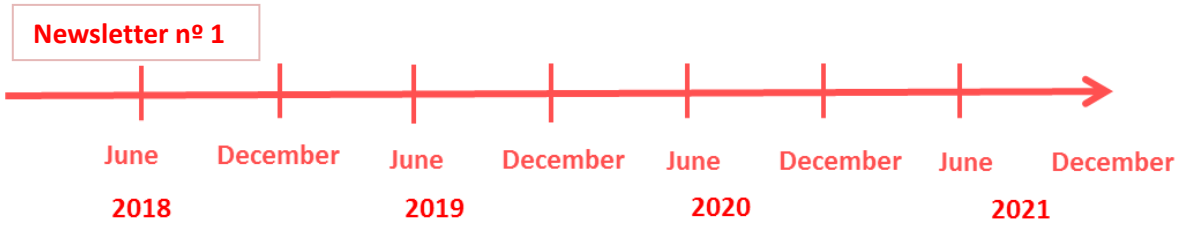
*Advanced MEMBranes and membrane assisted procEsses for pre- and post- combustion $CO_2$ captuRe*

# Newsletter – Issue 1 –2018




## Editorial

Welcome to this first 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 is the first release of the biannual letter that will be published by MEMBER presenting the progress on the project and highlighting information related to the R&D fields addressed. 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 for keeping the average global temperature rise below 2 °C.

The main challenge 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 is the major reason for the reduced overall net efficiencies. The lower efficiency turns into higher fuel consumption and higher fuel cost. 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 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).

MEMBER aims to demonstrate 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.

**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 |

MEMBER has been built on the best materials and technologies developed in three former FP7 projects, ASCENT, M$^4$CO2 and FluidCELL. In particular, special attention will be paid to the scale up and improvement to manufacturing processes of key materials and products such as Metal Organic Frameworks (MOFs), polymers, membranes and sorbents.

## 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%).

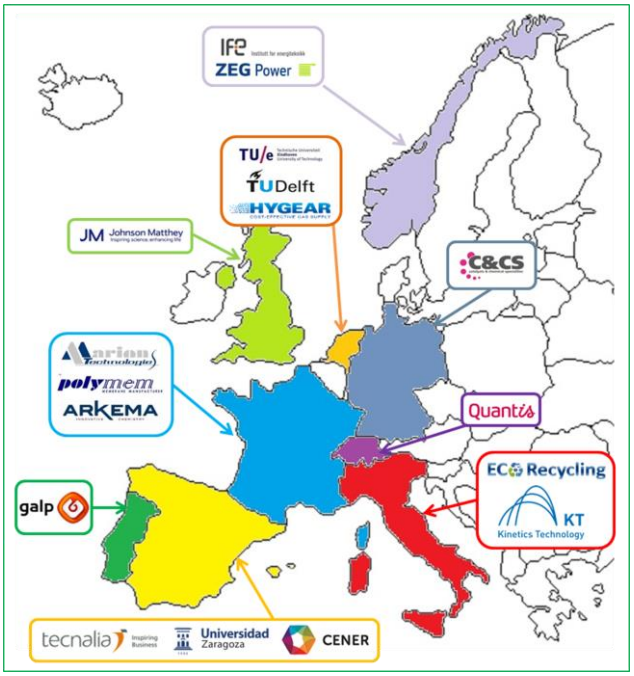



**Figure 1. European partnership in MEMBER**

## 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.

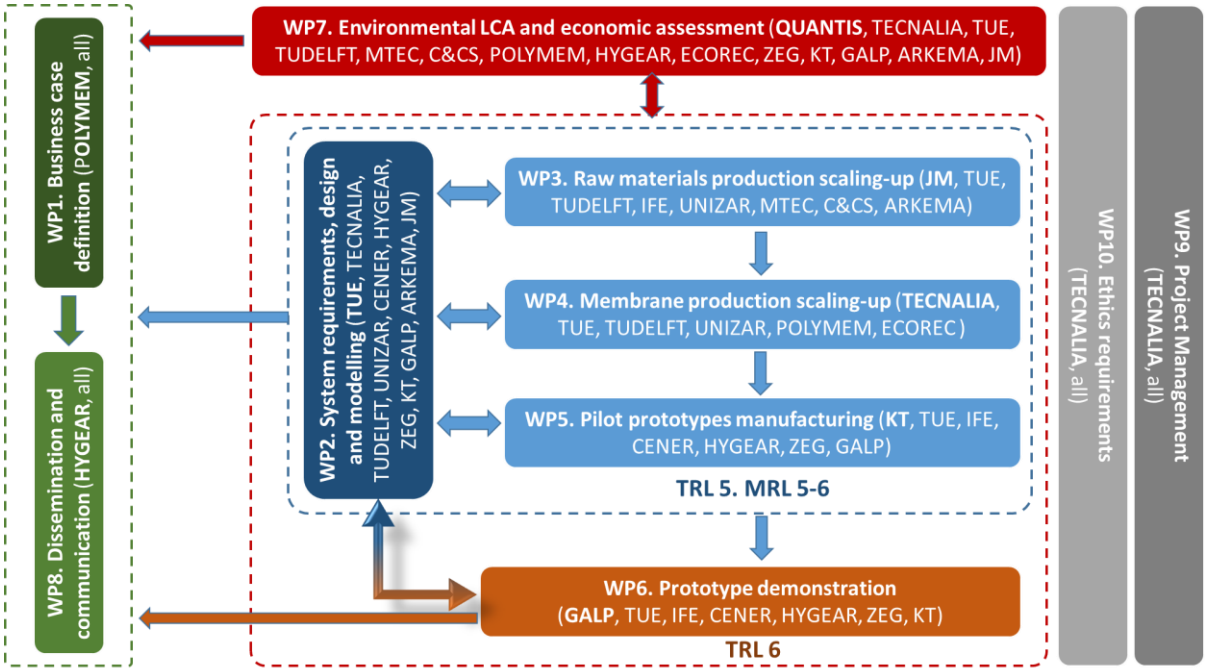



**Figure 2. Work structure and synergies between partners.**

# Latest news from the project

The latest new on different WP activities are now reported:

## Business case definition

During the 6 months period the objectives of the work was mainly to start the analysis of the market. First, the framework of the market was defined which is basically carbon capture in CCS excluded transport and storage. Due to the very large amount of document related to CCS a top-bottom analysis from global numbers coupled with a bottom-up analysis from end-users' needs are being applied. Indeed, the market size appears incredibly high and difficult to address quickly with an emerging technology like MMM membranes for large $CO_2$ emission plans. To address this issue, the bottom-up analysis would allow to identify few users, small first, which could be interested by small-size plants and targeting firstly plants emitting 15,000 to 25,000 $tCO_2$/year.

## System requirement, design and modelling

Main activities have been focussing on defining the industrial requirements targeting two different aspects: material properties and manufacturing and $CO_2$ capture system specifications according to demonstration site needs.

With regards to define the system performance for the three applications, the demo site owners and the engineering companies involved in the construction and validation of the different prototypes have gathered the information available on state-of-the-art systems and identified all the characteristic process parameters such as balance of plant; raw material specifications, process selectivity, current limitations and $CO_2$ capture cost.

With regards to define 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/)

## Core materials scaling-up

Work is progressing well within core materials work package. The consortium has met in Zaragoza to discuss the specifications and initial results of the project. Samples of active MOFs and polymers have been sent to partners to be incorporated into membranes and are undergoing testing.

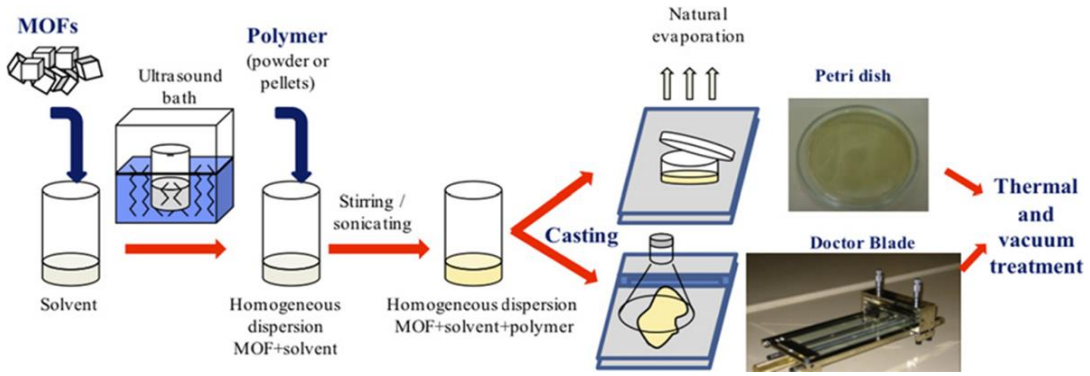



**Figure 3. Schematic diagram of flat sheet MMM synthesis. Reprinted from Microporous and Mesoporous Materials, 166, B. Zornoza, C. Tellez, J. Coronas, J. Gascon, F. Kapteijn, Metal organic framework based mixed matrix membranes: An increasingly important field of research with a large application potential, 67-78, Copyright (2013) with permission from Elsevier.**

Scale-up experiments are underway for the active MOF materials with some positive initial results; specifically, modifying synthesis conditions of ZIF-8 to increase yield while trying to maintain desired physical properties for membrane synthesis. Initial trials are also investigating solvent and ligand recycling for the synthesis of ZIF-8. Synthesis of membranes at lab scale has begun with extra focus on using scalable techniques. Polymers used for post

combustion have been dissolved using green solvents, and have been successfully adhered their support polymer.

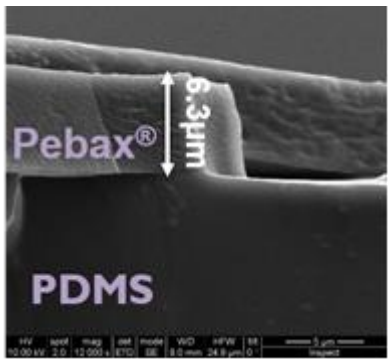



**Figure 4. SEM image of Pebax® adhered to support polymer. Reproduced with permission from University of Zaragoza.**

Initial batches of catalysts and sorbents have been made and testing is underway for the membrane assisted steam reforming application. Further optimisation of catalyst support and granulation has also started to achieve a fluidizable material. Overall, we are pleased with the status of the core materials scaling up work package and are progressing well to achieve a successful project.

## Membranes production scaling-up

Membrane production scaling-up is progressing according to the planned activities. The design for the scaling-up of the MMMs hollow fibers production for pre- and post-combustion $CO_2$ capture have been completed as well as the preliminary design for the new plating system for deposition of 8 Pd-Ag membranes per batch. The components for these new systems have been ordered and the system will be set up in the following months

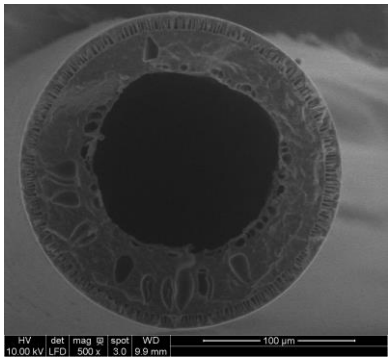


**Figure 5. PBI based dual layer hollow fiber membrane obtained at a take up rate of 50 m/min. Reproduced with permission from TECNALIA.**

Optimization of spinning parameters for dual layer PBI mixed matrix hollow fiber preparation has been started. The initial experiments were focused on obtaining a more

open substructure. A more open substructure with less resistance to gas flow gas obtained using an additive in the spinning dope. Furthermore, the use of the additive seems to be beneficiary to increase the as spun fiber elasticity and therefore reach industrially relevant take up rate values (>20 m/min). More spinning experiments are carrying out in order to further optimize the spinning parameters.

On the other hand, first metallic supported membrane for the lab-scale tests (Figure 6) has been delivered. This membrane has a $H_2$ permeance between 8.3 x $10^{-7}$ and 1.0 x$10^{-6}$ mol $m^{-2}$ $s^{-1}$ $Pa^{-1}$, and a $H_2/N_2$ ideal perm-selectivity between 23,000 and 47,000 at 400 °C and 1-4 bar $H_2$ pressure difference (Table 11), exceeding both the $H_2$ permeance and selectivity targets defined in MEMBER project for this type of membranes.


**Figure 6. Metallic-supported Pd-based membranes. Reproduced with permission from TECNALIA.**

In addition, the design of the modifications of the existing pilot plant for the recovery of the membrane supports from the Pd-based membranes has been also performed. Several Pd based membranes onto metallic supports has been also delivered for the first trials in lab-scale.

## Pilot prototypes design, construction and testing

The membrane systems for prototypes A and B are being modelled using the expected properties of the membrane materials. Various system layouts are reviewed, and properties varied. The modelling results show that a 90% $CO_2$ recovery can be achieved in combination with a high purity. With particular reference to Prototype A, different syngas cleaning scheme options have been reviewed in order to select the most suitable one to clean the syngas, making it compliant with a proper downstream membrane system operation.

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

## Environmental and economic assessment

The aim of WP7 is to perform an environmental LCA (Life Cycle Assessment) and economic assessment of membranes and sorbents that are used for pre- and post-combustion $CO_2$ capture. This will allow to understand and evaluate what environmental impacts and economic burdens are caused by the investigated systems related to their production, use and end-of-life. To further assess the advantages and challenges related to

the development of MEMBER's membrane systems, the results of the LCA and LCC will be compared with those of the current available technology on the market typically used for CCS. Further, by accompanying studying the developments and results of the other WPs, the objective is to steer the project towards the realisation of more environmentally friendly and affordable membrane systems by highlighting environmental hotspots along the value chain which may be optimised.

The first period of this project is being used for a comprehensive literature review of existing LCAs in the field of carbon capture and storage (CCS) technologies to have an overview of existing knowledge, type and magnitude of environmental impacts and reference systems.

# Highlights

### MEMBER Kick-off meeting

The Kick-off meeting was kindly hosted by TUE at TUE Office in Brussels (Eurotech Universities Alliance) on January the 17th 2018. 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 month 6 meeting

The second consortium meeting was hosted by University of Zaragoza in Zaragoza on July the 4th 2018. First achievements and project status and future activities inside each work package were discussed along reviewing the risks and action lists.

## 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/.

*Events:*

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 CO2 captuRe. 17th Aachener Membran Kolloquium. Aachen, Germany (November 14th – 15th, 2018). Poster.

3. Stefan Pouw, Fausto Gallucci, Martin van Sint Annaland. Membrane Assisted – SER: A process overview with CCR focused thermodynamic analysis. Hallway poster Chemical Engineering department to inform chemical engineering student about group projects. Technical University Eindhoven (The Netherlands). Poster

*Reports*

4. Industrial requirements.

## Upcoming events

| | |
|---|---|
| ***October 4-6, 2018*** | 5th World Conference on Climate Change, London (UK). https://climatechange.conferenceseries.com/ |
| ***November 14 – 15, 2018*** | 17th Aachener Membran Kolloquium, Aachen (Germany) https://conferences.avt.rwth-aachen.de/AMK/index.php?id=25 |
| ***December 4th, 2018*** | PROMECA workshop 2018: Membranes and Membrane Reactors, Eindhoven (The Netherlands). http://promecaproject.com/ |
| ***February 27 – 28, 2019*** | 12th Carbon Dioxide Utilization Summit, Houston (USA). https://www.wplgroup.com/aci/event/co2-us/ |
| ***March 20 – 21, 2019*** | 7th Conference on Carbon Dioxide as Feedstock for Fuels, Chemistry and Polymers, Cologne (Germany). http://co2-chemistry.eu/ |
| ***March 28 – 29, 2019*** | 21st International Conference on Carbon Capture and Storage Technologies (ICCCST 2019), Paris (France). https://waset.org/conference/2019/03/paris/ICCCST |
| ***April 24 – 26, 2019*** | 14th HYdrogen - POwer THeoretical and Engineering Solutions International Symposium (HYPOTHESIS XIV), Foz do Iguaçu (Brazil) http://www.hypothesis.ws/ |
| ***April 24 – 25, 2019*** | 6th World Conference on Climate Change and Global Warning, Vancouver (Canada) https://climate.conferenceseries.com/ |
| ***May 5 – 10, 2019*** | Tackling the Carbon Dioxide Challenge for a Sustainable Future. Carbon Capture, Utilization and Storage, Gordon Research Conference. Les Diablerets (Switzerland) |

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| | https://www.grc.org/carbon-capture-utilization-and-storage-conference/2019/ |
| ***May 5 – 8, 2019*** | 4th Green and Sustainable Chemistry Conference, Dresden (Germany) https://www.elsevier.com/events/conferences/green-and-sustainable-chemistry-conference/about |
| ***June 2 – 7, 2019*** | 8th World Hydrogen Technology Convention (WHTC 2019), Tokyo (Japan). http://whtc2019.jp/index.html |
| ***June 17 – 19, 2019*** | 10th "Trondheim Conference on $CO_2$ Capture, Transport and Storage, Trondheim (Norway). |
| ***June 16-20, 2019*** | 8th International Zeolite Membrane Meeting (IZMM2019), Lulea (Sweden). https://www.ltu.se/research/subjects/Kemisk-teknologi/Konferenser/IZMM2019?l=en |
| ***July 8-11, 2019*** | 14th International Conference on Catalysis in Membrane Reactors, Eindhoven (The Netherlands). https://www.iccmr14.com/ |
| ***July 15 – 18, 2019*** | Carbon Management Technology Conference (CMTC 2019), Houston (USA). http://fscarbonmanagement.org/cmtc/2019 |
| ***August 7 – 8, 2019*** | 21st International Conference on Carbon Dioxide Utilization and Sustainable Development (ICCDUSD 2019), Vancouver (Canada). https://waset.org/conference/2019/08/vancouver/iccdusd |
| ***September 9 – 11, 2019*** | 6th World Conference on Climate Change, Berlin (Germany). https://climatechange.insightconferences.com/ |
| ***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 |
| ***June 22 – 25, 2020*** | 23rd World Hydrogen Energy Conference (WHEC 2020), Copenhagen (Denmark) |
| ***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 |

**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/

## Acknowledgement:


This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 760944.


## Disclosure:

The present publication reflects only the author's views. The Commission is not responsible for any use that may be made of the information contained therein.