



BIONICO

BIOGAS MEMBRANE REFORMER FOR DECENTRALIZED H₂ PRODUCTION

Call: H2020-JTI-FCH-2014-1 Topic: FCH-02.2-2014 Decentralized hydrogen production from clean CO₂-containing biogas

SUMMARY

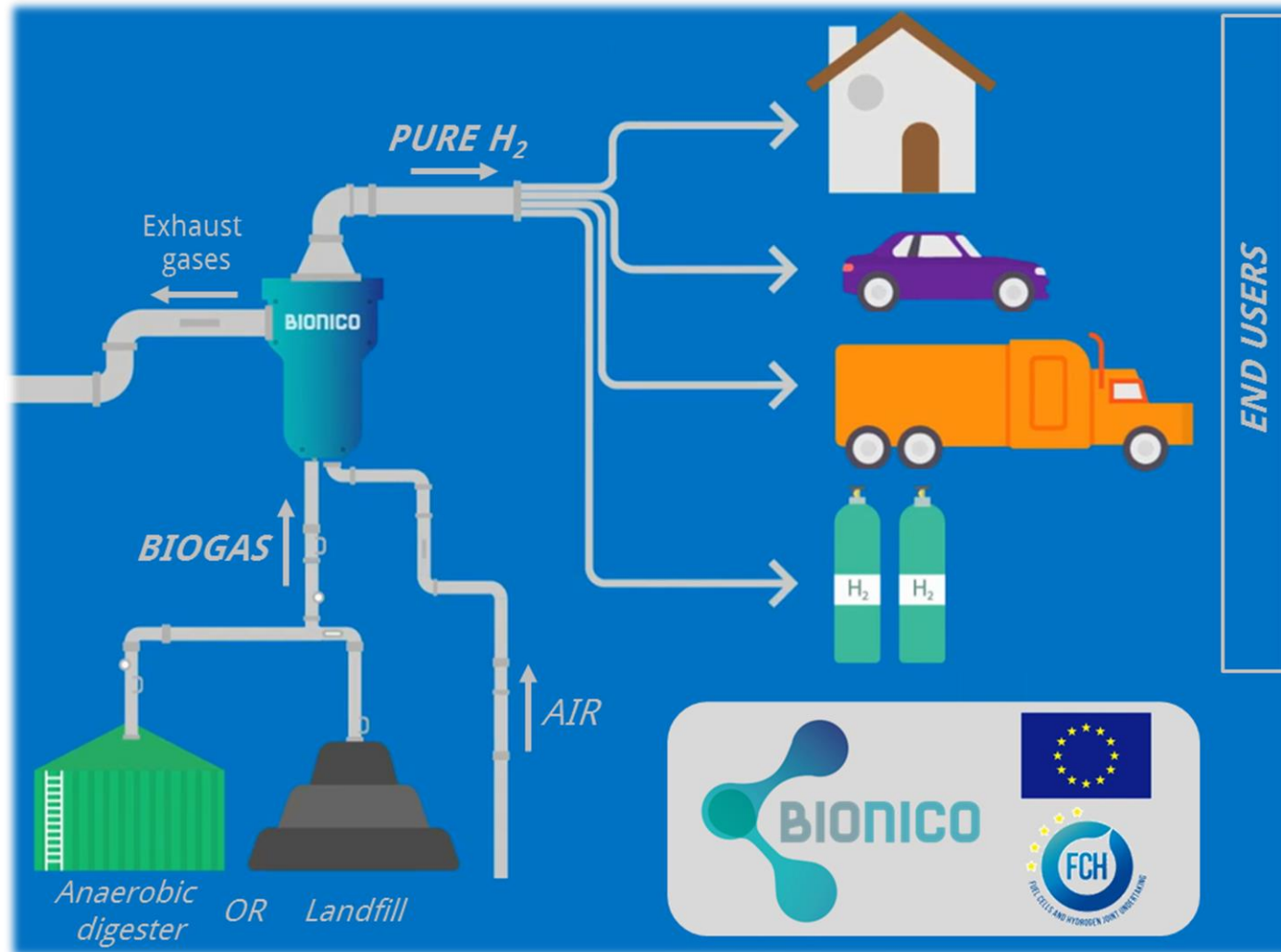
BIONICO **aims** at developing a **novel reactor** configuration at a **larger scale** to produce **H₂** from **biogas** production power plant based on:

- 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 H₂ 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.

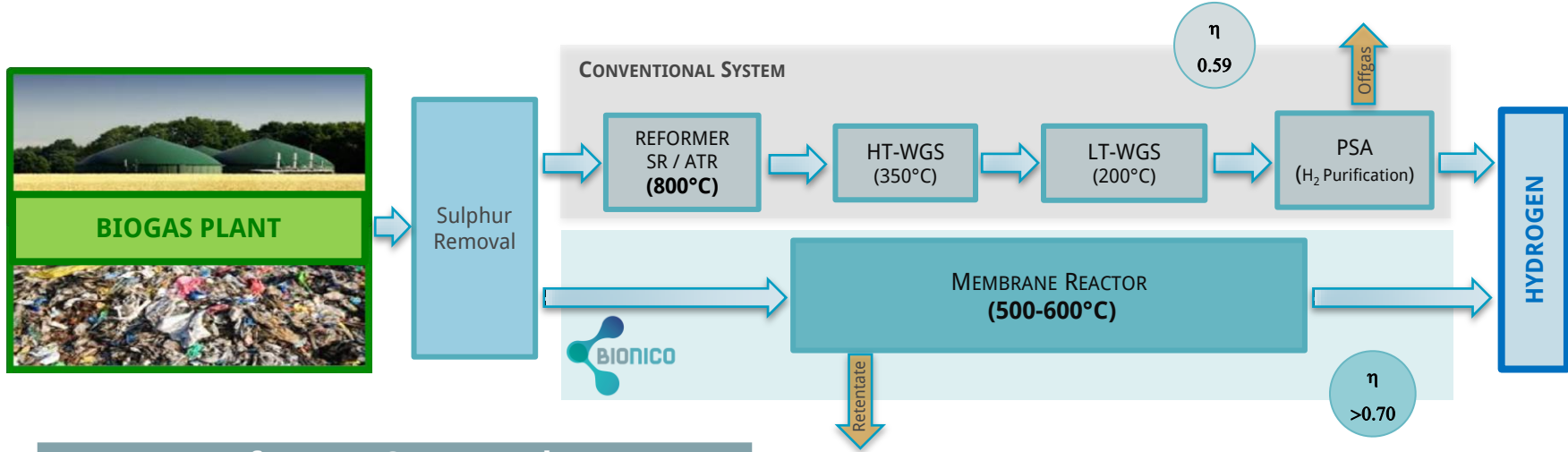
The main idea of BIONICO is to design and demonstrate an **efficient biogas-to-hydrogen conversion system** at real plant conditions using process intensification.



CONCEPT



WHY BIONICO?



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

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

The target of BIONICO is a system efficiency above 70%_{LHV}, which is about 15% higher than SR (59%_{LHV}). The higher efficiency together with equipment savings will end up in lower hydrogen production costs.

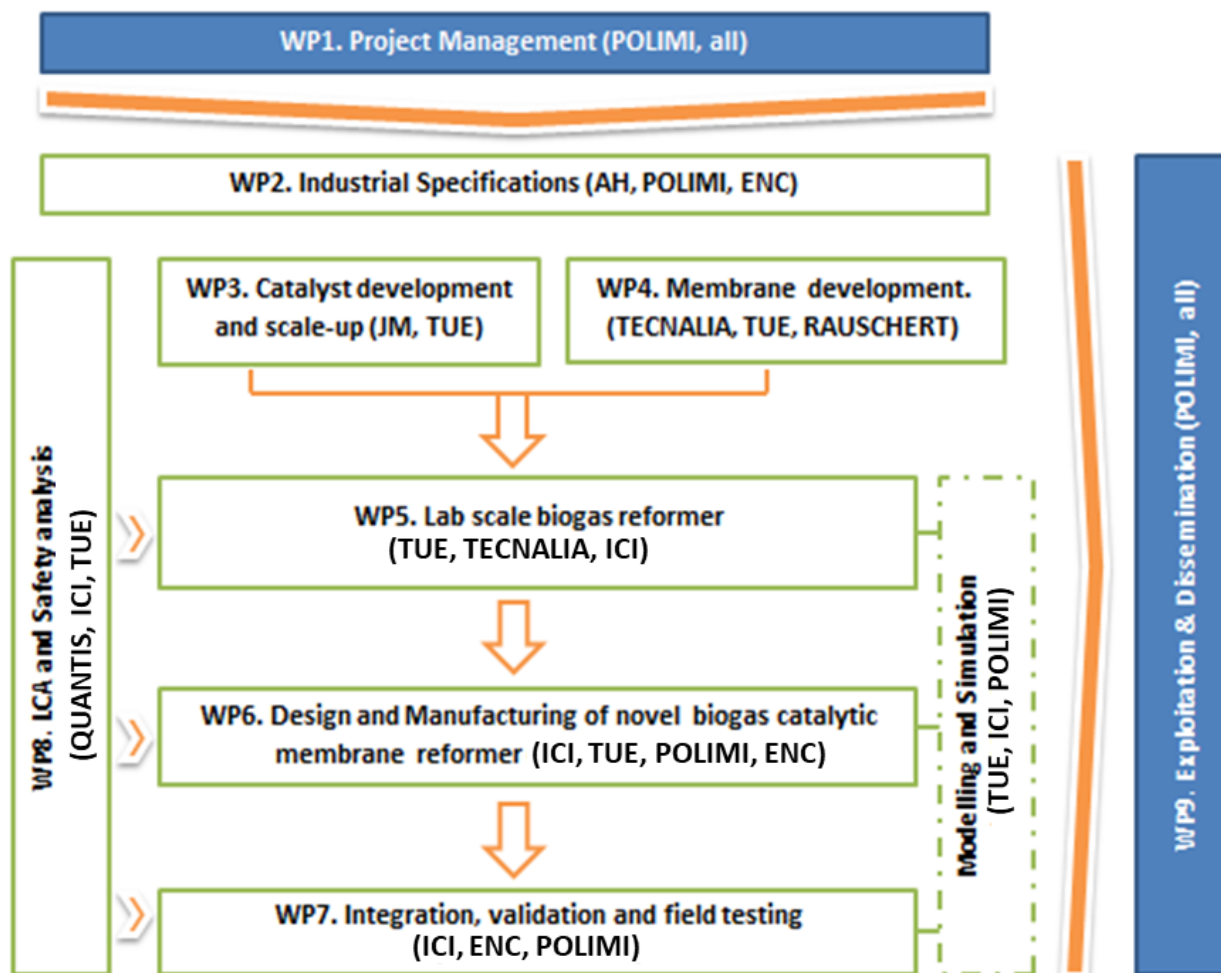
PARTNERSHIP

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.)

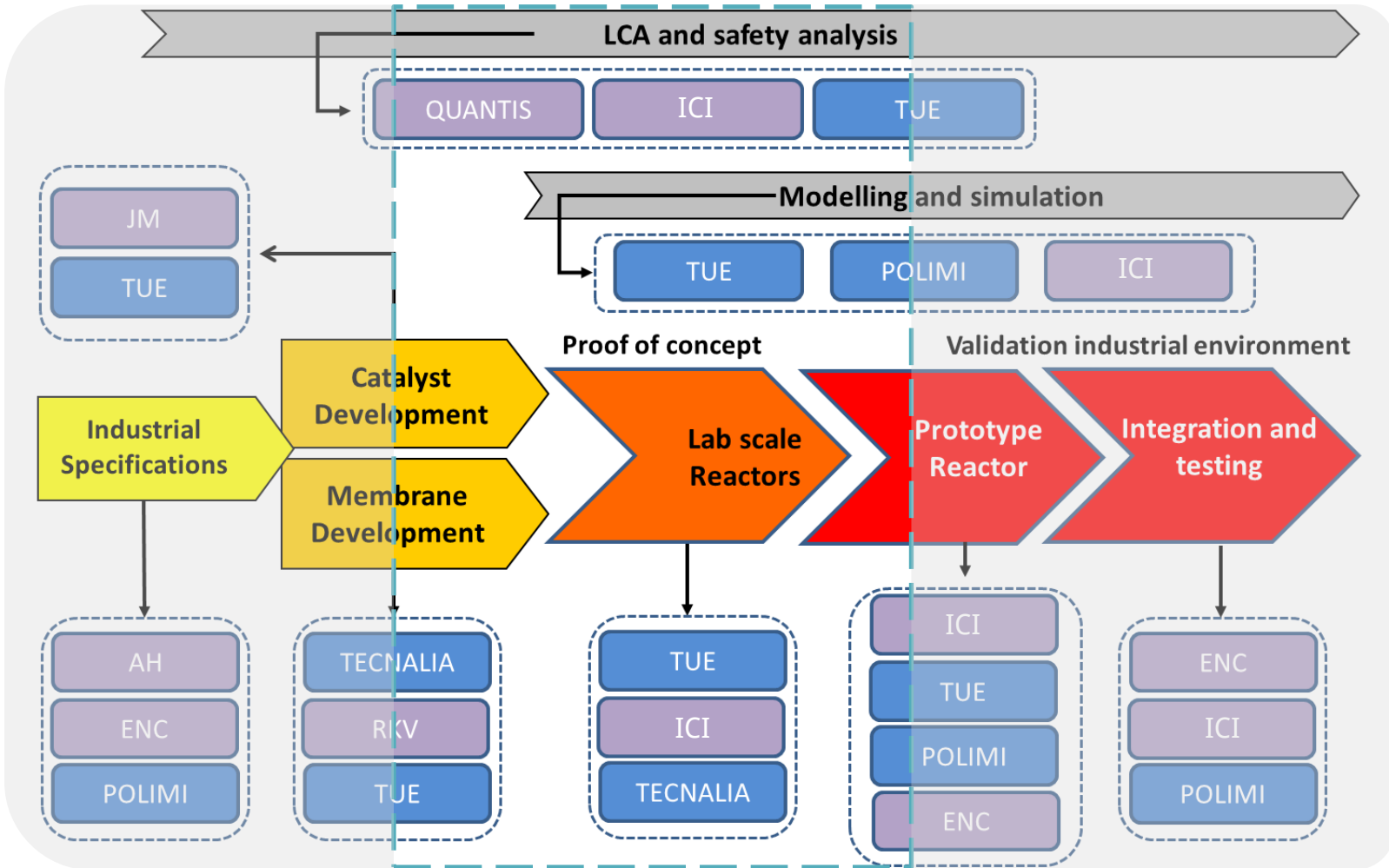
- POLIMI, Italy
- TU/e, The Netherlands
- Abengoa, Spain
- Tecnalia, Spain
- ICI caldaie, Italy
- Johnson Matthey, UK
- ENC Energy, Portugal
- Rauschert, Germany
- Quantis, Switzerland



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 HALF PROJECT ACTIVITIES

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

ACHIEVEMENTS

- 1st generation catalyst and 2nd generation catalyst able to work under fluidisation regime and at low temperature
- Final Catalyst formula produced and ready to be shipped to ICI

NOVEL MEMBRANE & SUPPORT

GOAL

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

FIRST HALF PROJECT 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.



Finger-like asymmetric porous ceramic supports

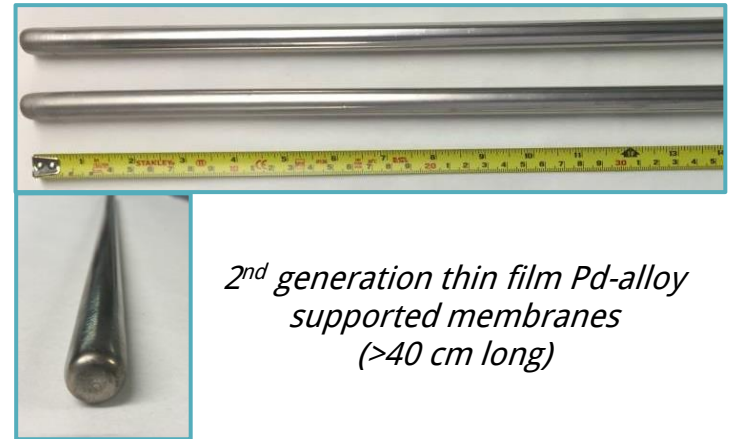
NOVEL MEMBRANE & SUPPORT

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 membrane & support.
 - Thin Pd-Ag layers have been deposited onto the 50 cm long finger-like supports.
- Definition of criteria for support quality
- Improvement of manufacturing procedure for membrane prototype production



2nd generation thin film Pd-alloy supported membranes (>40 cm long)

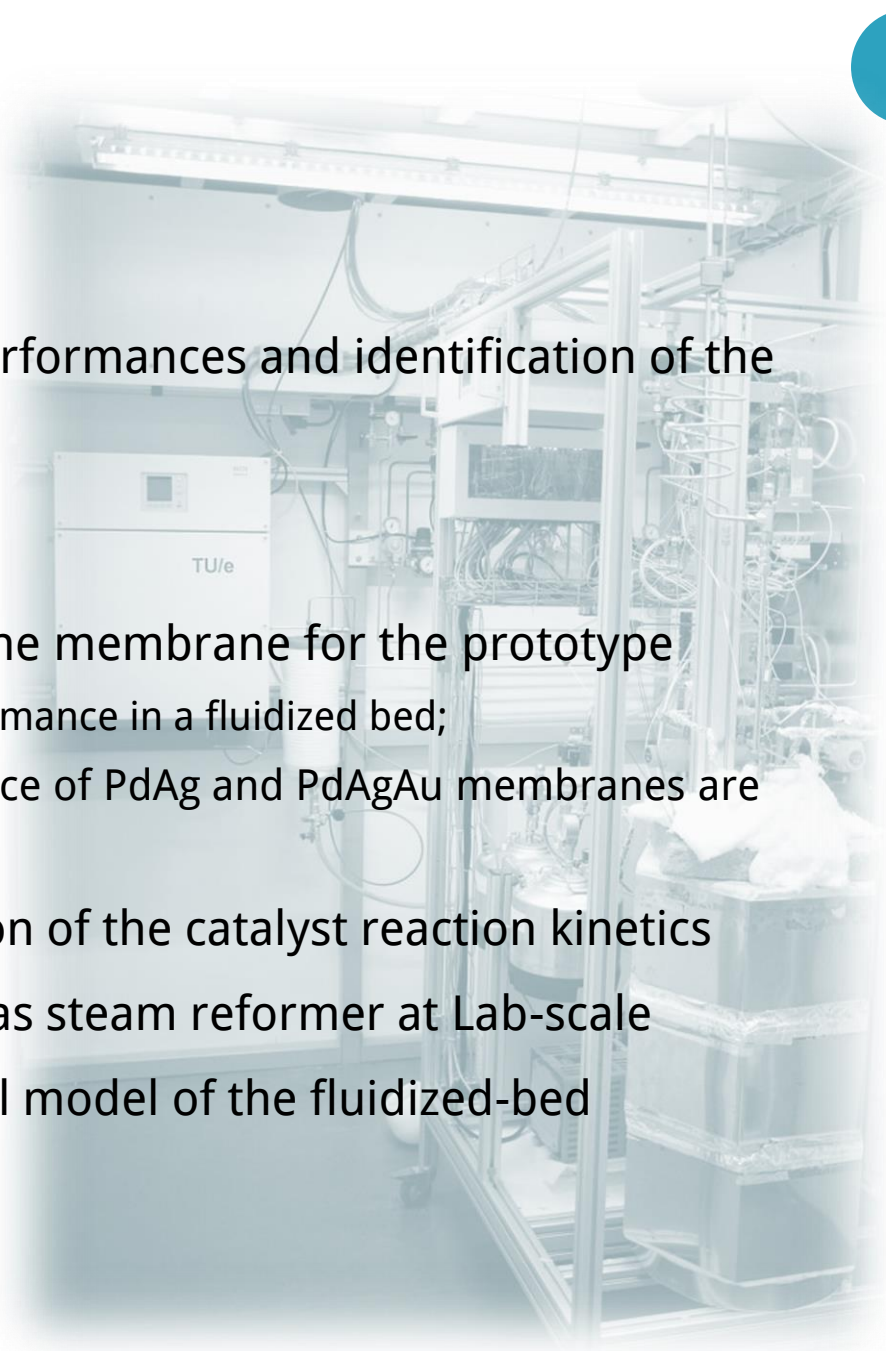
LAB SCALE REACTOR

GOAL

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

FIRST HALF PROJECT ACTIVITIES

- Selection and characterization of the membrane for the prototype
 - Study of long-term membrane performance in a fluidized bed;
 - The effect of H_2S on the performance of PdAg and PdAgAu membranes are studied
- Obtain a comprehensive description of the catalyst reaction kinetics
- Design and demonstration of biogas steam reformer at Lab-scale
- Development of phenomenological model of the fluidized-bed membrane reactor



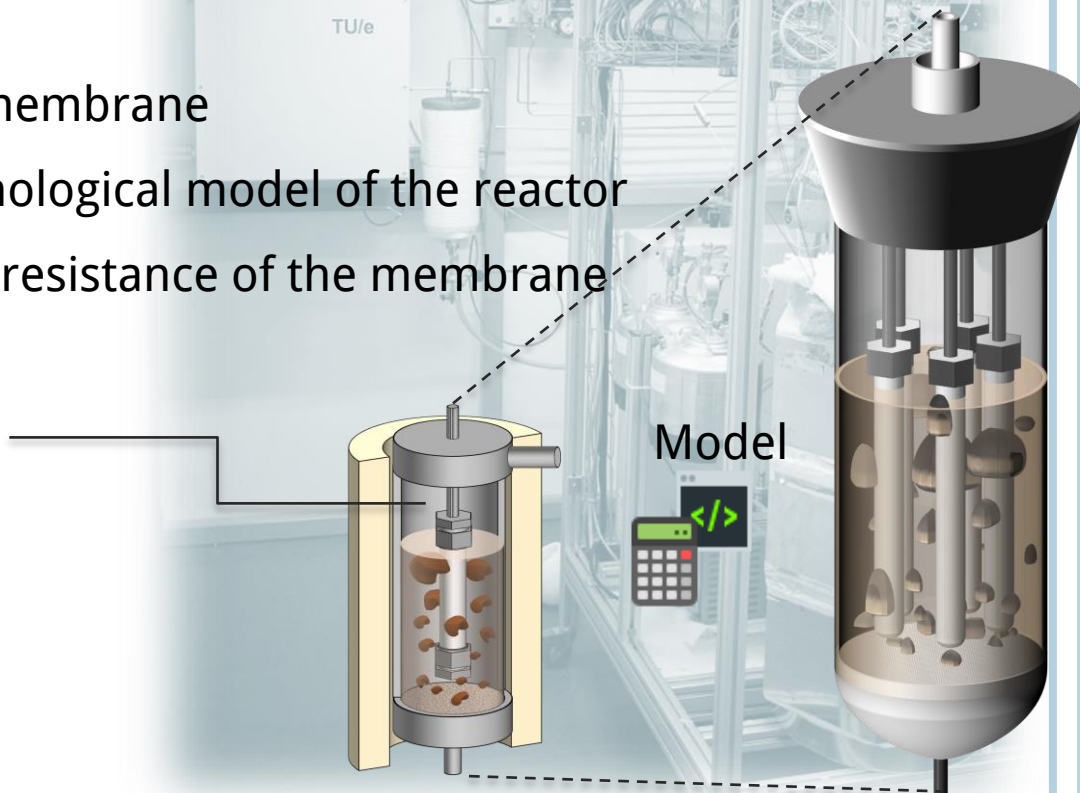
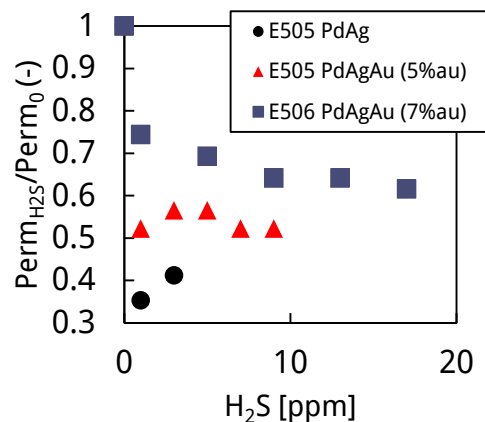
LAB SCALE REACTOR

GOAL

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

ACHIEVEMENTS

- Integration of catalyst and membrane
- One dimensional phenomenological model of the reactor
- Effect of Au addition on H₂S resistance of the membrane



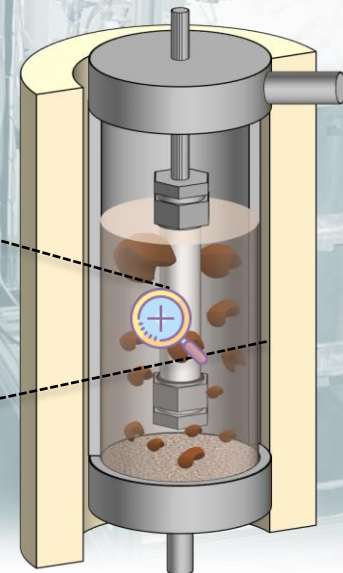
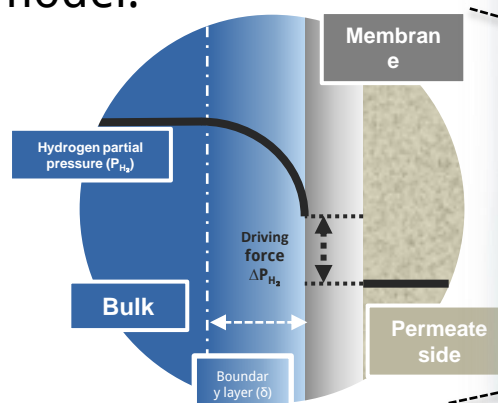
LAB SCALE REACTOR

GOAL

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

ACHIEVEMENTS

- Demonstration of biogas steam reforming in a single membrane reactor with a hydrogen purity of 99.88%;
- Successful description of concentration polarization in the reactor model.



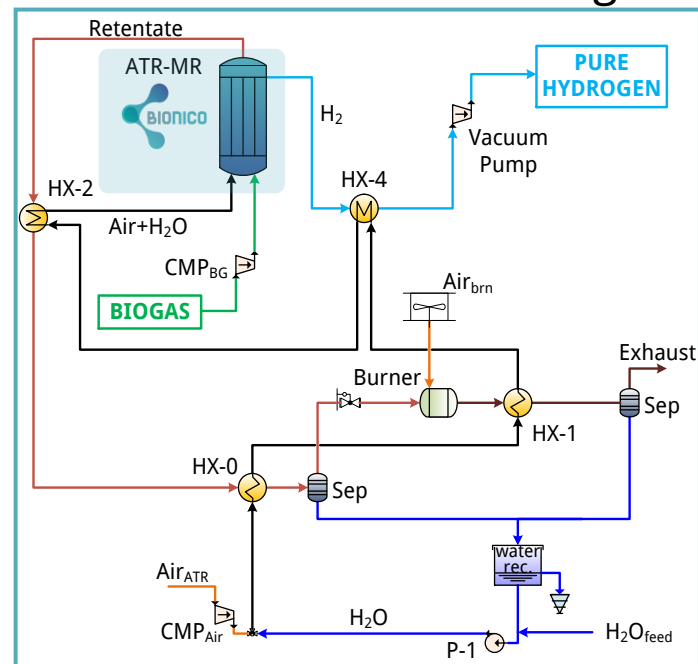
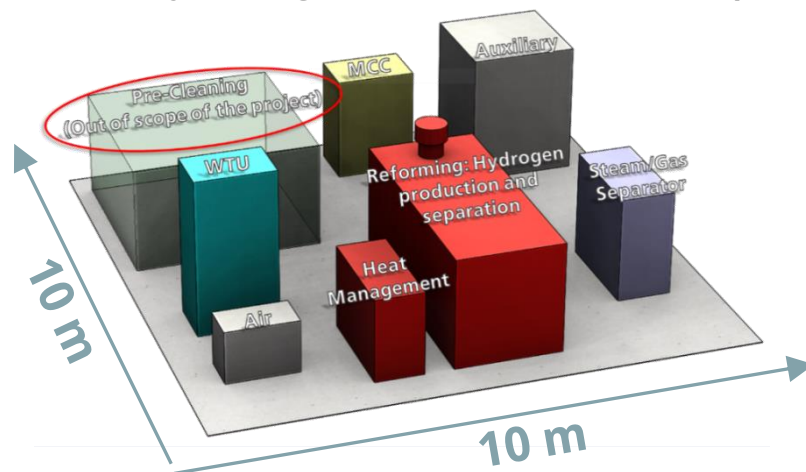
PROTOTYPE REACTOR

GOAL

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

FIRST HALF PROJECT ACTIVITIES

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



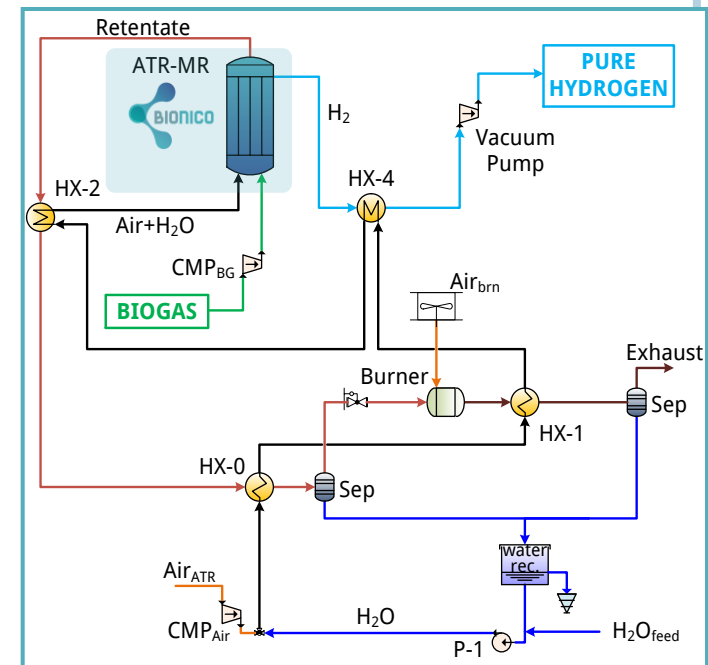
PROTOTYPE REACTOR

GOAL

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

ACHIEVEMENTS

- A techno-economic optimization of BIONICO system was assessed
- Different operating conditions (T , p , S/C), biogas compositions and permeate side configuration were investigated
- BIONICO system outperforms the reference cases by 10% points



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)

FIRST HALF PROJECT 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



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 HALF PROJECT ACTIVITIES

- Refined goal & scope of LCA analysis, in particular, 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

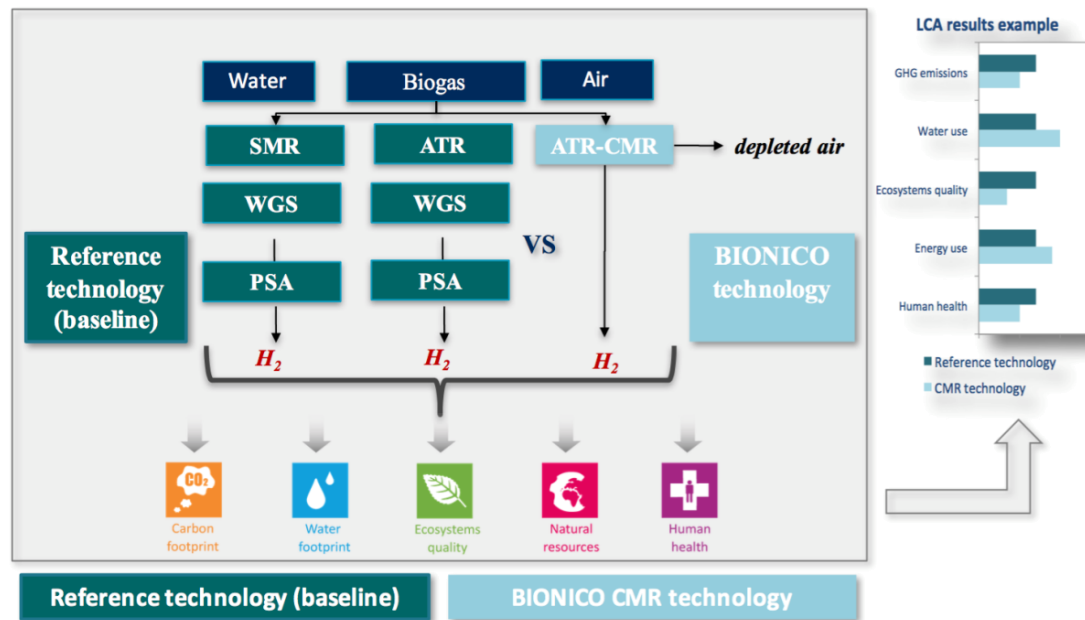
LIFE CYCLE ASSESSMENT & SAFETY ISSUES

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



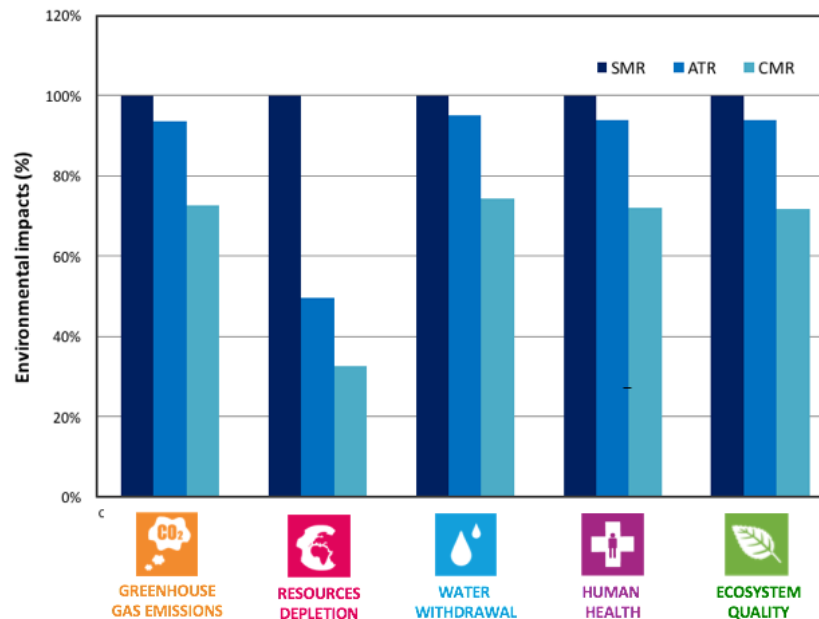
LIFE CYCLE ASSESSMENT & SAFETY ISSUES

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

BIONICO partners travelled for thousands of kilometers to disseminate the project and its achievements in the first half of the project

- Papers (2)
 - Achievements of EU projects on membrane reactor for hydrogen production, *Journal of Cleaner Production, open access*
 - Effect of Au addition on hydrogen permeation and the resistance to H₂S on Pd-Ag alloy membranes, *Journal of Membrane Science*
- Presentations (6+) & Posters (6)
 - 2017 - Stability of Ceramic supported PdAg membranes for hydrogen production in a fluidized bed membrane reactor, *ICCMR, USA*
 - 2017 - MRPI workshop: BIONICO activities mentioned together with other projects
 - 2016 - Achievements of EU projects on membrane reactor for hydrogen production, *SDEWES conference, Portugal*
 - 2016 - Palladium based membranes and membrane reactors for hydrogen production and purification, *WHEC 2016, Spain*
 - 2016 - Fluidized bed membrane reactors for hydrogen production using thin Pd-based (<5 μm) supported membranes, *ICIM conference, USA*
 - 2016 - Effect of the addition of Au in Pd-Ag alloy membranes on the hydrogen permeation performance under the presence of H₂S, *ICIM conference, USA*
 - 2017 - Bionico project - preliminary assessment of hydrogen production from biogas using a fluidised bed catalytic membrane reactor, *Regatec, Pacengo, Italy*
 - 2017 - Potentiality of a biogas membrane reformer for decentralized hydrogen production, *MR4PI workshop, Verona Italy*
 - 2016 - Biogas membrane reformer for decentralized H₂ production, *EBA conference, Belgium*
 - 2016 - Biogas membrane reformer for decentralized H₂ production, *WHEC, Spain*
 - 2016 - Steam reforming of biogas in a fluidized bed membrane reactor for pure hydrogen production, *Dutch Membrane Society, The Netherlands*
 - 2016 - Preparation and characterization of thin Pd-ag-au supported membranes for hydrogen separation, *Poster at EMS Summer School, Italy*



DISSEMINATION ACTIVITY

BIONICO consortium together with other 4 EU Projects organized the third European workshop on membrane reactors. A large participation of both academia and industry has been achieved.



3rd European Workshop on Membrane Reactors (MR4PI 2017)

MEMBRANE REACTORS FOR PROCESS INTENSIFICATION

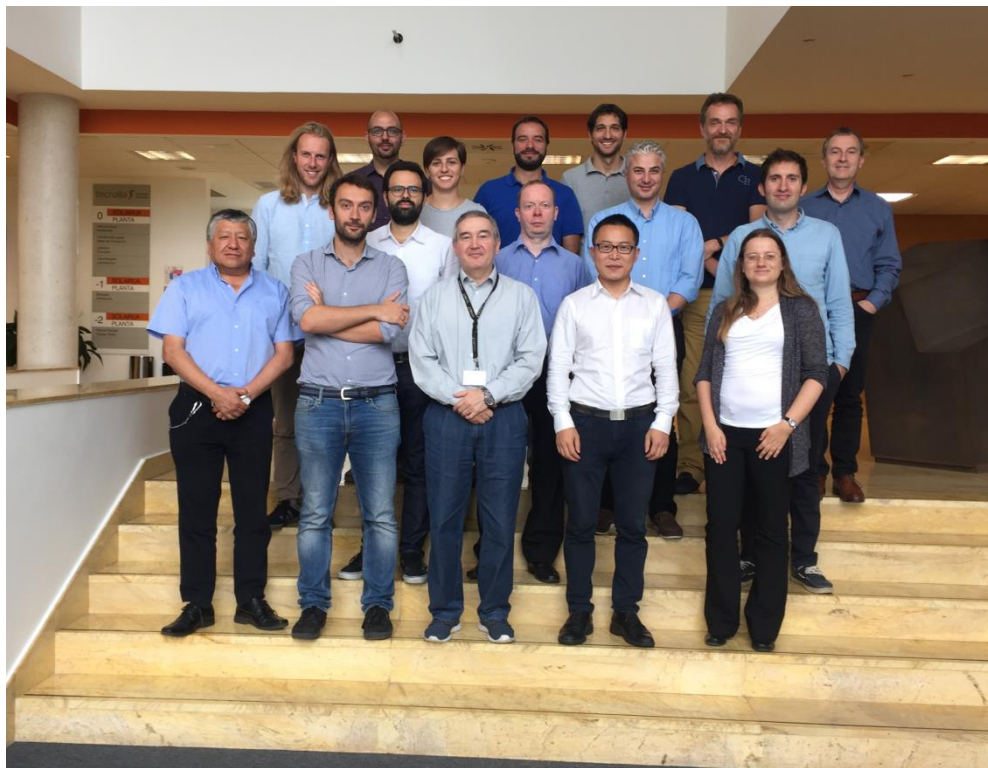
Villafranca di Verona (Italy)
March 9-10, 2017

BIONICO video
online on Youtube!



BIONICO PROJECT MEETING – M24

BIONICO M24 meeting was held in Tecnalia (San Sebastian, Spain). It was an opportunity to discuss on the project status and plan next project activities and to visit TECNALIA facilities.



Jon & Tecnalia Sword

BIONICO consortium

Thank you for your attention!



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