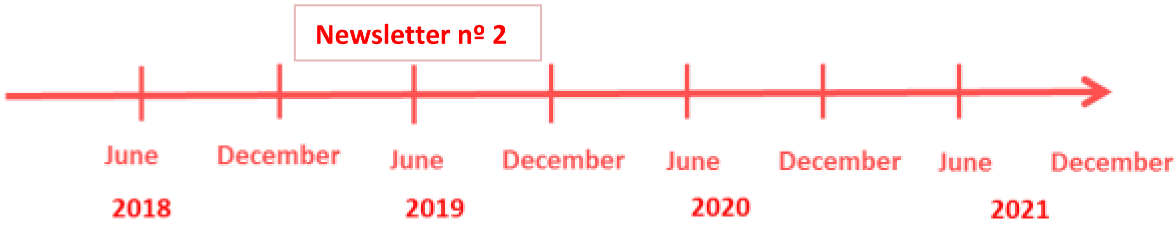
Advanced MEMBranes and membrane assisted procEsses for pre- and post- combustion CO_2 captuRe

Newsletter – Issue 2 –2019



Editorial

Welcome to this second MEMBER newsletter. MEMBER is a four-year project aiming to demonstrate state-of-the-art CO_2 capture technologies in an industrially relevant environment. MEMBER will scale-up and manufacture advanced materials and prove their added value in terms of sustainability and performance. It targets three advanced solutions based on: Innovative MOF -MMMs for pre- and post- combustion CO_2 capture in power plants, and an intensified reforming process combining high temperature solid CO_2 sorbent and dense Pd membranes for pure H_2 production with integrated CO_2 capture (MA-SER).

The present newsletter presents the progress of the project and highlights information related to the R&D fields addressed in the period since the first newsletter was released. We hope you will find the info in this newsletter interesting. On our website https://member-co2.com/ you will find public presentations, all the public deliverables of the project and more interesting news. Stay tuned!

In this Issue:

What is MEMBER?

The concept

Currently, more than 80% of global primary energy use is fossil based. Over the last decade, 85% of the increase in global use of energy was fossil based. In the transition to a fully low-carbon economy, the Carbon Capture and Storage (CCS) technology is one of the key ways to reconcile the rising demand for fossil fuels, with the need to reduce greenhouse gas emissions. Globally, CCS is likely to be a necessity in order to keep the average global temperature rise below 2 °C.

The main drawback of including CCS in power generation or other industrial sectors is related to the energy consumed by the separation processes needed to achieve low carbon emissions (e.g. heat for solvent regeneration). This energy requirement results in a higher fuel consumption and higher fuel cost, leading to reduced overall net efficiencies. Together with the increased CAPEX, due to additional equipment (separation processes or chemical reactors), it determines the substantial increase of the cost of electricity or of an industrial product when CO_2 capture is included.

In order to reduce this energy penalty, MEMBER develops three advanced CO_2-capture solutions using less energy. These technologies are:

- Innovative Mixed-Matrix-Membranes (MMM) filled with Metal-Organic-Frameworks (MOF) for pre- and post- combustion CO_2 capture in power plants;
- An intensified reforming process combining high temperature solid CO_2-sorbent and dense Pd-membranes for pure H_2 production with integrated CO_2-capture (Membrane Assisted Sorption Enhanced Reforming, MA-SER).

MEMBER aims to demonstrate these state-of-the-art capture technologies in an industrially relevant environment. To achieve this, MEMBER will scale-up and manufacture advanced materials and will prove their added value in terms of sustainability and performance under industrially relevant conditions (TRL 6) in novel membrane based technologies. These new technologies will outperform current technologies for pre- and post-combustion CO_2 capture in power plants as well as H_2 generation with integrated CO_2 capture and meet the targets of the European SET plan. In both cases, a significant decrease of the total cost of CO_2 capture will be achieved. MEMBER targets CO_2 capture technologies that separate >90% CO_2 at a cost below 40€/ton for post combustion and below 30€/ton for pre-combustion and H_2 production.

The developments within MEMBER have started using the best materials and technologies developed in three former FP7 projects, ASCENT, M^4CO2 and FluidCELL. In particular, special attention will be paid to the scale-up and improvements of manufacturing processes of key materials and products such as Metal-Organic-Frameworks (MOFs), polymers, membranes and sorbents.

Table 1. Performance targets for the MEMBER prototypes

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

Project objectives

The key objective of the MEMBER project is the scale-up and manufacturing of advanced materials and their demonstration at industrially relevant conditions (TRL6) in novel membrane-based technologies that outperform current technologies for pre- and post-combustion CO_2 capture in power plants as well as H_2 generation with integrated CO_2 capture and meet the targets of the European SET plan.

Three 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 respectively)
- 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.

The main objectives of the MEMBER project are:

- Increasing the manufacturing readiness level (from MRL 4-5 to MRL 6) of a portfolio of materials for the production of Mixed Matrix Membranes for pre- and post-combustion CO_2 capture in power plants (H_2/CO_2 and N_2/CO_2 separation).
- Increasing the manufacturing readiness level (from MRL 4-5 to MRL 6) of hydrogen membranes, reforming catalysts and CO_2 sorbents materials, and integrating them into an advanced Membrane Assisted Sorption Enhanced Reforming (MA-SER) process for pure H_2 production with CO_2 capture.
- Development of a software tool to simulate MEMBER components, the processes and CO_2 capture energy performance.
- Design and construction of 3 prototypes for CO_2 capture for testing of the developed materials in relevant operating conditions at TRL6.

- Demonstration of the MEMBER systems and related business models in 3 representative demonstration sites across Europe, covering different sectors, membrane-based technologies and CO_2 containing streams:
  - Prototype A targeted for pre-combustion in a gasification power plant using MMM at the facilities of CENER (BIO-CCS).
  - Prototype B targeted for post-combustion in power plants using MMM at the facilities of GALP.
  - Prototype C targeted for pure hydrogen production with integrated CO_2 capture using (MA-SER) at the facilities of IFE-HyNor.
- Quantification of the environmental impacts of the proposed holistic solutions through life cycle assessment.
- Exploitation of the results including the definition of a targeted and quantified development roadmap to bring the technologies to the market.
- Overcoming the CCS market barriers with an ambitious set of CCS solutions.

Partnership

The consortium brings together multidisciplinary expertise on the entire value chain: material development (MOFs, polymers, sorbents and catalyst), membrane development (MMMs, Pd based membranes); chemical and process engineering, modelling (from thermodynamics to unit operation modelling to system integration), membrane modules and reactors development, recycling, LCA and industrial study, innovation management and exploitation. It is composed of 17 partners from 9 countries: 6 RTO/HES and 11 SMEs/INDs (65%) it is an industrial oriented consortium, including 7 innovative SMEs (41%) and 4 Large industries (24%).

Figure 1. European partnership in MEMBER

Project structure

The MEMBER project structure is subdivided in ten work packages following the focus on the development of the CO_2 capture processes. Furthermore, the project will demonstrate the capture technologies in industrially relevant environment. Therefore, the work structure is based on the following work packages.

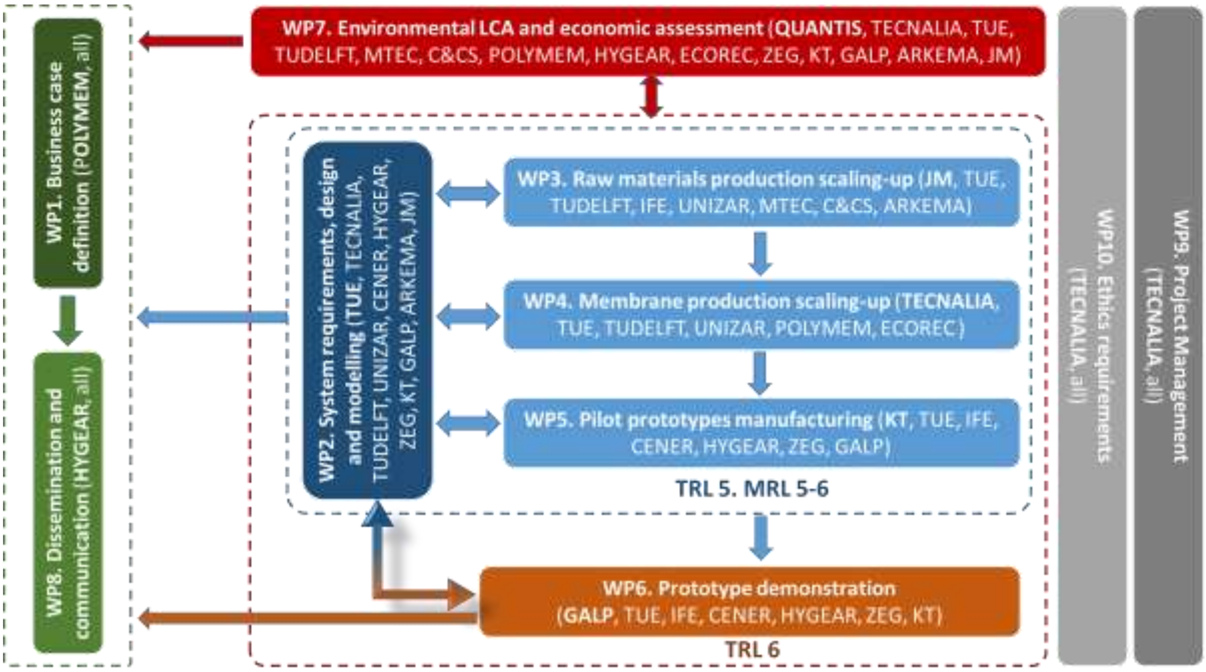


Figure 2. Work structure and synergies between partners.

Latest news from the project

The latest new on different WP activities are now reported:

Business case definition

A study has been conducted analysing and comparing the current and prospective market trends on CO2 capture. Relevant scientific literature, white papers and European open access databases have been used for this study.

The main conclusions from the market analysis are:

1. The CCS market is in its infancy.
2. Carbon prices need to increase considerably to make a sustainable business case.

3. Launching customers will be small-size CO_2-emitters, up to about 25000 T/y having a need for CO_2 in their processes. For instance, sodium carbonate producers, water treatment (pH regulation), and food industries.

System requirement, design and modelling

The industrial requirements have been defined targeting two different aspects: 1) material properties and manufacturing methods, and 2) CO_2-capture system specifications according to demonstration site needs.

The system specifications relating to the demonstrations of the three different prototype systems have been inventoried and all the characteristic process parameters such as balance of plant; raw material specifications, process selectivity, current limitations and CO_2 capture cost, have been identified. This serves as input for the activities on pilot prototypes design, construction and testing.

With regards to the definition of the advanced materials (membranes, sorbents, catalyst) scale up requirements, the technical specifications for the advanced materials and the expected performance at every level have been defined and quantified, as well as the optimal manufacturing process. Technical specifications include mainly permeability, perm-selectivity, mechanical & chemical stability, together with CO_2 capture performance.

The industrial requirements have been reported in the public deliverable that could be downloaded from the member public website (https://member-co2.com/)

The material specifications, process conditions and current limitations are used as input for the modelling of prototype A, B and C elements. These modelling activities are currently being executed. For the MMM module modelling UNIZAR is determining the MMM intrinsic performance. For the dense Pd-membranes TUE has modelled and evaluated the effect of the elementary steps for the hydrogen permeation. This model is used in the development of the overall MA-SER model. In a next step the effect of operation conditions on the MMMs and MA-SER systems will be used for the technical and economical assessments with comparison to benchmark technologies by KT and HYGEAR.

Core materials scaling-up

Good progress has been made in the past period, large scale routes to synthesise the advanced materials used in the project are taking shape. Manufacturing routes for the sorbent used in the MA-SER technology has been aligned with lab-based synthesis provided by IFE. A first batch of sorbent manufactured at MTEC has shown stable performance over 100 cycles (Figure 3). Reforming catalyst development is still ongoing with positive results achieved with each new catalyst iteration.

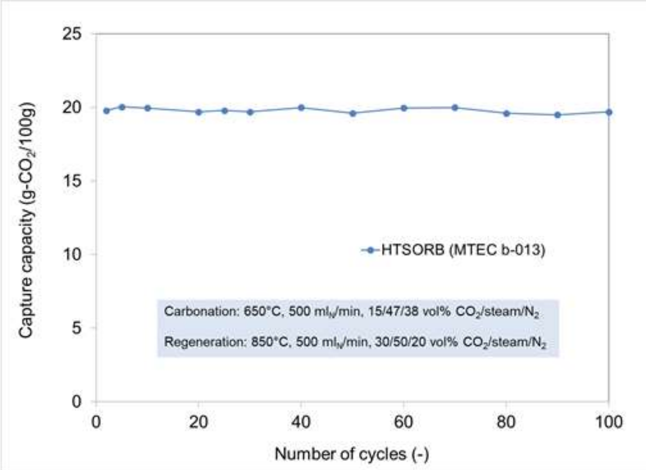


Figure 3. CO_2 capture performance of HTSORB manufactured at MTEC after 100 carbonation-regeneration cycles.

Along the mixed matrix membrane line, development of large-scale manufacturing routes for MOFs are progressing well, lab-based material can now be made up-to 500 g and work is ongoing to take this further. Manufacturing equipment is being prepared ready for kilogram scale production toward the end of the year. Extensive membrane synthesis, characterisation and testing is ongoing. Different compositions of polymer layers (Figure 4) are being tested to improve properties of the membrane such as selectivity and permeation.

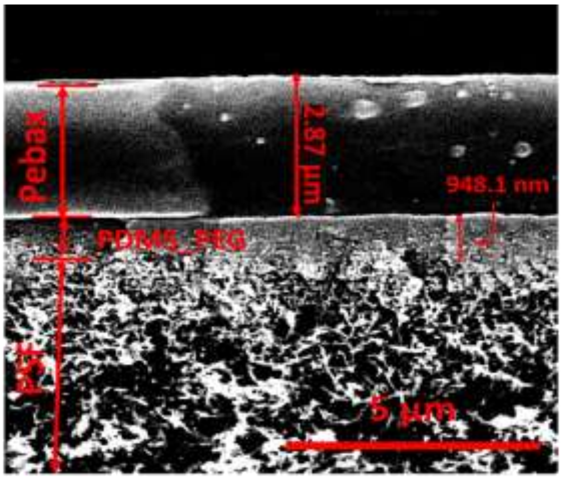


Figure 4. SEM image of composite membrane: dense Pebax® 1657/PDMS+PEG on asymmetric PSf support.

Synthesis of membranes at lab scale is continuing with extra focus on using scalable techniques.

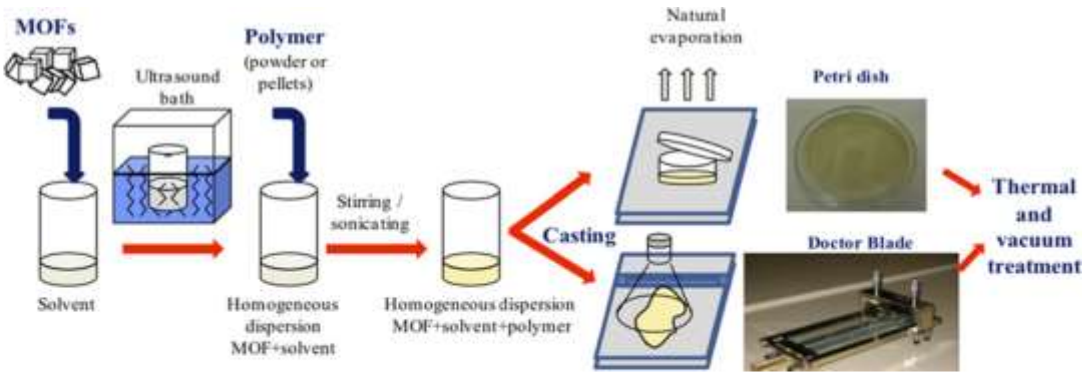


Figure 5. Schematic diagram of flat sheet MMM synthesis.

Membranes production scaling-up

The main activities have been focused on membrane production setups and recycling systems revamping. Optimization of preparation parameters to scale up the manufacturing processes of membranes for the three CO_2 capture prototypes is progressing according to the planned activities.

The pilot line for mixed matrix membrane production by dip coating has been designed and constructed. The innovation of the new set up consists in the continuous and multi-layer coating aspect: with one single production step a composite multi-layer dense membrane can be produced. The first tests show that a homogeneous coating without defects can be achieved (Figure 6). Process parameter optimization to produce the membranes is underway.

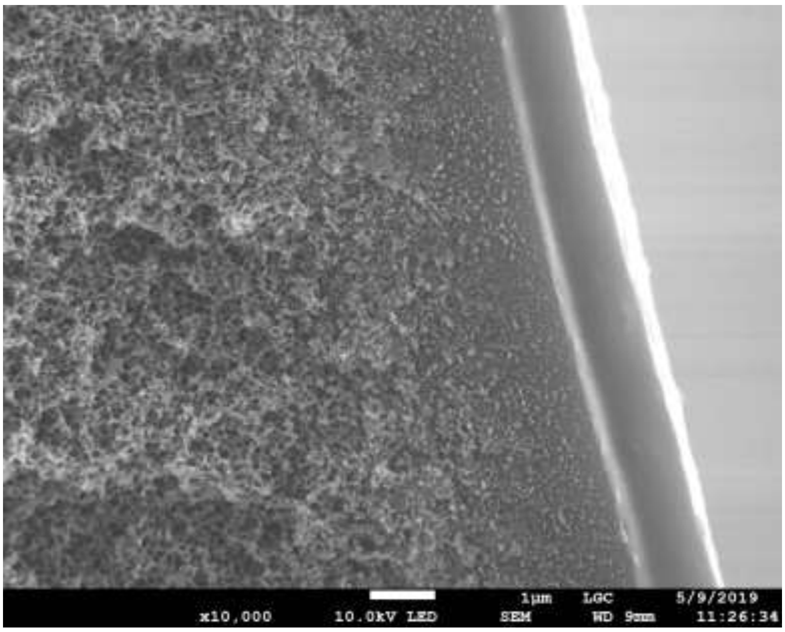


Figure 6. SEM picture of the multiple layer coating with a dense selective layer of ~1 µm thickness

A new plating system has been designed and set up for depositing 8 Pd-Ag membranes per batch (prototype C). The new design was based on the specifications of the previously available process for depositing one membrane per batch. This system has been already validated for the deposition of Pd-Ag membranes onto 8 ceramic supports of 50 cm length in a batch. The optimization of the deposition of a thin palladium layer on 50 cm long metallic supports is on-going. The first two 50 cm long membranes prepared and tested at Tecnalia (Figure 7) showed hydrogen permeation properties very close or exceeding the targets (H_2 permeance: > 8 x 10^{-7} mol m^{-2} s^{-1} Pa^{-1} at 400 °C; H_2 ideal perm-selectivity: > 10,000). Long-term permeation test of this membranes are being carried out at TU Eindhoven.

Figure 7. Thin Pd-based membrane onto 50 cm long porous metallic support

The basic and detailed engineering for the revamping of Pd-based membranes recycling pilot plant has been completed. In parallel experiments for recycling Pd-based membranes are being done.

Pilot prototypes design, construction and testing

The objective is the design and set-up of the three prototypes of MEMBER project plus the syngas cleaning system to be installed upstream the Prototype A at CENER facilities.

The membrane systems for prototypes A and B have been modelled using the expected properties of the membrane materials. Various system layouts have been reviewed and properties varied, and, on this basis, the two process layouts have been selected. The modelling results show that a 90% CO_2 recovery can be achieved in combination with a high purity. With reference to Prototype A, the syngas cleaning process scheme has been optimized in order to properly clean the syngas making it compliant with the downstream membrane system operation.

For Prototype C the process scheme has been selected and the MA-SER reactor process design has been addressed.

The process design of the 4 prototypes has been concluded according to the project time schedule, with issue of Process Books for Prototype A, B and C and finalization of process Book for Syngas Cleaning System.

Environmental and economic assessment

State-of-the-art environmental Life Cycle Assessment (LCA), Life Cycle Costing (LCC) and other economic assessment tools are applied to evaluate the environmental and cost performance of the developed MEMBER solutions compared to current technologies. Specific objectives aim at assessing the environmental and cost performance of MMMs and MA-SER, and associated components (materials), including all aspects related to recyclability in agreement with the learnings from the membrane scaling-up work, to guide the design and development of the novel concept towards more sustainable solutions, to benchmark the MEMBER materials and technology against alternatives from a sustainability perspective, to define and evaluate comprehensive scenarios for the successful deployment and commercialisation of the developed materials and technologies in Europe and possibly globally and to develop a user-friendly foot-print to communicate the environmental performance of the developed innovative advanced materials (membranes, catalyst and sorbents) for pre- & post-combustion CO_2-capture.

Main goal in the first period was the definition of the goal and scope for the environmental LCA and economic assessment. The goal and scope definition is the first step in a LCA study and lays the basis for all subsequent stages. It defines the aim of the study and thereby identifies challenges in modelling as well as in data availability. Moreover, upon completion of the study, the goal and scope definition helps interested parties in understanding under which framework the study was derived and to what extend its results can be compared to the ones presented in other studies. Some of the most important questions in the goal and scope definition are: What is the functional unit of the system under study? What are the system boundaries under study?

The purpose (or function) of the systems developed in MEMBER is the capture of CO2 in power plants, either at pre- or post-combustion stage, or integrated in the process of pure hydrogen production. For this reason, the functional unit is:

- 1 kg of CO2 captured and stored for the pre-combustion, post-combustion systems using the MMM's and for the hydrogen production system using MA-SER's

The system boundaries include the production, transport, use, disposal or recycling of the main materials developed in MEMBER such as membranes, catalysts, sorbents and MOF's as well as the impact of the additional fuel used in the plants due to decreased efficiencies.

Currently, a preliminary LCA and LCC is being conducted, to identify the most significant areas of environmental impacts and costs with the aim to steer the project towards more eco-efficient solutions.

Highlights

MEMBER meetings

The third consortium meeting was held at Tecnalia in San Sebastian (E) on January 16 and 17, 2019. The fourth consortium meeting was held at TUD in Delft (Nl) on July 16 and 17, 2019. Objectives, role of team members, deliverables, and dissemination activities were presented, as well as each work package work plan. Lastly, the process for managing risks and issues was covered.

MEMBER workshop 2020
Introduction to Membrane-based system for CO_2 capture
Mid-January 2020, Eindhoven – The Netherlands

Mid-January 2020, a Workshop will take place in Eindhoven University of Technology. The workshops will be focus on membrane-based systems for CO_2 capture. Detailed program will be available beginning October 2019. Please visit the MEMBER website for updates (https://member-co2.com/).

Dissemination activities, publications and presentations:

MEMBER public presentations, open access articles and public reports are available online in the dissemination section of the project website: https://member-co2.com/.

Member partners have contributed to the following conferences and workshops:

1. Miren Etxeberria. MEMBER project. Advanced MEMBranes and membrane assisted procEsses for pre- and post- combustion CO_2 captuRe. Euromembrane 2018. Valencia, Spain (July 9-13, 2018). Poster.

2. Oana David. MEMBER project. Advanced MEMBranes and membrane assisted procEsses for pre- and post- combustion CO_2 captuRe. 17th Aachener Membran Kolloquium. Aachen, Germany (November 14-15, 2018). Poster

3. M. Malankowska, Post-combustion gas separation by Mixed Matrix Membranes, 8th International Zeolite Membrane Meeting, Lulea, Sweden (16-6-2019).

4. L. Martínez-Izquierdo et al., Influence of the casting solution concentration on the morphology, thermal properties and CO2/N2 separation performance of Pebax® 1657 membranes, XXXVII Reunión Bienal de la Real Sociedad Española de Química, San Sebastian, Spain (May 26-30, 2019).

5. O. David et al., Advanced membranes and membrane-assisted processes for pre- and post- combustion CO2 capture (MEMBER project), XXXVII Reunión Bienal de la Real Sociedad Española de Química, San Sebastian, Spain (May 26-30, 2019). Poster.

6. J.L. Viviente, Advanced MEMBranes and membrane assisted procEsses for pre- and post- combustion CO2 captuRe, 10th Trondheim CCS conference, Trondheim, Norway (June 17 -19, 2019). Oral presentation.

7. A. Deacon et al., Developing efficient MOF scale-up routes for carbon capture applications, ICCDU XVII conference, Aachen , Germany (23-27 June , 2019).

8. Ir. S. Pouw, et al., Study on Internal membrane resistances in dense supported membranes with mesoporous support, ICCMR14, Eindhoven, The Netherlands (July 8 - 11, 2019).

9. Ir. S. Pouw, et al., Thermodynamic comparison of MA-SER and MA-CLR processes, with outlook on techno-economic evaluation, ICCMR14, Eindhoven, The Netherlands (July 8 - 11, 2019). Oral presentation.

10. J.L. Viviente, Advanced MEMBranes and membrane assisted procEsses for pre- and post- combustion CO_2 captuRe, ICCMR14, Eindhoven, The Netherlands (July 8 - 11, 2019). Oral presentation.

MEMBER team member F. Galluci (TUE) opening the 14th International Conference on Catalysis in Membrane Reactors

Publications:

1. L. Martínez-Izquierdo et al., Poly(ether-block-amide) copolymer membrane for CO_2/N_2 separation: The Influence of the casting solution concentration on its morphology, thermal properties and gas separation performance, accepted paper in Open Science.

Upcoming events

September 5, 2019	European High-Level Conference on Carbon Capture and Storage (CCS), Oslo (Norway).
September 9 – 11, 2019	6th World Conference on Climate Change, Berlin (Germany). https://climatechange.insightconferences.com/
September 11-12, 2019	13th Carbon Dioxide Utilization Summit, Calgary (Canada) https://www.wplgroup.com/aci/event/co2-canada/
September 17-19, 2019	5th Post Combustion Capture Conference, Kyoto (Japan) https://ieaghg.org/conferences/pccc/2-uncategorised/914-pccc5-information
September 23-27, 2019	18th Asian Pacific Confederation of Chemical Engineering (APCChE) Congress, Sapporo (Japan) http://www.apcche2019.org/index.html
October 1-6, 2019	14th Conference on Sustainable Development of Energy, Water and Environment Systems (SDEWES), Dubrovnik (Croatia) http://www.dubrovnik2019.sdewes.org/
October 9-10, 2019	14th Carbon Dioxide Utilisation Summit, Dusseldorf (Germany) https://www.wplgroup.com/aci/event/co2/
October 21-22, 2019	6th Global summit on Climate Change, Amsterdam (The Netherlands) https://climatechange.global-summit.com/
October 22-28, 2019	5th International Congress on Energy Efficiency and Energy Related Materials (5th ENEFM 2019), Oludeniz (Turkey) http://www.enefmcongress.org/
October 29-31, 2019	Argus Biomass Nordics and Baltics conference, Copenhagen (Denmark) https://www.argusmedia.com/en/conferences-events-listing?page=1
November 6-7, 2019	European Biomass to Power Conference, Helsinki (Finland) https://www.wplgroup.com/aci/event/european-biomass-to-power/
November 13-14, 2019	European Methanol Summit, Dusseldorf (Germany) https://www.wplgroup.com/aci/event/european-methanol-summit/
November 27-28, 2019	Asian Biomass to Power, Kuala Lumpur (Malaysia) https://www.wplgroup.com/aci/event/asian-biomass-to-power/

December 2-3, 2019	International Conference on Green Energy and Recycling" (Green Energy 2019), Berlin (Germany). https://www.europeanmeetings.net/conferences/greenenergy
January 20 – 21, 2020	22nd International Conference on Carbon Dioxide Utilization and Sustainable Development (ICCDUSD 2020), London (United Kingdom). https://waset.org/conference/2020/01/london/iccdusd n
February 17-19, 2020	4th International Conference on Fossil and Renewable Energy" (F&R Energy-2020), Houston – TX (USA) https://energy-conferences.com/
February 24-26, 2020	Fourth International Conference on Catalysis and Chemical Engineering (CCE-2020), Los Angeles – CA (USA) https://unitedscientificgroup.com/conferences/catalysis/conference-info
March 5-6, 2020	International Conference on Carbon Dioxide Capture and Storage Technologies ICCDCST (ICCDCST 2020), Barcelona (Spain) https://waset.org/conference/2020/03/barcelona/ICCDCST
March 26-27, 2020	International Conference on Geological Sequestration of Carbon Dioxide (ICGSC 2020), Madrid (Spain) https://waset.org/conference/2020/03/madrid/ICGSC
March 26-27, 2020	International Conference on Carbon Dioxide Utilization and Reduction (ICCDUR 2020), Madrid (Spain) https://waset.org/conference/2020/03/madrid/ICCDUR
April 20-21, 2020	23rd Annual Energy, Utility, Environment Conference (EUEC2020) https://www.euec.com/uncategorized/carbon-capture-storage-co2-capture/
May 22-24, 2020	World Chemistry Forum 2020 (WCF-2020), Osaka (Japan) https://www.istci.org/wcf2020/
May 31 – June 3, 2020	11th International Symposium on Catalysis in Multiphase Reactors & 10th International Symposium on Multifunctional Reactors, Milano (Italy) https://www.aidic.it/camure11-ismr10/
June 22 – 25, 2020	23rd World Hydrogen Energy Conference (WHEC 2020) http://www.whec2020.com/
July 12-17, 2020	12th International Congress on Membranes and Membrane Processes (ICOM2020), London (UK) http://www.icom2020.co.uk/
September-October 2020	15th International Conference on Greenhouse Gas Control Technologies (GHGT-15)
December 10 – 11, 2020	22nd International Conference on Carbon Dioxide Utilization and Sustainability (ICCDUS 2020), Havana (Cuba). https://waset.org/conference/2020/12/havana/ICCDUS

June 2021	11th Trondheim Conference on CO_2 Capture, Transport and Storage (TCCS-10)
September 19-20, 2021	International Conference on Carbon Dioxide Reduction (ICCDR 2021), Paris (France) https://waset.org/conference/2021/09/Paris/ICCDR
September 2021	6th Post Combustion Capture Conference

MEMBER in figures:

- *17 partners (6 RES, 4 IND, 7 SME)*
- *9 countries*
- *9 596 541€ project (7 918 901€ EU funded)*
- *Start January 2018*
- *Duration: 48 months*
- *Key milestones:*
  - *February 2020 – three CO_2 capture concepts designed*
  - *December 2020 – prototypes ready for testing*
  - *December 2021 – demonstration of the prototypes in industrial relevant conditions at TRL 6*

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More information on MEMBER (including a presentation of the project) is available at the project website: https://member-co2.com/

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Disclosure: