Advanced MEMBranes and membrane assisted procEsses for pre- and post- combustion CO_2 captuRe

MEMBER

https://member-co2.com/

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Contact: joseluis.viviente@tecnalia.com

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1. Introduction

MEMBER project aims to reduce the cost of the Carbon Dioxide capture technologies to fight against the climate change.

MEMBER has been built on the basis of the best materials and technologies developed in three former FP7 projects:

- M^4CO_2 (Energy efficient MOF-based Mixed Matrix Membranes for CO_2 Capture),
- FluidCELL (Advanced m-CHP fuel CELL system based on a novel bio-ethanol Fluidized bed membrane reformer),
- ASCENT (Advanced Solid Cycles with Efficient Novel Technologies)

H2020 – Topic addressed:

NMBP-20-2017: High-performance materials for optimizing carbon dioxide capture

2. Project Objectives

The key objective of MEMBER is to demonstrate state-of-the-art CO_2 capture technologies in an industrially relevant environment. To achieve this, MEMBER will **scale-up and manufacture advanced materials** and prove their added value in terms of sustainability and **performance at TRL 6** in novel **membrane based technologies** for **pre- and post-combustion CO_2 capture in power plants** as well as **in H_2 generation systems with integrated CO_2 capture** and meet the targets of the European SET plan.

Two different technological solutions involving advanced materials will be developed and demonstrated at three different end user's facilities:

- Advanced Mixed Matrix Membranes (MMMs) for pre- and post-combustion CO_2 capture in power plants (H_2/CO_2 & CO_2/N_2 respect.)
- A combination of metallic hydrogen membranes and CO_2 sorbent integrated into an advanced Membrane Assisted Sorption Enhanced Reforming (MA-SER) process for pure H_2 production with CO_2 capture.

2. Project Objectives

- Prototype A, targeted for **pre-combustion capture in power plants** using MMMs at the 2MWth biomass gasifier of **CENER (Spain) aimed for BIO-CCS demonstration.**
- Prototype B targeted for **post-combustion capture in power plants** using MMM at the 8.8MW CHP facilities of **Agroger (GALP, Portugal).**
- Prototype C targeted for **pure hydrogen production with integrated CO_2 capture** using MA-SER at the **IFE-HyNor Hydrogen Technology Centre (Norway)** under the supervision of ZEG POWER.

Main operation conditions & performance targets for the MEMBER prototypes.

	Technology	CO_2 Capture [%]	Capture cost [€/ton]	Demo site
Pre-comb. Power (IGCC)	MMM	> 90	< 30	CENER
Post-comb. Power (Coal)	MMM	> 90	< 40	GALP
H_2 with integrated CO_2 capture	MA-SER	> 90	< 30	IFE-HYNOR

3. Main Goals and S&T objectives

OBJ. 1: MARKET & BUSINESS OBJECTIVES

- To overcome CCS market barriers with an ambitious set of CCS solutions.
- To take European industrial companies (Materials manufacturers, engineering companies and end users) to a leading position in the CCS market, generating economic growth and job opportunities.

OBJ. 2: ECONOMIC OBJECTIVES

- Compliance with strict cost-effectiveness and performance targets:
  - Pre-combustion Mixed Matrix Membrane system for Power generation
  - Post-combustion Mixed Matrix Membrane system for Power generation
  - Mixed Matrix Membrane materials for MEMBER
  - MA-SER system for pure hydrogen production with integrated CO_2 capture
  - MA-SER materials for MEMBER

3. Main Goals and S&T objectives

OBJ. 3: TECHNICAL OBJECTIVES

- To take to manufacturing development stage (from MRL 4-5 to MRL 6) a portfolio of materials and membranes of MMM technology:
  - Process optimization on pilot production lines (Polymers and MOFs).
  - Scaling production lines for the fine-tuned core material: MOF > 1kg/batch;
  - Scaling up the production of hollow fibres MMMs to >10.000 hollow fibers / batch
  - Scale up the membrane module size to >10 m^2
  - Manufacturing of MMM modules for the pre- and post-combustion CO_2 capture in Power Plants
  - ……
- Move from MRL 4-5 to MRL 6 a portfolio of materials of MA-SER technology:
  - Scale up production for core material: Sorbents: 50-100 kg/day; catalyst: 50 kg/batch;
  - Scaling up the production of Pd-based H_2 membranes to 8 membranes / batch
  - Lifetime Analysis of MA-SER at TRL6
  - Demonstration of compliance with CCS codes and standards. Installations in experimental demo plants to support and provide additional information on product characterization from qualification testing.

3. Main Goals and S&T objectives

OBJ. 3: TECHNICAL OBJECTIVES

- Development of a software tool to simulate MEMBER components and CO_2 capture energy performance from the earliest design phases:
  - Module/reactor design and process simulation (at large scale) for full integration of the MMM systems for pre- and post-combustion, and for MA-SER for pure H_2 production with integrated CO_2 capture
  - Development of a model of the MA-SER reformer
  - Validation of the models through demonstration in relevant conditions (demo site)

OBJ. 4: DEMONSTRATION OBJECTIVES

- Demonstration of MEMBER systems and related business models in 3 representative demonstration sites across Europe, covering different sectors, membrane based technologies and CO_2 containing streams

3. Main Goals and S&T objectives

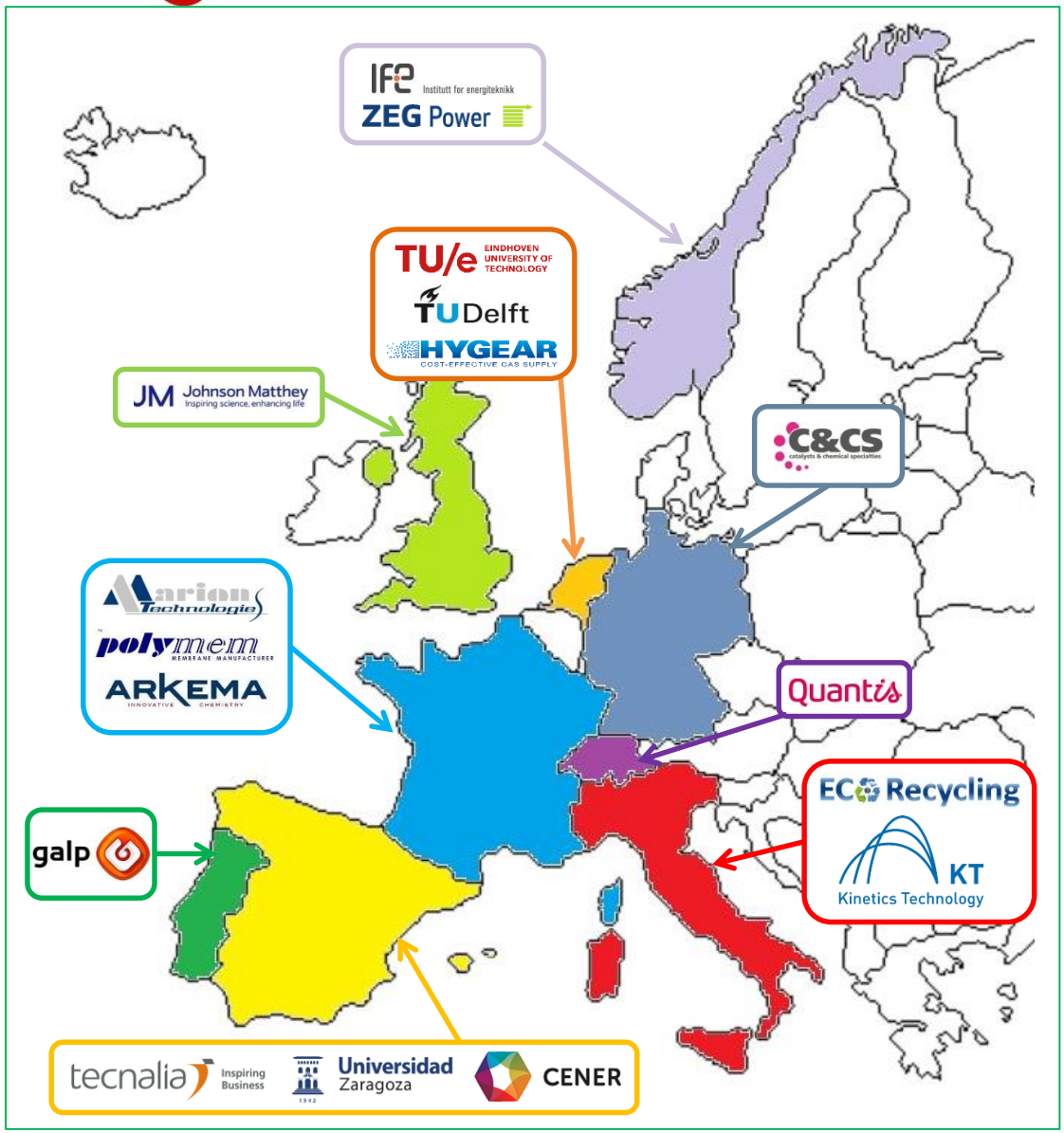
OBJ. 5: ENVIRONMENTAL OBJECTIVES

- To quantify the environmental impacts of the proposed holistic solutions through life cycle assessment based on 3 case studies throughout Europe

OBJ. 6: SOCIAL OBJECTIVES

- Job creation and increase awareness and involvement within the whole social & industrial chain: plant owners, manufacturers, installers, authorities, students, CCS organizations, general public, etc.

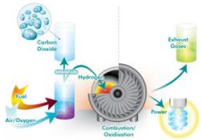
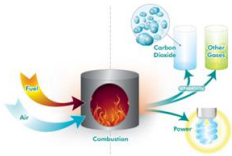
4. Partnership

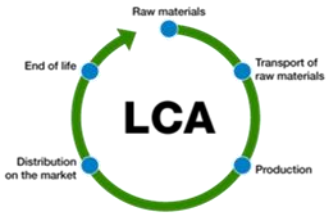


- Multidisciplinary and complementary team.
- 17 partners from 9 countries.
- Industrial oriented (65%):
  11 SME/IND + 6 RTO/HES
- 7 SMEs (41%) & 4 IND (24%)

5. Overall approach and methodology

MMM

Material Production and Scale up			Prototype Manufacturing		Demonstration
Core Material	Processing &Scale Up	Process, Quality Control & Recyclability	Module / Reactor	CO_2 Capture System	Application
MOFs   **Polymers**	 **Mixed Matrix Hollow Fibers**	**Process Control:** • Homogeneity • Morphology • Permeation • … **Product Control & Recyclabilit** • Polymer • MOFs • Membranes			 **Pre-Combustion**  **Post-Combustion**
Johnson Matthey ARKEMA TU Delft Universidad Zaragoza	tecnalia polymem	Johnson Matthey ARKEMA polymem TU Delft Universidad Zaragoza	polymem	HYGEAR TU Delft	galp energia CENER



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5. Overall approach and methodology

MA-SER

Material Production and Scale up

Core Material Manufacturing & Scale up

Sorbents

Membranes

Catalyst

Marion Technologie

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C&CS catalysts & chemical specialities

IFE

Process, Quality Control & Recyclability

Process Control:

- Homogeneity
- Morphology
- Permeation
- …

Product Control & Recyclability

- Catalyst
- Sorbents
- Membranes

Marion Technologie

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C&CS catalysts & chemical specialities

ECO Recycling

Prototype Manufacturing

Module / Reactor

KT Kinetics Technology

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

CO_2 Capture System

KT Kinetics Technology

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

IFE

Demonstration

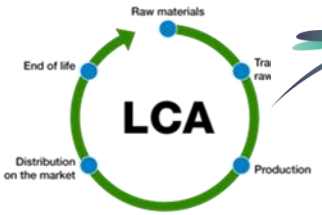
Application

Hydrogen production with integrated CO_2 capture for industrial sectors

Hynor Lillestrøm

IFE

ZEG Power



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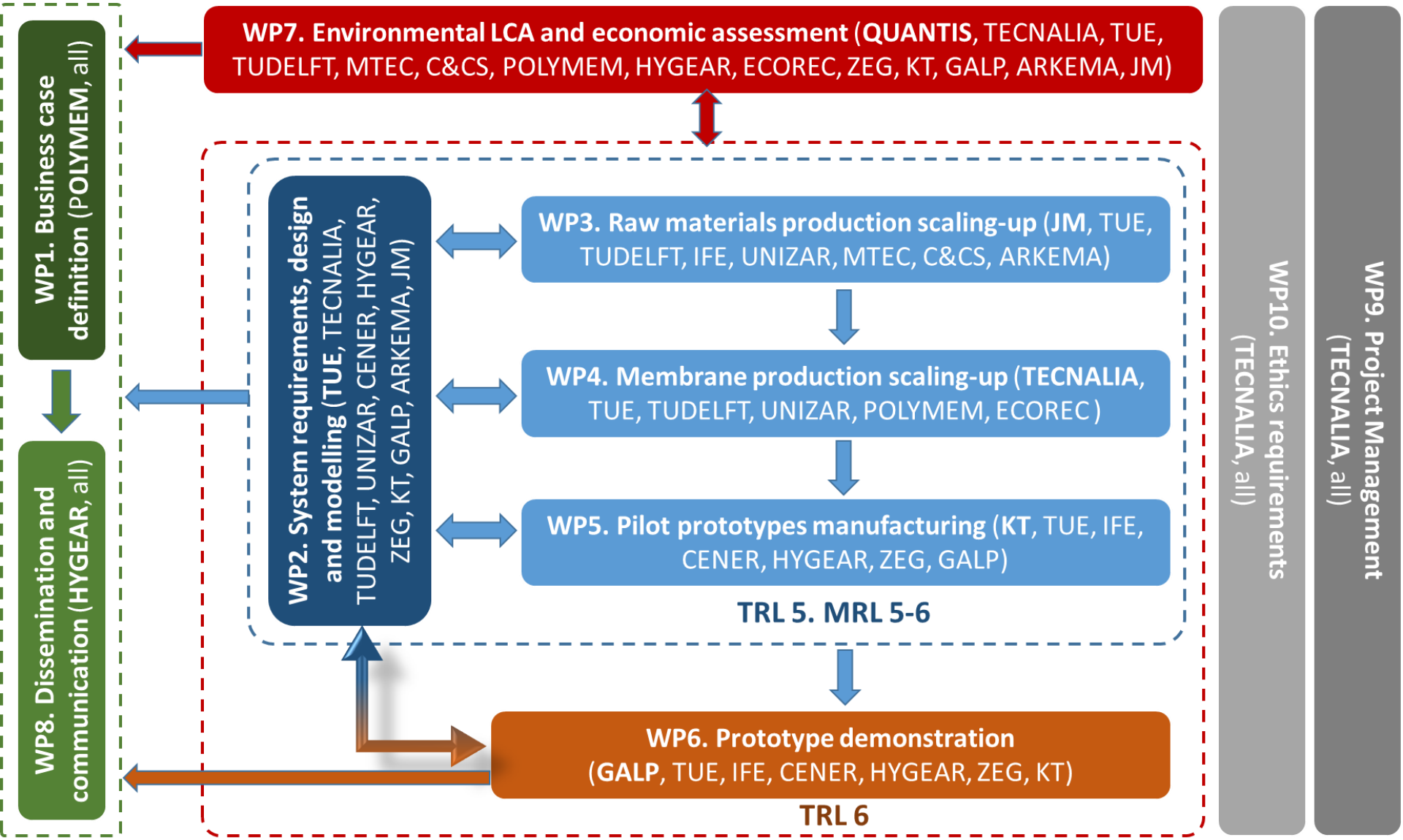
5. Overall approach and methodology



6. Expected results

#	Main exploitation product/ technologies/ others
1	MMM based system for pre-combustion CO_2 capture
2	MMM based system for post-combustion CO_2 capture
3	MA-SER system for pure H_2 production with integrated CO_2 capture
4	Advanced polymers for post-combustion MMMs
5	Advanced MOFs for pre- and post-combustion MMMs
6	Advanced MMMs for pre- and post-combustion
7	Advanced sorbents for MA-SER
8	Advanced catalysts for MA-SER
9	Advanced Pd-based H_2 membranes for MA-SER
10	Software tool for Membrane reactor and SER design. Membrane separation modules
11	Consulting services on LCA of CO_2 capture

7. Prototype status: Prototype A

- System layout selected
  - 1 membrane module system, operating at 4.5 bar
    Recovery rate 88%; Purity: 98.3%.
  - Multi-module systems enhance the hydrogen recovery: 73% (1 stage) to 86% (2 stages)
  - Lower Permeance reduces the hydrogen separation
  - Reduced Selectivity reduces the CO_2 recovery
- System states defined
  - Start-up sequence, normal operation, stand-by, controlled shut-down and emergency shut-down described
- P&ID made
  - Interfaces with gas cleaning system and gasifier defined
  - Power consumption estimated
- Information documented in Process Book Prototype A

7. Prototype status: Prototype B

- System layout selected
  - 2 membrane module system, operating at 8 bar_a
    Membrane area 10 m^2 and 0.7 m^2 respectively for module 1 and 2
    Recovery rate >90%; Purity: >90%.
  - Reduced Permeance lowers the recovery while purity is not affected
    An increase in operation pressure can counteract the effect
  - Lower Selectivity lowers the CO_2 purity
- System states defined
  - Start-up sequence, normal operation, stand-by, controlled shut-down and emergency shut-down described
- P&ID made
  - Interfaces with the 8.8 MW CHP facility of Agroger defined
  - Power consumption estimated
- Information documented in Process Book Prototype B

7. Prototype status: Prototype C

- Process scheme
  - The process scheme has been finalised in order to integrate the MA-SER reactor in existing facility at IFE-HyNor premises
- MA-SER reactor
  - The design of MA-SER reactor has been addressed in order to address the project objective of pure H_2 production with integrated CO_2 capture
- Piping & Instrumentation Diagrams
  - Interfaces with the existing facility at IFE-Hynor premises defined
- Information documented in Process Book Prototype C

8. Environmental LCA and economical analysis

Reference Systems, to which MEMBER systems are compared

	Without capture	With capture
Pre-combustion	IGCC power plant	IGCC power plant with Selexol absorption
Post-combustion	Coal Power Plant	Coal Power Plant with MEA absorption
Integrated H_2 production	Steam reforming process (biomass based scenario)	Steam reforming process with MDEA absorption

Thank you for your attention

https://member-co2.com/

Contact:
joseluis.viviente@tecnalia.com

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