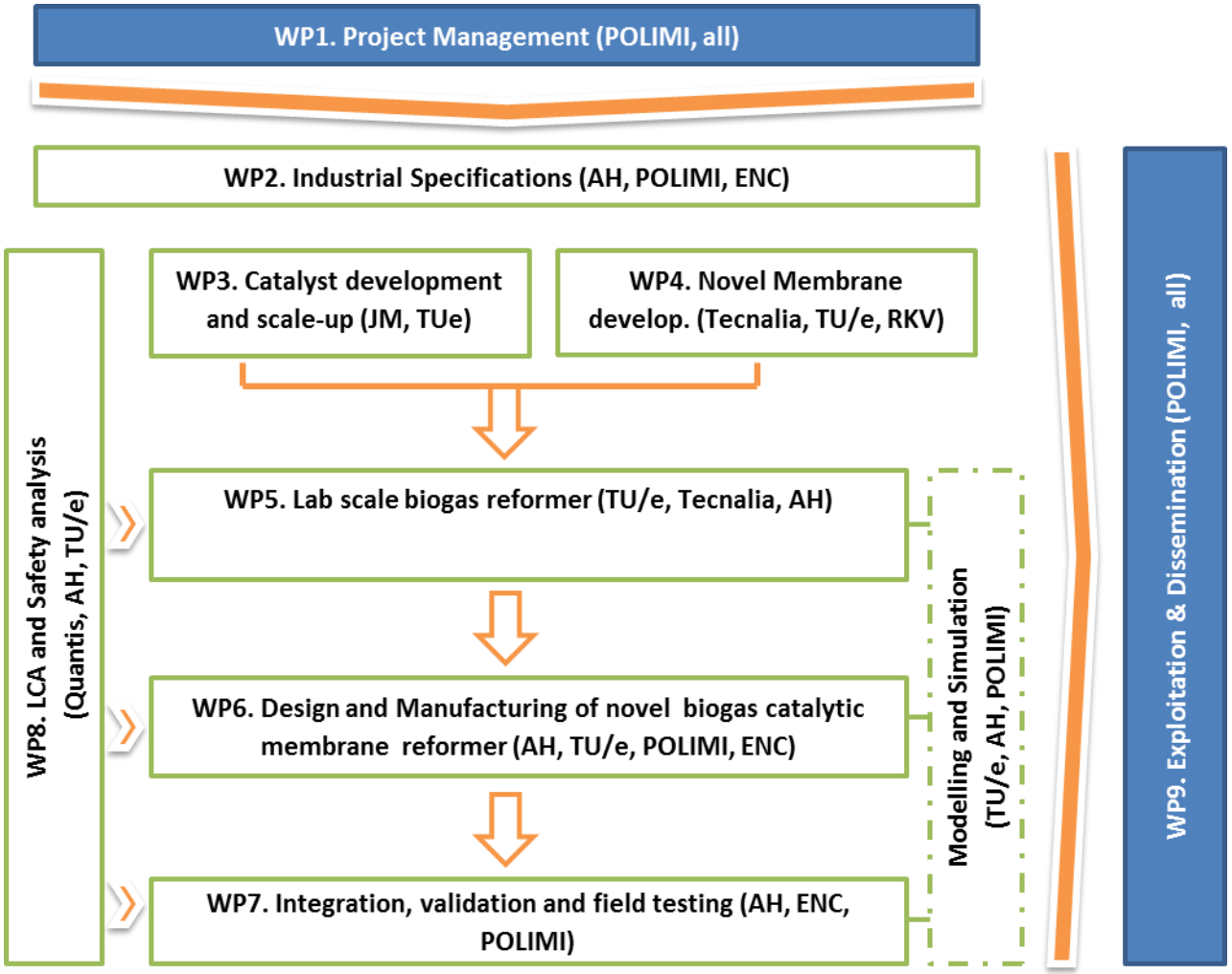
The target of BIONICO is a system efficiency above 70%$_{LHV}$, which is about 20% higher than SR (59%$_{LHV}$). The higher efficiency together with equipment savings will end up in lower hydrogen production costs.

PARTNERSHIP

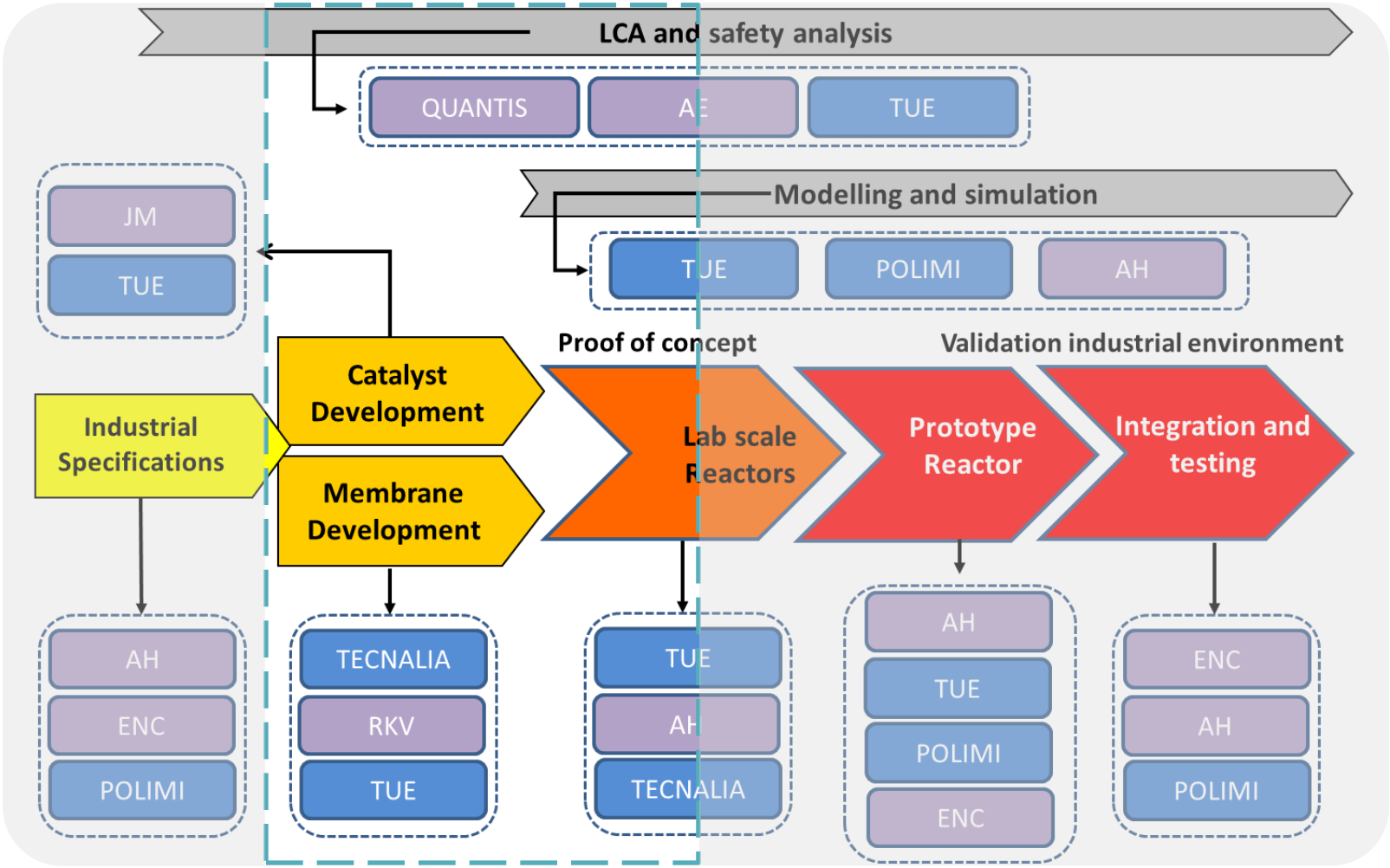
Multidisciplinary and complementary team: 8 top level European organisations from 7 countries including: 3 Research Institutes and Universities and 4 representative top industries in different sectors (from catalyst to membranes to chemical and process engineering, etc.)

- POLIMI, Italy
- TU/e, The Netherlands
- Abengoa, Spain
- Tecnalia, Spain
- Johnson Matthey, UK
- ENC Energy, Portugal
- Rauschert, Germany
- Quantis, Switzerland

WORK STRUCTURE



PARTNERSHIP SYNERGIES



Novel Catalyst

Goal

Development of highly active reforming catalysts to produce hydrogen from diverse biogas mixture coupled with steam and air in a fluidised bed regime.

First Year Activities

- PGM doped alumina catalysts have been tested under biogas reforming conditions for dry, steam or auothermal reforming
- Coke formation resistance improvement

Achievements

- 1st generation catalyst
- 2nd generation catalyst able to work under fluidisation regime and at low temperature

Novel Membrane & Support

Goal

Development of Pd based tubular supported membranes, for application in biogas reforming catalytic membrane reactors

First Year Activities

- Preparation of porous ceramic tubes of different diameters and materials for their use as supports for thin Pd-based membranes
- Manufacturing of thin film (<5 μm thick) Pd-Ag and Pd-Ag-Au membranes on top of the ceramic supports.
- Development of new finger-like porous asymmetric ceramic supports in which one of the ends of the tube is a closed porous part.

1st generation thin film Pd-alloy (< 5 μm) supported membranes

Novel Membrane & Support

Goal

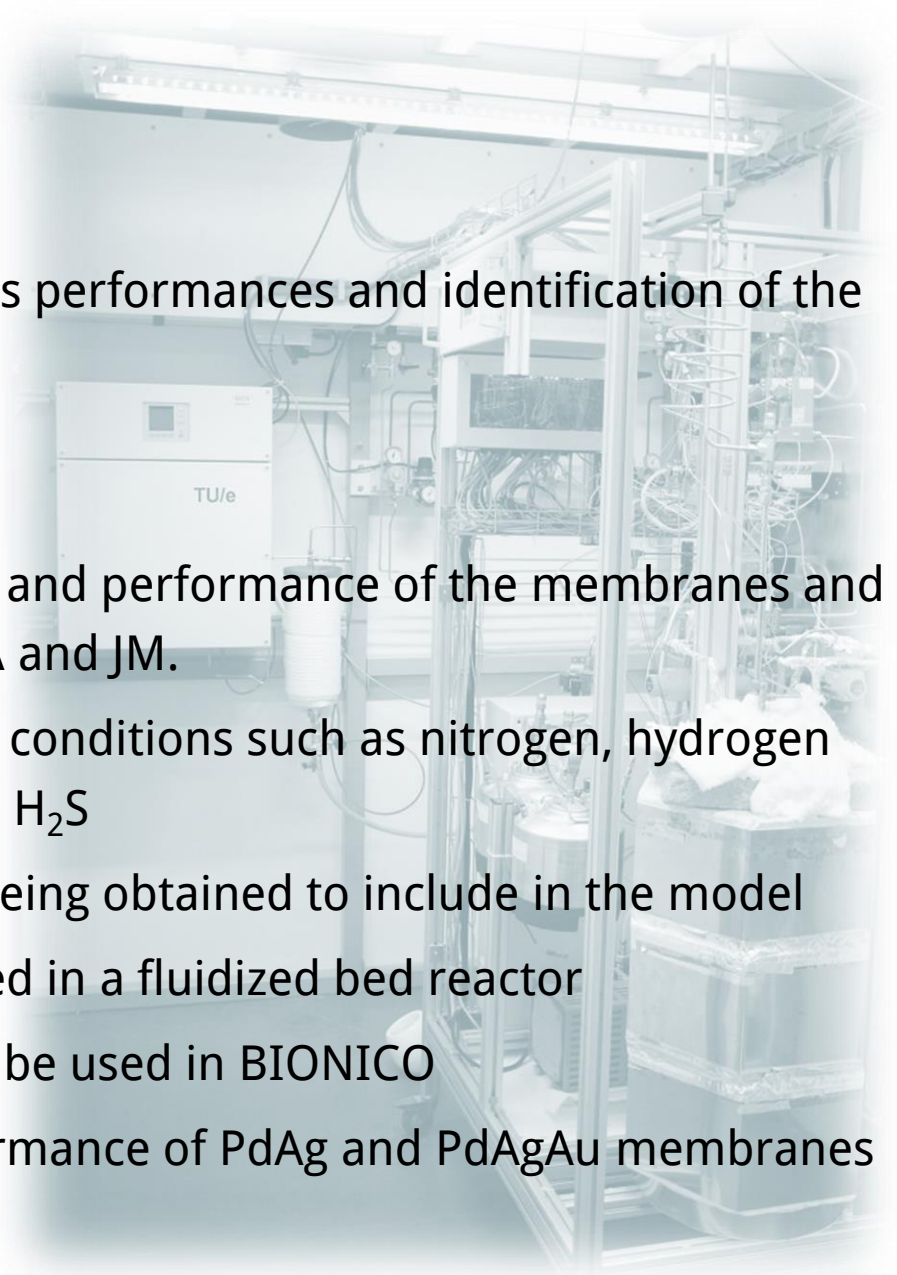
Development of Pd based tubular supported membranes, for application in biogas reforming catalytic membrane reactors

Achievements

- 1st generation membrane & support
- Installation of a new plating system for preparation of >40 cm long membranes.
- 2nd generation supports are finger-like porous tubes.
  - Thin Pd-Ag layers have been deposited onto the first 50 cm long finger-like supports

2nd generation thin film Pd-alloy supported membranes

Lab Scale Reactor



Goal

Definition of the lab scale reactors performances and identification of the best design for prototype pilot.

First Year Activities

- Testing separately the stability and performance of the membranes and catalyst delivered by TECNALIA and JM.
- Membranes tested in pure gas conditions such as nitrogen, hydrogen and mixtures containing CO or H_2S
- Catalyst reaction kinetics are being obtained to include in the model
- Membrane & catalyst integrated in a fluidized bed reactor
- Identify the sealing method to be used in BIONICO
- The effect of H2S on the performance of PdAg and PdAgAu membranes are studied

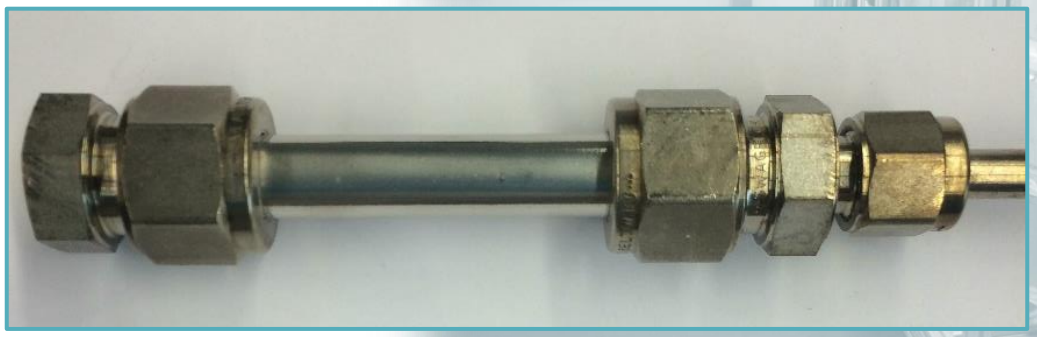
Lab Scale Reactor

Goal

Definition of the lab scale reactors performances and identification of the best design for prototype pilot.

Achievements

- Interaction between membrane and catalyst. The results showed that the hydrogen permeance is not affected by the presence of the catalyst
- The sealing of the tested membranes are improved with specific sized ferrules according to the membrane size



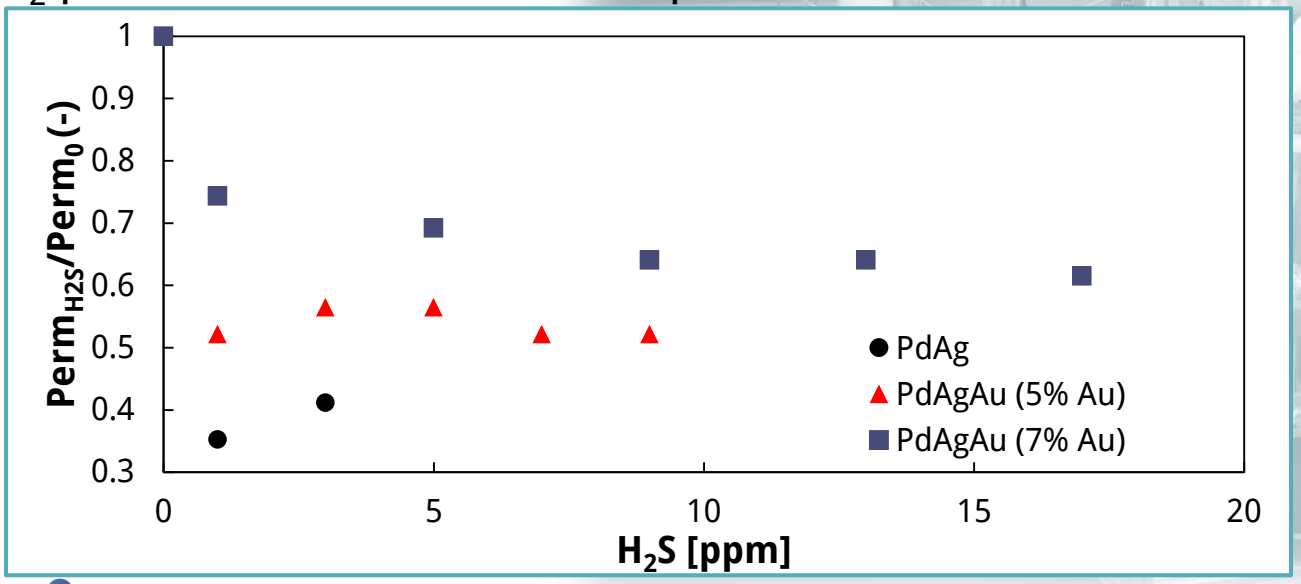
Lab Scale Reactor

Goal

Definition of the lab scale reactors performances and identification of the best design for prototype pilot.

Achievements

- Membranes including Au showed better resistance to the exposure to H_2S: H_2 permeance decrease was dependent on the concentration of H_2S



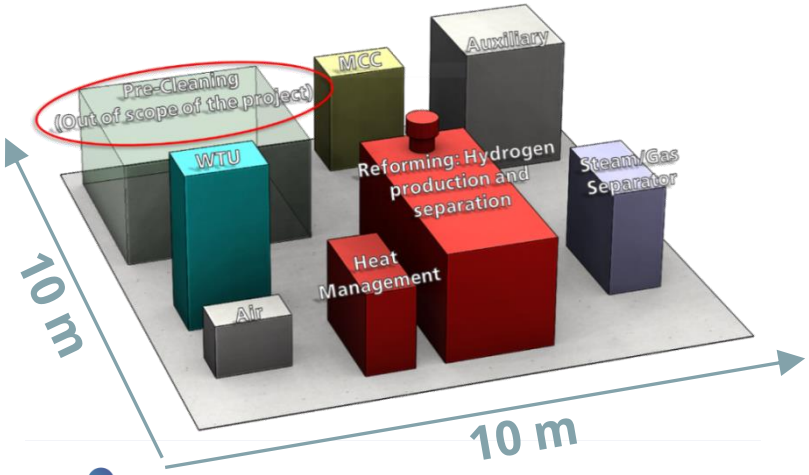
Prototype Reactor

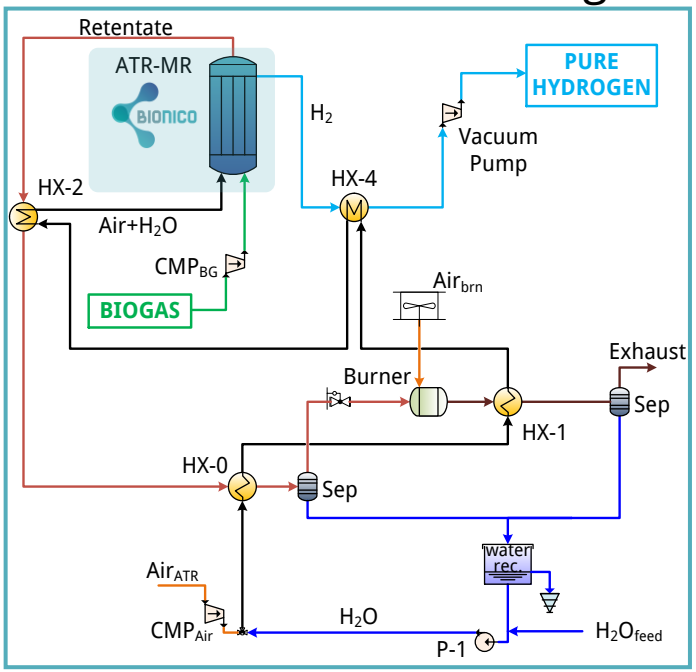
Goal

Final design and construction of MR prototype for the production of approximately 100 kg/day of pure hydrogen

First Year Activities

- Preliminary design of the prototype catalytic membrane reactor at large scale including control system design
- Preliminary design of the balance of plant





Integration&Testing at Biogas Production Site

Goal

Final evaluation of the innovative process to directly produce pure hydrogen in a real biogas production site (ENC Landfill plant in Chamusca)

First Year Activities

- Definitions of input needed for starting the plant licensing procedure
- Evaluating the integration of the prototype reactor in the overall BIONICO system at biogas production site

Biogas cleaning unit

Chamusca Landfill plant

Life Cycle Assessment & Safety Issues

Goal

Development strategy towards sustainable solutions and provide guidance on how operate the reactor prototype under safe conditions.

First Year Activities

- Refined goal & scope of LCA analysis, in particularly, with further clarifications with regard to: (i) reference systems (baseline), i.e., SMR and ATR, (ii) level of details of inventory modeling and (iii) system boundaries
- Improved data collection for key data points, especially related to functional unit, biogas input, conversion efficiency, energy and water use as well as direct GHG emissions during conversion processes
- Performed 1st screening comparative LCA analysis between BINICO CMR and reference technologies

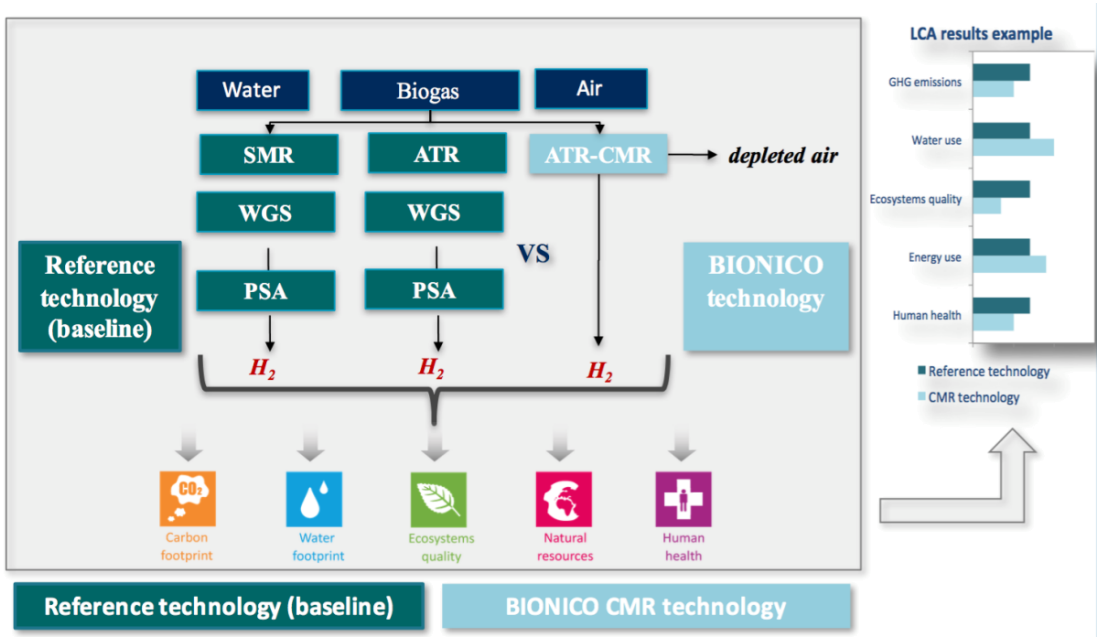
Life Cycle Assessment & Safety Issues

Goal

Development strategy towards sustainable solutions and provide guidance on how operate the reactor prototype under safe conditions.

Achievements

- 1st screening LCA modeling : BIONICO CMR vs reference technology



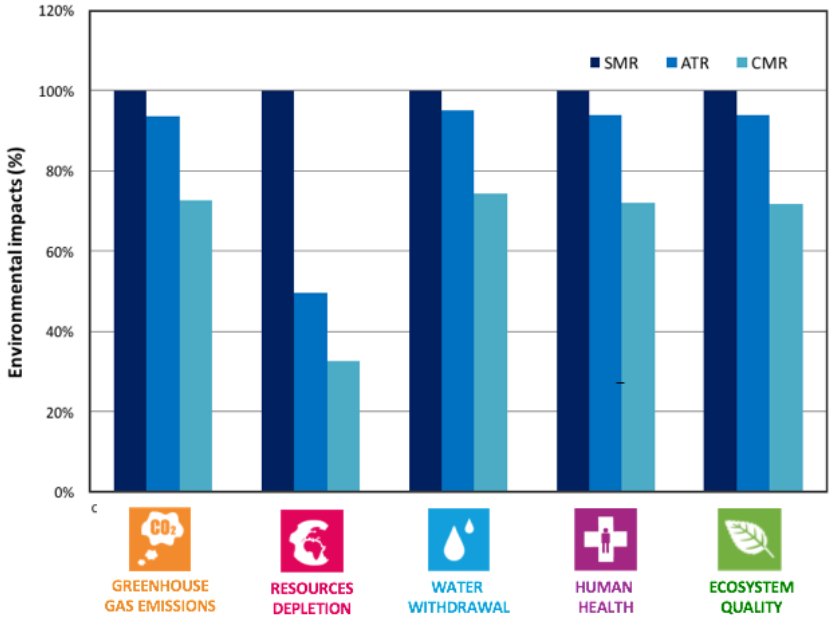
Life Cycle Assessment & Safety Issues

Goal

Development strategy towards sustainable solutions and provide guidance on how operate the reactor prototype under safe conditions.

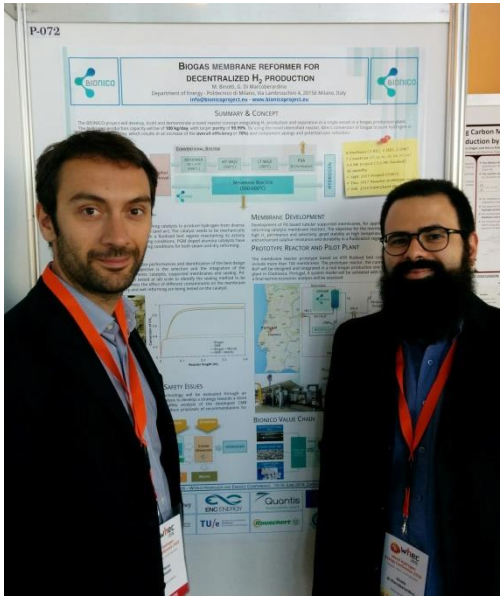
Achievements

- Screening LCA results: BIONICO CMR performs better than reference systems



Dissemination Activity

During summer, BIONICO partners travelled for thousands of kilometers to disseminate the project and its achievements in this first year



Coordinator and Dissemination Manager @ WHEC 2016

Dissemination Activity

- M. Binotti, G. Di Marcoberardino, G. Manzolini, F. Gallucci, N. Ibanez Lirio, *Biogas membrane reformer for decentralized H2 production*, European Biogas Association Conference (EBA 2016), 27-29 September 2016, Ghent, Belgium.
- G. Di Marcoberardino, M. Binotti, G. Manzolini, J. L. Viviente, F. Gallucci, L. Roses, N. Ibanez Lirio, *Achievements of EU projects on membrane reactor for hydrogen production*, 11th Conference on Sustainable Development of Energy, Water and Environment Systems (SDEWES 2016), 4-9 September 2016, Lisbon, Portugal.
- D.A. Pacheco Tanaka, E. Fernandez, J. Melendez, A. Arratibel, A. Helmi, J.A. Medrano, N. Nooijer, K. Coenen, V. Spallina, J.L. Viviente, J. Zuñiga, M. van Sint Annaland, F. Gallucci, *Fluidized bed membrane reactors for hydrogen production using thin Pd-based (< 5 µm) supported membranes*, 14th International Conference on Inorganic Membranes (ICIM 2016), 10-13 July 2016, Atlanta, USA.
- N.C.A. de Nooijer, J. Melendez, K. Coenen, E. Fernandez, F. Gallucci, M. van Sint Annaland, P.L. Arias, D.A. Pacheco Tanaka, *Effect of the addition of Au in Pd-Ag alloy membranes on the hydrogen permeation performance under the presence of H2S*, 14th International Conference on Inorganic Membranes (ICIM 2016), 10-13 July 2016, Atlanta, USA.
- J. Meléndez, D. A. Pacheco Tanaka, A. Arratibel, N. de Nooijer, E. Fernandez, M. van Sint Annaland, P. L. Arias, F. Gallucci, *Preparation and characterization of thin Pd-Ag-Au supported membranes for hydrogen separation*, European Membrane Society Summer School on "Membranes and Membrane Processes Design", 26 June – 1 July 2016, Bertinoro, Italy.
- N.C.A. de Nooijer, J. Melendez, E. Fernandez, D.A. Pacheco Tanaka, M. van Sint Annaland, F. Gallucci, *Steam reforming of biogas in a fluidized bed membrane reactor for pure hydrogen production*, Dutch membrane society Jubilieum posterday, June 2016, Apeldoorn, The Netherlands.
- E. Fernandez, A. Helmi, J. A. Medrano, K. Coenen, A. Arratibel, J. Melendez, N. de Nooijer, V. Spallina, J. L. Viviente, J. Zuñiga, M. van Sint Annaland, D.A. Pacheco Tanaka, F. Gallucci, *Palladium based membranes and membrane reactors for hydrogen production and purification*, 21st World Hydrogen Energy Conference (WHEC 2016), 13-16 June 2016, Zaragoza, Spain.
- M. Binotti, G. Di Marcoberardino, *Biogas membrane reformer for decentralized H2 production*, 21st World Hydrogen Energy Conference (WHEC 2016), 13-16 June 2016, Zaragoza, Spain.

BIONICO PROJECT MEETING – M12

The Sixth month BIONICO meeting was held at Reading (UK) on the 31st of August 2016. It was the chance to update all the consortium on the single WP progresses, to take important decisions for the project and to visit JM facilities.

Consortium

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Thank you for your attention!

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