MemCCSea
Innovative membrane systems for $CO_2$ capture and storage at sea

# Final review report

## 1. Identification of the project and report

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|---|---|
| Project title | **Innovative membrane systems for $CO_2$ capture and storage at sea (MemCCSea)** |
| Project ID | 299690 |
| Coordinator | Dr George Skevis[1] |
| Project website | http://memccsea.certh.gr/ |
| Reporting period | 1/05/2021 – 31/10/2022 |

**Participants**

| Organisation | Main contact(s) + E-mail + Phone | Role in the project |
|---|---|---|
| Centre for Research & Technology Hellas/Chemical Process & Energy Resources Institute (CERTH) (Greece) | Dr George Skevis<br>gskevis@certh.gr<br>+30 2310 498143<br>Dr Akrivi Asimakopoulou<br>asimak@certh.gr<br>+30 2310 498245 | – Project coordination<br>– Laboratory scale experimental and demonstration campaigns<br>– Materials development<br>– Process optimization<br>– Techno-economic feasibility studies |
| DNV Hellas SA (DNV) (Greece) | Dr George Dimopoulos<br>George.Dimopoulos@dnv.com<br>Dr Chara Georgopoulou<br>Chara.Georgopoulou@dnv.com<br>+30 211 0003137 | – Marine case specifications<br>– Integrated system modelling<br>– Simulation and optimization<br>– Scale-up analysis<br>– System marinization |
| Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V./Fraunhofer Institute for Ceramic Technologies and Systems (IKTS) (Germany) | Dr Hannes Richter<br>hannes.richter@ikts.fraunhofer.de<br>+49 36601 9301-1866 | – Development of hydrophobic ceramic membrane contactors and ceramic membranes for direct $CO_2$-separation<br>– Membranes preparation and characterization in experimental test campaign<br>– Contribution in techno-economic feasibility studies |

[1] According to the unanimous decision of the consortium on November 2022, Dr. Akrivi Asimakopoulou, Collaborating Researcher in CERTH, became Coordinator of the project after November 8th, 2022 when Dr Skevis started his leave of absence.

Accelerating CCS Technologies

MemCCSea project (Project ID 299690) is funded through the ACT programme (Accelerating CCS Technologies, Horizon2020 Project No 294766). Financial contributions made from GSRT (GR), BMWi (DE), RCN (NO) and DoE (USA) are gratefully acknowledged.

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|---|---|---|
| National Energy Technology Laboratory (NETL)<br>(USA) | Dr David Hopkinson<br>David.Hopkinson@netl.doe.gov | − Polymeric membrane preparation<br>− CFD & multiphysics simulations to optimize the geometry and operating conditions of a hollow fiber module for carbon capture |
| Norges teknisk-naturvitenskapelige universitet (NTNU)<br>(Norway) | Prof Solon Oikonomopoulos<br>solon.oikonomopoulos@ntnu.no<br>+47 73559966 | − Synthetic aspect for active materials for $CO_2$ capture<br>− Membrane surface modification and graphene/graphene oxide coatings for highly efficient $CO_2$ capture<br>− Contribution in techno-economic feasibility studies |
| DBI Gas- und Umwelttechnik GmbH (DBI)<br>(Germany) | Mr Udo Lubenau<br>Udo.Lubenau@dbi-gruppe.de<br>+49 341-2457160 | − Lab- and semi-pilot scale membrane characterization<br>− Engineering of membrane pilot plant<br>− Participation in the marinized pilot testing<br>− Collaboration for process modelling of advanced membrane systems for techno-economic analysis |

## 2. Short description of activities and final results

Activities performed in the frame of the MemCCSea project during the current reporting period and the relevant final technical results are presented in this section. The presentation is structured as per work package and at overall level.

**WP1: Definition of process requirements and specifications**

The activities undertaken within WP1 aimed at addressing the specific objectives of the work packages which are summarized as follows:

(1) Definition of the marine environment specifications and the case studies to be assessed (i.e. design, operational conditions, applicable constraints) (Task 1.1)

(2) Assessment of $CO_2$ storage options onboard (Task 1.1)

(3) Review the membrane-based $CO_2$ capture technologies (Task 1.2)

WP1 Achievements:

- Actions related to the specifications of the CCS system ship integration and the identification of recent developments in membrane-based technologies in post-combustion $CO_2$ capture from flue gases have been completed.
- The case ship is defined. Operational profile is analyzed and typical routes are developed. Machinery specifications are defined, including potential onboard sources of power and heat for the CCS system. $CO_2$ storage possibilities have been explored based on experience, including liquefaction, or potential overboard release (this is questionable in terms of the regulatory framework). Data on exhaust gas stream properties have been also gathered.
- A review of commercial/conceptual projects involving on-board $CO_2$ capture technologies and solvents choice (membrane-based vs scrubber/stripper) systems has been performed focusing specifically on the effect of seawater and exhaust gas composition on the capture process and on the constraints imposed by marine environmental issues on storage options. A common publication/review paper on these outcomes has been published in an open-access journal[2].
- A comprehensive solvent assessment program has been finalized that includes experimental assessment of membrane performance of selected solvents (WP3), numerical evaluation of selected solvents performance under relevant conditions (WP4) and hazard identification analysis (WP5).

**Deviations from the Work Plan**: In all Tasks of WP1, no deviations from described work plan in the proposal have been occurred and all Deliverables were submitted on time.

**WP2: Materials development**

The WP2 objectives, set in the beginning of the project, are summarized as following:

(1) Development of ceramic membrane contactors (Task 2.1)

(2) Development of polymeric based membranes (permeators) (Task 2.2)

(3) Development of novel carbon nano-based materials as fillers for MMM to facilitate $CO_2$ capture at defined process conditions and selected environments (Task 2.3)

WP2 Achievements:

[2] Damartzis, T.; Asimakopoulou, A.; Koutsonikolas, D.; Skevis, G.; Georgopoulou, C.; Dimopoulos, G.; Nikolopoulos, L.; Bougiouris, K.; Richter, H.; Lubenau, U.; Economopoulos, S.; Perinu, C.; Hopkinson, D.; Panagakos, G. Solvents for Membrane-Based Post-Combustion $CO_2$ Capture for Potential Application in the Marine Environment. Appl. Sci. 2022, 12, 6100. https://doi.org/10.3390/app12126100

- Novel functionalized materials (i.e. porous ceramic, carbon and graphene-based hybrid materials) for $CO_2$ separation systems have been synthesized.
- Concerning the gas-liquid membrane contactor application, porous ceramic membranes have been treated with hydrophobic/superhydrophobic agents (e.g. organosilanes) and Liquid Entry Pressures (LEP) up to 12 bar have been achieved.
- Scaled-up ceramic capillary bundles with hydrophobization and LEP of 2 bar
- Concerning the gas permeator application, functionalized graphene has been successfully dispersed in ethanol (EtOH) and added to aqueous PVAm. Polyvinylamine/Graphene–Mixed Matrix Membrane (MMM) (i.e. PVAm/graphene and PVAm/piperazine) has been synthesized and characterized based on gas separation properties (selectivity and permeability).
- Very high flux and selectivity was achieved with thin film PVAm/piperazine composite membranes.
- Novel fully water-soluble graphene derivative was developed.

**Deviations from the Work Plan**: In all Tasks of WP2, no deviations from described work plan in the proposal have been occurred and all Deliverables were submitted on time.

**WP3: Definition of process requirements and specifications**

The aim of this WP is to consolidate most of the activities performed in the framework of WP1 and WP2 and proceed with the experimental evaluation of membranes and processes. WP3 is structured in two tasks

(1) Initial evaluation of membrane performance (Task 3.1)
(2) Ashore pilot testing of the marinized units (Task 3.2)

<u>WP3 Achievements:</u>

- Test protocols for the experimental evaluation have been set up defining boundary conditions (pressure, temperature). Gas separation properties have been measured for several membranes.
- Carbon membranes for direct $CO_2$ capture by gas separation were prepared by IKTS (ceramic tubes, single channel geometry) and delivered to DBI (see WP2).
- Conditions of mixed-gas permeation tests (feed composition, gas stream, feed and permeate pressure, temperature, methods of analysis) were established between DBI and IKTS.
- Gas separation measurements have been conducted at DBI.
- Surface modified ceramic membranes prepared (IKTS) and various other commercial membrane materials for $CO_2$-absoprtion have been evaluated as potential membrane contactors (CERTH, DBI).
- In membrane contactor applications, several absorption solvents have been evaluated and respective solvent regeneration studies under various have been conducted (CERTH).
- Construction and of the ashore pilot unit has been completed and pilot operation has been demonstrated (CERTH).

**Deviations from the Work Plan**: In all Tasks of WP3, no deviations from described work plan in the proposal have been occurred and all Deliverables were submitted on time.

**WP4: Process modelling of advanced membrane systems and performance assessment**

The WP4 objectives can be summarized as follows

(1) Modelling of transport processes and mechanisms in ceramic membranes for gas-liquid system separation (Task 4.1)
(2) Modelling of transport processes and mechanisms in gas membranes permeators without and with facilitated transport (Task 4.1)
(3) Gas-liquid membrane contactor module ship board integration (Task 4.2)
(4) Model based assessment and optimization of the marinized system (Task 4.2)

WP4 Achievements:

- Process model for gas-liquid membrane contactors has been extended and a computational strategy for scaled-up shipboard integration of membrane modules has been established with preliminary estimates of space and energy requirements.
- Models of facilitated transport (FT) membranes have been developed in 1D considering the effect of $CO_2$ partial pressure developed, membrane thickness, carrier concentration, equilibrium constant, relative humidity and temperature on permeance. The 1D models lead often to analytical results leading to equivalent resistance calculations and have been extended to 2D and 3D models, which are solved numerically leading to concentration profiles and accurate mass-transfer calculations. A trained MS student on multi-physics modeling in Comsol and in 1D models for facilitated transport membranes.
- A derived overall mass transfer coefficient and a regression-type model for $CO_2$ removal have been developed.
- Establishment of system-level models using actual information for the baseline model. A roadmap for connecting the system-level model and the more detailed models of the ceramic and the FT membranes has been conceptualized and realized.
- A baseline LNG fuel cargo ship baseline simulation model including assessment and comparison of available gas (dual fuel) main engines and calculation of exhaust stream flow rate and emissions content has been completed.
- Energy demand and emissions mitigation calculations for different scenarios. Techno-economic assessment of vessel operation and feasibility study of on-board CCS system for optimal marinized system.

**Deviations from the Work Plan**: In all Tasks of WP4, no deviations from described work plan in the proposal have been occurred and all Deliverables were submitted on time.

**WP5: Market analysis and hazard identification analysis**

The aim of this WP is to conduct technical, environmental and economic related studies to determine the feasibility, the environmental benefits, and the overall prospects of the specific technology to be launched into the marine environment and other marketplace.

The WP5 objectives can be summarized as following:

(1) Techno-economic analysis (Task 5.1)

(2) Marinization of the advanced membrane CCS system (Task 5.2)

(3) Connection with other post-combustion $CO_2$ capture applications (Task 5.3)

WP5 Achievements:

- Baseline vessel model completed.
- Definition of specifications for membrane model connectivity with the DNV COSSMOS model.
- Energy demand and emissions mitigation calculations for different scenarios have been set up.
- Techno economic assessment of vessel operation and feasibility study of an on-board CCS system for optimal marinized system has been conducted.

**Deviations from the Work Plan**: A deviation from described work plan in the proposal has been occurred in Task 5.3 “Connection with other post-combustion $CO_2$ capture applications” (Task 5.3) so the Deliverable D5.3 “Report about other potential applications of the developed technology” was not submitted.

**WP6: Coordination, management and dissemination**

This WP gathers all activities related to the management and scientific coordination of the project. Moreover, it includes activities for the communication of the project's results to relevant stakeholders (scientific community, shipping companies, maritime industry, opinion-makers, etc.) through workshops, publications, conference presentations etc.

WP6 Achievements:

- Grant Agreement (GA), Consortium Agreement (CA), Non-Disclosure Agreement (NDA) and all National Grant Agreements (NGA of Greece, Germany, Norway, USA) that have been signed.
- Project coordination activities performed in a timely fashion (Traffic Light Reports submitted, Kick-off (in-person), 6M (virtual), 12M (virtual), 18M (virtual), 24M (virtual), 30M (in-person), 36M (in-person) meetings completed, Deliverables completed).
- Communication between partners through several actions (Data Repository has been set at USA partner facilities, Monthly WP2 and WP4 technical meetings).
- Project website (http://memccsea.certh.gr/) and social network accounts (Twitter, LinkedIN) up and running on time and after the completion of the project.
- Project Final Dissemination Event organized with great success in Athens, 14 October 2022, with active participation from ACT coordinator and representatives from National Funding Agencies (Germany, Greece).
- Project results have been published in international journals and presented in conferences world-wide. MemCCSea project has been presented in scientific, technical and policy fora.

**Deviations from the Work Plan**: A 6M extension based on Consortium unanimous decision, requested by ACT Secretariat and National Funding Agencies due to COViD-19 pandemic effects, was approved and the project total duration of 30 months was extended to 36 months.

## 3. Project impact

### *Contribution to the facilitation of the emergence of CCUS*

Carbon capture is one of the few viable options for the decarbonization of the shipping industry. The introduction of alternative, renewable propulsion technologies, such as Wind-Assisted Propulsion (WAP) or operational measures, such as weather routing or slow steaming, are very much dependent on externalities (such as weather) and can at best contribute to marginal reductions in the overall carbon emissions. Alternative fuels (including e-fuels, such as e-methanol, liquid biofuels, ammonia and hydrogen) can in principle lead to near zero carbon emissions but they are currently at a very early stage of application as they are limited by (a) the limited availability of green hydrogen that will make them truly sustainable, (b) the limited availability of bunkering infrastructure and (c) the need for significant engine and overall ship energy system modifications. Electrification through the use of batteries or fuel cells is generally limited to short sea shipping and auxiliary small boats mainly due to their low specific power, need for frequent recharging and safety concerns. Further, CCS is very attractive as a retrofit solution as it does not require significant modifications in the ship powertrain and is largely fuel agnostic.

The introduction of a specific carbon capture technology is limited by the on-board space availability both for the capture unit and the storage of captured carbon. The MemCCSea-developed MGA technology requires almost an order of magnitude less space compared to the more traditional absorption-desorption technologies and as such it is ideal for on-board integration. Therefore the MGA technology will make the adoption of carbon capture more appealing to the maritime sector and as such will facilitate the overall penetration of CCUS.

Overall the shipping industry is a major contributor to GHG emissions. Currently, global $CO_2$ emissions from shipping are estimated at almost 900 Mt/yr and constitute almost 3% of the total GHG emissions[3,4]. In the EU the maritime sector contributes almost 14% of the total carbon emissions – calculated as emissions from intra-EU trade of by non-EU ships entering EU waters. These emissions are expected to rise significantly in the next decades both in absolute numbers (as world trade intensifies) and as a percentage (as the energy and heavy industry sectors decarbonize rapidly). This will naturally increase the need for on-board carbon mitigation technologies and will have a multiplicative effect in the penetration of CCUS.

### *Strengthen the competitiveness and growth of European companies*

Shipbuilding has moved away from Europe. Currently, the EU shipbuilding sector has a market share of only around 6% in terms of tonnage[5]. However, the EU is leading the market in key specialized equipment including marine engines. The adoption of CCS technology by EU-based shipping companies mainly through retrofitting of existing vessels will clearly have a positive effect on the growth of European shipyards. Solutions like MGA will require specialized, high added value industry for key components (membrane, solvents) and system integration. Further, EU owned or operated vessels fitted with CCS systems will be better positioned to secure higher freight rates and thus contribute to increased competitiveness of the EU shipping sector.

### *Other environmental or socially important impacts, such as public acceptance*

Public acceptance of CCS technologies may be harder than it appears. Although $CO_2$ is definitely benign it is perceived as (and legally is!) a waste. Recent studies in the frame of the NFR CLIMIT projects

[3] European Maritime Safety Agency & European Environment Agency, European Maritime Transport Environmental Report 2021

[4] CE Delft, Update of maritime greenhouse gas emission projections, Report 2019

[5] Shipbuilding sector (europa.eu)

PerCCSeptions[6] and CCSMARKET[7] have pinpointed the following issues that present barriers to CCS public acceptance: hard to understand (science-fiction), worries that CCS will slow energy transition, worries about leakages from storage and transportation, worried about costs. Concerning the rest of MemCCSea partners' countries, public acceptance of Carbon Capture and Storage (CCS) technologies in the USA was mixed and often influenced by various factors. CCS involves capturing carbon dioxide (CO2) emissions from industrial processes and power plants and storing them underground to mitigate climate change. Public acceptance can vary based on the following factors: and Greece public acceptance. Finally in Greece, many people may not be familiar with the concept of CCS or may have misconceptions about its safety and effectiveness, even though Greece's commitment to reducing greenhouse gas emissions and transitioning to cleaner energy sources has already started (Energy Transition Goals) and the state should shape public views on CCS as a potential tool to achieve these goals.

Overall demonstrations projects with strong dissemination activities, such as MemCCSea, will help to familiarize the general public with the details of the CCS process and promote the advantages and long-term benefits of the technology as a powerful tool against climate change.

### *Chances for commercializing the technology further*

The potential of commercializing CCUS technologies, in general, and MGA, in particular, in the maritime sector is huge. There are currently more than 58,000 merchant vessels worldwide with an annual increase rate of more than 5%. However, more than 90% of them has no Energy Saving Devices installed on-board, more than 85% requires improvements to become EEXI[8] compliant and a significant fraction ranging from 50% (for LNG carriers) to more than 80% (for bulk carriers) will require an operational change or improvement to stay within A, B or C Class of CII[9]. This opens up the possibility of extensive commercialization of the CCS technologies. ABS has estimated that the annual global capacity for off-shore CCS will increase to 200 Mt/yr in 2030 up to 1250 Mt/yr in 2050[10].

This will be reflected to the MemCCSea-developed MGA technology that offers significant advantages for shipboard integration. The technology, currently at TRL 5, will be further developed, through appropriate land-based and off-shore pilot projects, to TRL 7 and expected to reach commercial level in less than 5 years from project completion.

### *Gender issues*

Shipping is a male-dominated sector although recently the percentage of women in the workforce is growing. Today women represent only 1.2% of the global seafarer workforce, however this represents a more than 45% rise compared to 2015[11]. Barriers to entry have included working conditions that alienated the female workforce. The quest towards decarbonization expands the knowledge base required in the sector (e.g. process engineers, digitalization, R&D) making careers in shipping more attractive to women. Projects such as the MemCCSea can contribute in catalyzing this transition by presenting a more female-friendly aspect of the maritime industry.

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[6] Public perceptions of carbon capture and storage - Norce (norceresearch.no)

[7] Does the nationality of CO2 matter? Public perceptions of a Northern European market for CO2 storage (CCSMARKET) - Norce (norceresearch.no)

[8] The Energy Efficiency Existing Ship Index (EEXI) measures $CO_2$ emissions per transport work, by only considering the ship's design parameters.

[9] The Carbon Intensity Indicator (CII) is an operational index which measures all the carbon emissions divided by the deadweight and the distance sailed in a year (grams of $CO_2$ per deadweight-tonne-mile). Ships are grouped into different CII ratings, ranging from A to E. The most environmentally friendly receive an A rating, while the highest polluters are rated E.

[10] ABS (2022) Zero Carbon Outlook: Setting the Course to Low-Carbon Shipping

[11] Women in Maritime (imo.org)

## 4. Implementation

The implementation of the MemCCSea project results is in line with the SET Plan Implementation Action #9 on CCUS and the Mission Innovation Zero-Emission Shipping Mission. MemCCSea has also successfully engaged industrial participation at different stages in its work.

The updated EU CCUS SET-Plan identifies the importance of R&D activities for the deployment of CCUS. The original CCU and CCS implementation plan had identified and quantified 10 strategic targets critical for the implementation of the EU CCUS strategy[12]. These targets have been updated and intensified in the most recent version of the SET-Plan. Target 6 in particular sets a goal of "*At least 3 pilots on promising new capture technologies, and at least one to test the potential of sustainable Bio-CCS at TRL 6-7 study*". The SET-Plan has also identified R&I activities required to deliver the stated targets. R&I Activity 6 focuses in the development of next-generation $CO_2$ capturing technologies which explicitly include membrane-based separation technologies. The expected deliverables of the specific activity (a capture rate of 90% or more and a 30% reduction in CAPEX and non-fuel OPEX) have been demonstrated by the results of the MemCCSea project. A further objective of Target 6 is "*Pilots of emerging technologies tested at TRL5-7 and fitted to work with flue gas or boundary conditions, as present in large non-power industries*". This is precisely the longer-term goal of the MemCCSea consortium: A pilot scale demonstration of the MGA technology on-board ship using realistic marine exhaust conditions (TRL 7).

Mission Innovation (MI) is a global initiative catalysing a decade of action and investment in research, development and demonstration to make clean energy affordable, attractive and accessible for all and accelerating pathways to net zero. MemCCSea project results are directly relevant to Zero-Emission Shipping Mission which aims to demonstrate commercially-viable zero-emission ships by 2030. The deployment of the modular and compact MGA technology on-board ships is a viable possibility and can be realized by the middle of the decade thus contributing significantly to the Mission goals.

Industrial participation was achieved at the highest level, from the maritime (DNV) and industrial gas separation (DBI) sectors. This has ensured that the scientific and technological advancements of the project could be directly transferred to the respective sectors. The participation of EURONAV, the leading crude oil tanker shipping company worldwide, has been crucial for providing specifications for technology integration on-board ships and assessing the techno-economic feasibility and deployment potential of the proposed solution. The innovative MGA technology developed by CERTH within the MemCSea project will be further optimized towards industrial deployment by utilizing additional funding secured from Horizon Europe research projects and private service contracts. The participation of academic/research partners in related industrially-driven research projects (e.g. the RECODE project, CERTH) ensures further exposure and potential commercialization of the MemCCSea technologies to diverse industrial applications (e.g. cement, lime industries). Advanced materials and membranes can be commercially exploited by IKTS, NTNU, NETL, CERTH, either directly or through specialized spin-offs.

[12] Home - IMPACTS9 (ccus-setplan.eu)

## 5. Collaboration and coordination within the Consortium

A solid frame for the coordination of research activities has been setup early in the project in order to ensure the protection of knowledge generated within the consortium, the efficient flow of information and resources among partners and the communication between the Project Coordinator and the ACT Secretariat.

A Consortium Agreement has been signed between the European partners of the project (CERTH, DNV, IKTS, NTNU, DBI) and a separate Non-Disclosure Agreement (NDA) has been signed by NETL and all other partners.
The MemCCSea website (memccsea.certh.gr) has been established early in the project (M3) and serves both as a repository of publicly-available information on the project results and dissemination activities. A repository for documents has been implemented as a key tool for exchanging information within the consortium and for supporting the management of the project. The access to the repository is obtained only with credentials provided by the project coordinator (CERTH) to the members of the consortium. These credentials are used to access private area through the "Partners Area" section. CERTH is solely responsible for editing (e.g. upload, delete) the material and files of the private area. However, all members of the consortium are able to freely browse and download material. In case any member desires to upload or edit material needs to contact with info.memccsea@certh.gr. If needed, material edit privileges can be provided to any member. The files of this repository are stored in a server owned by CERTH.
The private area structure is visualized in Figure 3.1 and divided into the following folders:

- Useful Files
- Meetings
- Templates
- Proposal /DOW
- Official Documents and
- Promotional material

In "Useful Files" many widely used files are included. Here, anyone can find the various MemCCSea logos that have been created for all uses, partner and funding agency logos, the official acknowledgement text, etc.

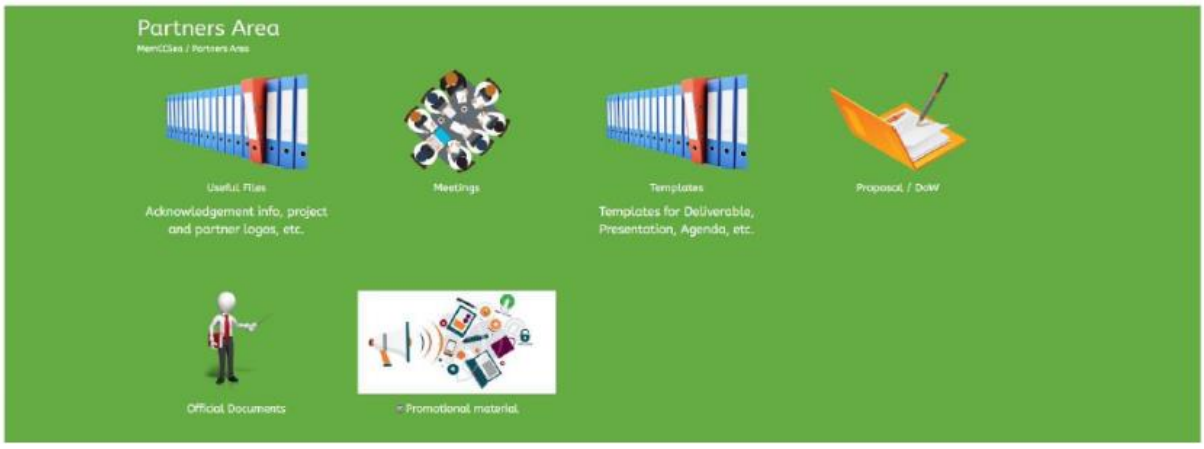


**Figure 5.1:** "Partners Area" structure in MemCCSea official website.

In "Meetings" folder there all the information and files of the meetings that have been held, such us the meeting agenda, presentations and family photos. The templates created for project documentation to ensure common appearance of all documents are stored in "Templates" folder. More specifically, templates for deliverables, agenda, presentation, participants list and minutes are available in "Templates". The files created during the proposal of the MemCCSea project are in "Proposal / DoW" folder, while consortium and grant agreement can be found in "Official Documents" folder. Finally, in "Promotional material" any partner member can download posters, videos and other

dissemination material created for the MemCCSea project. The structure and material of the Partners private area is possible to be updated / altered anytime during the project.
Detailed description of the project website is provided in the **Deliverable D6.5 "Project website set-up and electronic communication networks establishment"**.
Working group technical meetings have also been established and convene regularly (mostly monthly). A Simulation Working Group has been established with the participation of CERTH, DNV and NETL with regular meetings the last Friday of each month. An Experimental Working Group among WP2 partners has similarly been established for coordinating work in materials development. A repository of technical and scientific information of activities related to modelling, simulation and marinization has been established by NETL with the participation of CERTH and DNV.

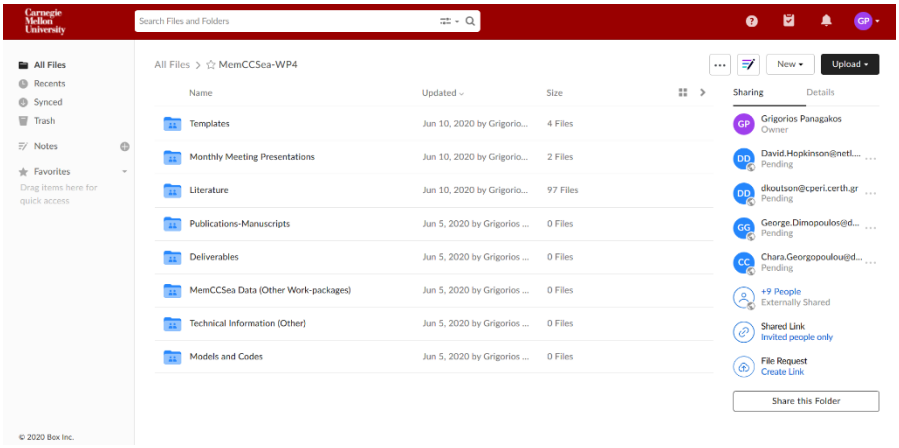


**Figure 5.2:** WP4 Repository established by NETL

The MemCCSea project is characterized by its international character spanning two continents and 5 countries. This is of particularly added value as the shipping industry has a truly international character and technical solutions and regulations are not confined to single country or even continent. Note here that the MemCCSea countries are the leaders of the shipping industry worldwide. Further, carbon capture and storage also involves transnational collaboration mainly stemming from the need to optimally match $CO_2$ production, transportation and eventual storage.

## 6. Dissemination activities (including list of publications where applicable)

In order to disseminate the concept, the goals and the objectives of the MemCCSea project, as well as the scientific results of the project achieved so far, several actions has been accomplished by the Coordinator and the whole Consortium, despite the difficulties that arose due to the COVID-19 pandemic and resulting deviations in dissemination activities compared to the Description of the Work. Firstly, the **Communication, Dissemination and Exploitation plan** (Deliverable D6.4) was completed in the first reporting period, in which an overview of measures adopted by the consortium to ensure effective communication of the project and dissemination of its results is provided.

The **MemCCSea Project logo** (Figure 6.1) for the single and uniform visual image of the dissemination and publicity actions has been produced.


**Figure 6.1:** MemCCSea project Logo designed for various uses

The **MemCCSea project public website** (Figure 6.2) is available at the following link: http://memccsea.certh.gr/. It has been established early in the project (M3) and is constantly updated. The project website serves as a key tool for internal and external communication and knowledge transfer. This website is composed of a public and private section. The MemCCSea public website is the main source of information and contact point for parties and stakeholders interested in the project background and results. It is one of the key tools of the project communication and dissemination strategy. As such, the website targets the research community, industrial stakeholders as well as the general public. The website provides updated information on main project activities and achievements, as well as comprehensive information about the universities, research centres, SMEs and industrial

partners taking part in the action. As mentioned before, the private area designed and found as "Partners Area" serve as a working space for internal consortium collaboration and documents distribution. Further details can be found in **D6.5 "Project website set-up and electronic communication networks establishment"**.


**Figure 6.2:** Snapshots of the public website of project MemCCSea.

**Social network** (Twitter) account and professional network account (LinkedIN) have been set up and operates (M3) (Figures 6.3 & 6.4). There are numerous posts for MemCCSea project and its events on social media and at websites to make the actions known, not only to those who are interested in such topics, but also to the general public. Also there are 15 reposts on LinkedIn for the MemCCSea project from other users and 1089 hits at the website that designed for the project.

Project ambitious concept and results have presented in the official **CERTH Newsletter** (issue February-March 2021) in Greek and English versions (Newsletter - No 28 / 2021 (certh.gr)). CERTH newsletter is released every two months and disseminates important scientific results of CERTH research groups to a wide research, scientific and relevant stakeholders' network (Figure 6.5).

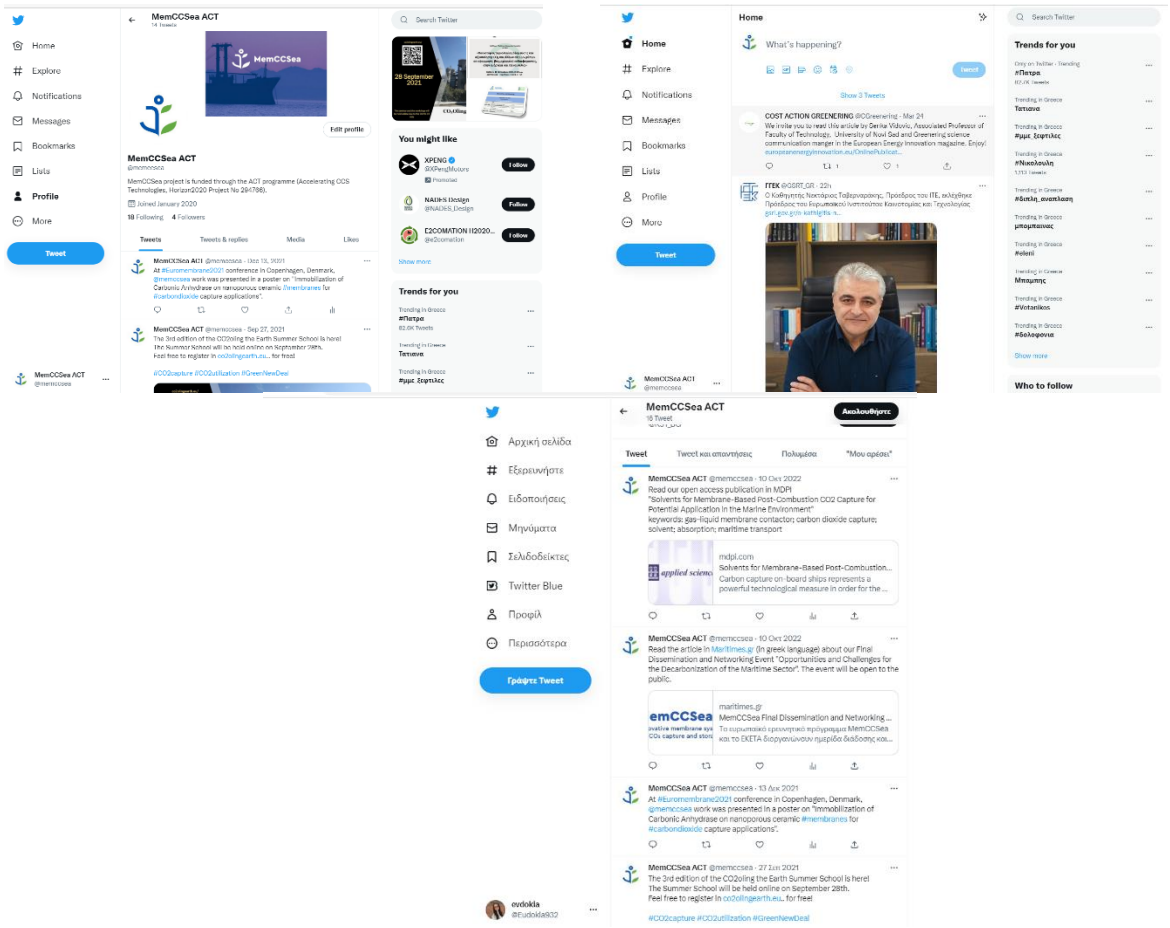


**Figure 6.3:** Twitter account of MemCCSea project (screenshot at 10-7-2023)

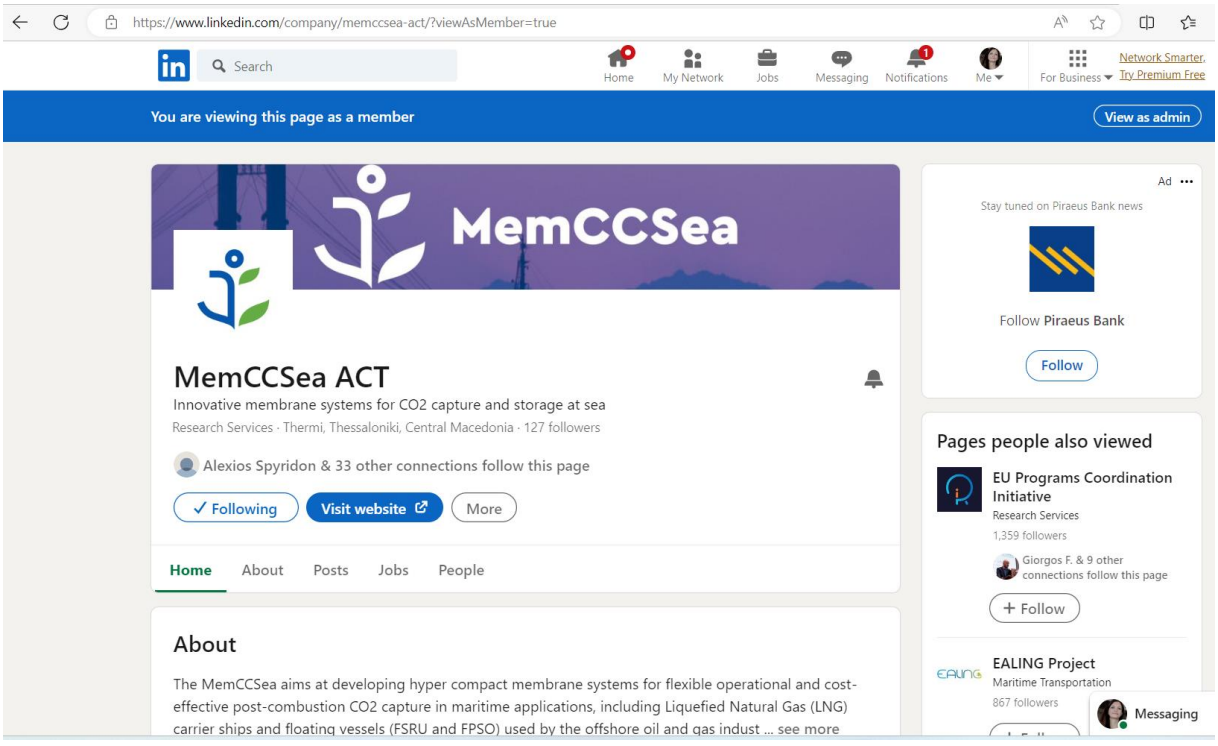


**Figure 6.4:** LinkedIN account of MemCCSea project (screenshot at 10-7-2023)

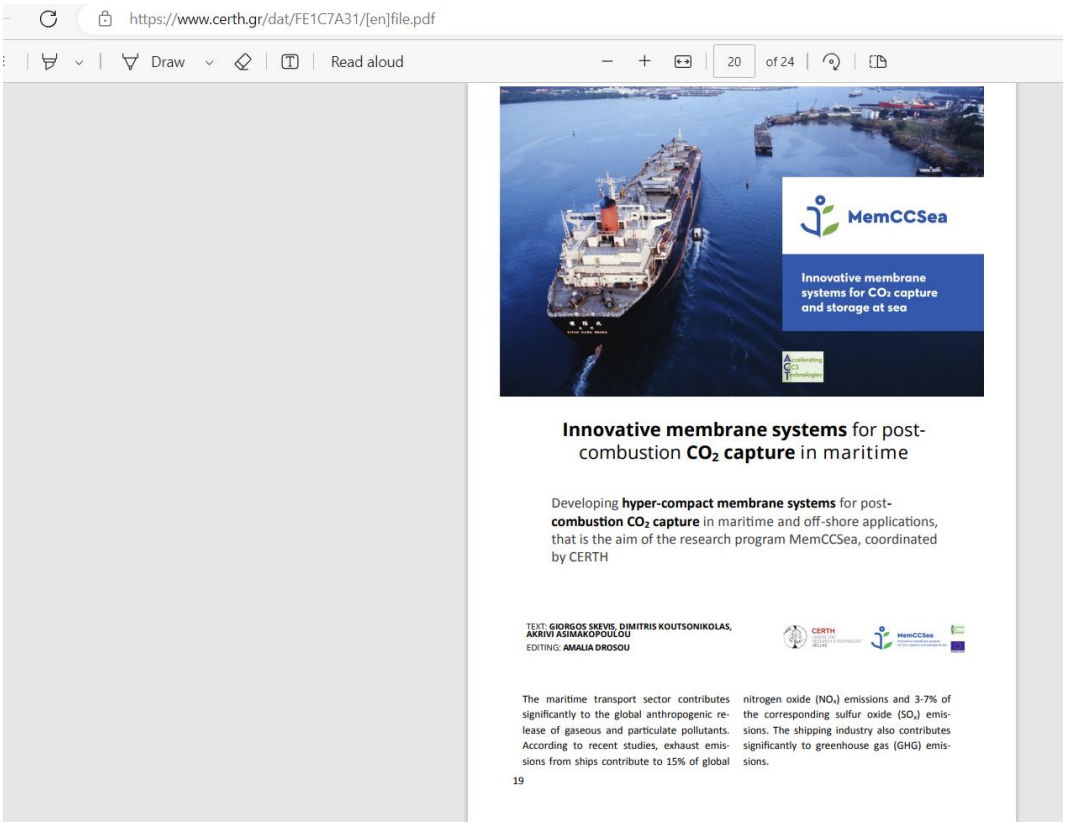


**Figure 6.5:** Presentation of the MemCCSea project in the official **CERTH Newsletter** (issue February-March 2021) in Greek and English versions.

In the framework of the **85th Thessaloniki International Fair**, the Center for Research and Technology Hellas (CERTH) organizes a round table discussion on "Innovative technologies for $CO_2$ capture and utilization in the energy, marine and industrial sectors "on Friday, September 18 2021, at 7 pm, at the stand of the General Secretariat for Research and Innovation (GSRI) (Figure 6.6). The following discussion presented experience gained in the context of the MemCCSea and other research projects, which partially sponsor the event. Given the COVID-19 restrictions, attendance of the event was restricted and a strict sanitary protocol was followed. In the same venue (Pavilion 7, GSRI stand) and throughout the 85th TIF, visitors were immersed in the virtual reality exhibition of $CO_2$ capture under realistic ship conditions (MemCCSea version of Ship VR) (Figure 6.7).

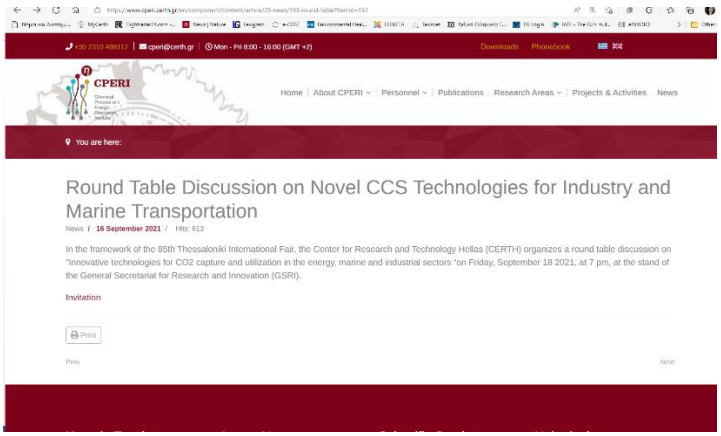



**Figure 6.6:** Presentation of the MemCCSea event at 85th Thessaloniki International Fair through website of CERTH/CPERI Coordinator (screenshot at 29-3-2022)


**Figure 6.7:** Snapshot from the use of the tool Ship VR and instant image from the inside of the ship

Project coordinator has presented the MemCCSea project in ACT 6th Knowledge Sharing Workshop on 9-10 June 2022, in Rotterdam, Netherlands and also participated in the roundtable discussion organized on CCUS Conference Rotterdam about the technologies developed within ACT projects.


**Figure 6.8:** Snapshot from CERTH participation in CCUS Conference, on 9-10 June 2022, Rotterdam, Netherlands.

The **Final dissemination and networking event** was organized in Athens on 14/10/2022 on the Opportunities and Challenges for the Decarbonization of the Maritime Sector. The event aimed to present the key project results to a wider audience while providing a forum for discussion on the technical, environmental, financial and societal aspects of integrating CCS and other decarbonization technologies in the shipping sector. The event took place in the Stavros Niarchos Foundation Cultural Centre in Athens and was open to the public. High participation (~100 participants) has been achieved Dr George Skevis, Principal Researcher in CERTH, Dr Chara Georgopoulou, Senior Engineer - DNV Maritime R&D and Advisory in Greece, Dr Akrivi Asimakopoulou, fellow Researcher in CERTH and Solon Oikonomopoulos, Associate Professor, Department of Chemistry in the Faculty of Natural Sciences - NTNU spoke about the development of new decarbonization technologies, being developed in Greece, which are applicable to the shipping sector. The Interviews are published in maritimes.gr in Greek language. In addition, a radio interview was given by Dr. A. Asimakopoulou (in Greek) in Channel One of Piraeus on the highly impactful results of the MemCCSea project. All related material is available on project's website.





**Figure 6.9:** Snapshots from the MemCCSea Final dissemination and networking event that took place in Athens, Greece on 14/10/2022.

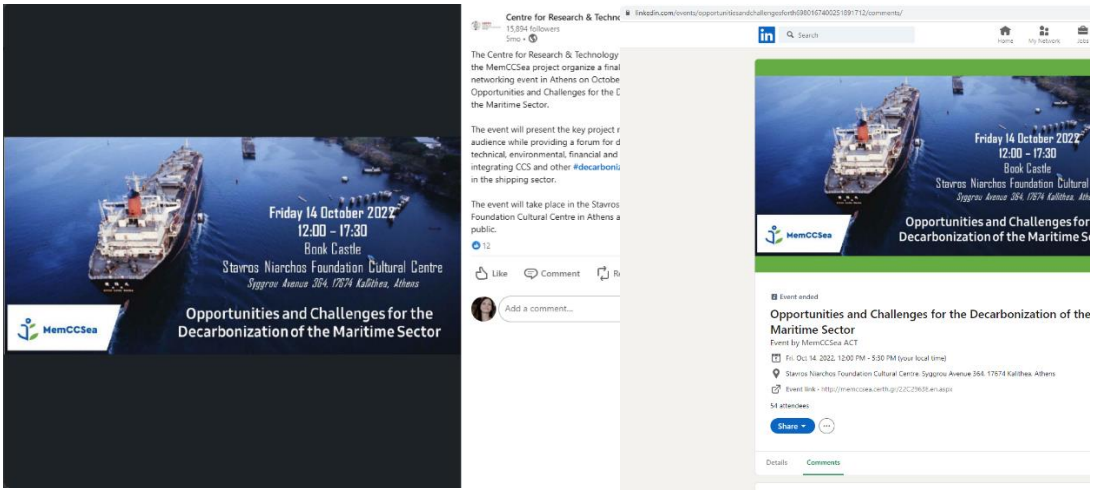


**Figure 6.10:** Posts on LinkedIn to the accounts of Centre for Research & Technology Hellas and of MemCCSea project (screenshot at 10-3-2023)


**Figure 6.11.:** Posts on Facebook by official account CERTH (screenshot at 10-3-2023).

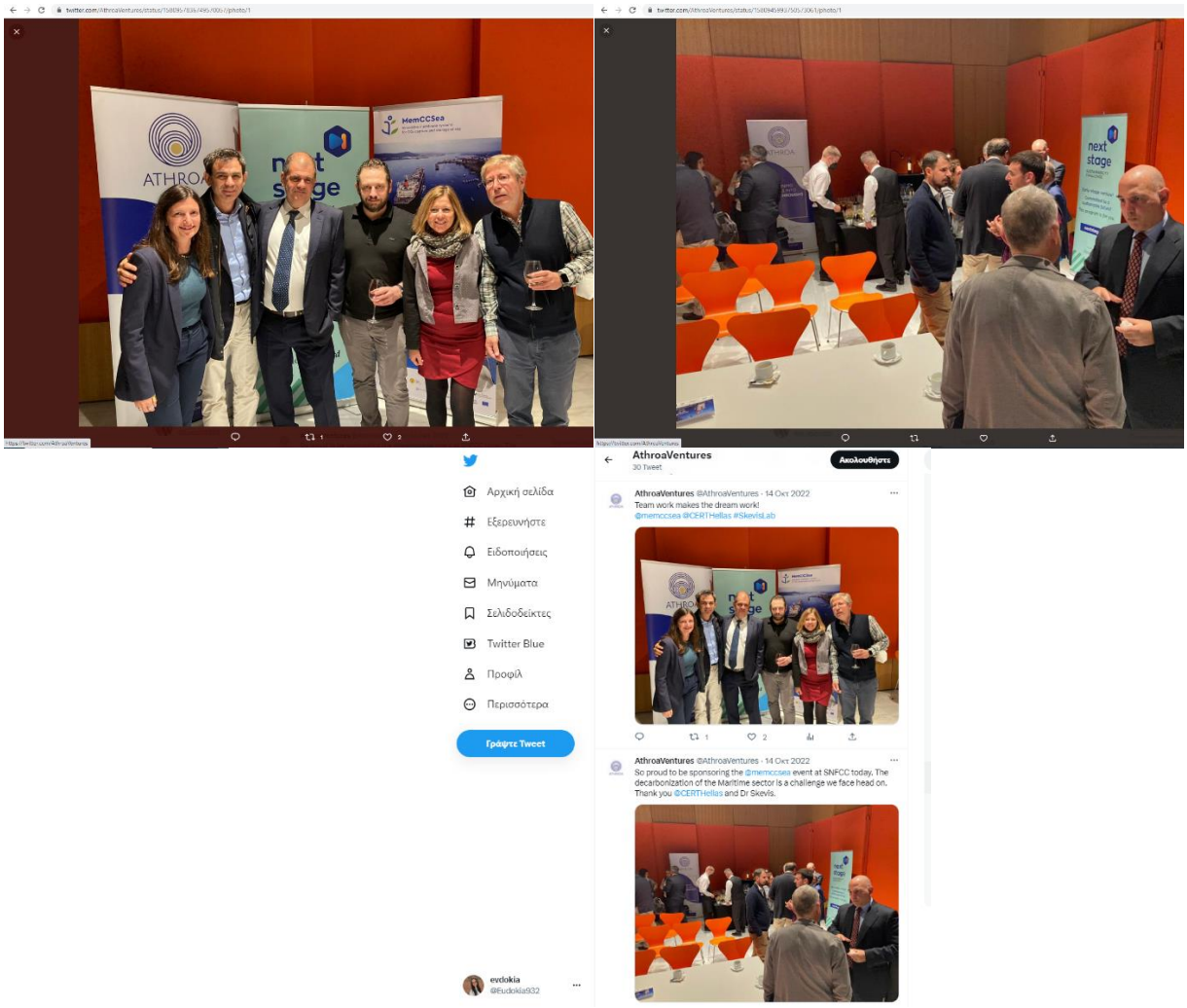


**Figure 6.11:** Posts about MemCCSea Final Dissemination Event on Twitter in other accounts

Finally, the full list of publications and dissemination activities is presented below, which are also available on the project website, and project social media.

**List of publications and dissemination activities**

| | Type of publication | Author | Title | Reference | Date | Partners involved | Others |
|---|---|---|---|---|---|---|---|
| **1.** | **Oth (Website post)** | Udo Lubenau (DBI) | Verbundvorhaben MemCCSea - Innovative Membransysteme für die $CO_2$ Separierung und Speicherung auf See (https://www.dbi-gruppe.de/files/PDFs/Projekte/31_Projektsteckbrief_MemCCSea_03EE5019B.pdf)<br><br>*Linkage to MemCCSea project: Presentation of project concept and goals* | https://www.dbi-gruppe.de/files/PDFs/Projekte/31_Projektsteckbrief_MemCCSea_03EE5019B.pdf | 6/9/2019 | CERTH, DNV, IKTS, NETL, NTNU, DBI | - |
| **2.** | **Po** | George Skevis (CERTH) | MemCCSea - Membrane systems for $CO_2$ capture and storage at sea (http://www.act-ccs.eu/archive)<br><br>*Linkage to MemCCSea project: Presentation of project concept and goals* | ACT 4th Knowledge Sharing Workshop 2019 | 6/11/2019 | CERTH, DNV, IKTS, NETL, NTNU, DBI | - |
| **3.** | **O** | George Skevis (CERTH) | MemCCSea - Membrane systems for $CO_2$ capture and storage at sea (http://www.act-ccs.eu/archive)<br><br>*Linkage to MemCCSea project: Presentation of project concept and goals* | ACT 4th Knowledge Sharing Workshop 2019 | 7/11/2019 | CERTH, DNV, IKTS, NETL, NTNU, DBI | - |
| **4.** | **Po** | Hans-Petter Larsen and Solon Oikonomopoulos (NTNU) | Synthesis of a polyurethane/graphene-polymer nanocomposite with self-healing and conductive properties<br><br>*Linkage to MemCCSea project: Presentation of WP2 results* | OKV 2020 -Organic Chemistry Winter meeting | 9 – 12/01/2020 | NTNU | - |
| **5.** | **Po** | Mats Solberg Nes, Solon Oikonomopoulos (NTNU) | Understanding the Effects of $TiO_2$ Anchoring Groups on the Optical Properties of Chromophores in Dye-Sensitized Solar Cells | OKV 2020 -Organic Chemistry Winter meeting | 9 – 12/01/2020 | NTNU | - |

| | Type of publication | Author | Title | Reference | Date | Partners involved | Others |
|---|---|---|---|---|---|---|---|
| | | | *Linkage to MemCCSea project: Presentation of WP2 results* | | | | |
| **6.** | **Po** | Maren Hauknes Ranheim, Solon Economopoulos, Sina Maria Lystvet and Olav Marstokk (NTNU) | Crosslinking of polyesters in emulsion droplets<br><br>*Linkage to MemCCSea project: Presentation of WP2 results* | OKV 2020 -Organic Chemistry Winter meeting | 9 – 12/01/2020 | NTNU | - |
| **7.** | **Po** | Sigmund Mordal Lucasen and Solon Economopoulos (NTNU) | Synthesis and evaluation of graphene based materials for solid phase extraction of plasticizers from water samples<br><br>*Linkage to MemCCSea project: Presentation of WP2 results* | OKV 2020 -Organic Chemistry Winter meeting | 9 – 12/01/2020 | NTNU | - |
| **8.** | **Po** | A. Asimakopoulou, D. Koutsonikolas, M. Mouratidis, G. Karagiannakis, G. Skevis (CERTH) | Smart decarbonisation of energy-intensive industrial sectors<br><br>*Linkage to MemCCSea project: Presentation of project concept and goals* | Joint Meeting GREENERING COST Action CA18224 | 17-18/2/2020 | CERTH | - |
| **9.** | **Po** | A. Asimakopoulou, D. Koutsonikolas, G. Skevis (CERTH). | Membrane-based technologies for $CO_2$ capture and mineralization from energy-intensive Industries.<br><br>*Linkage to MemCCSea project: Presentation of WP2 & WP3 results* | Low Carbon Combustion, Lille, France | 6-7/5/2020 (postponed) | CERTH | - |
| **10.** | **O** | G. Skevis (CERTH) | CCS Overview: Outlook towards wide commercial deployment<br><br>*Linkage to MemCCSea project: Presentation of project concept and goals* | CO2oling the Earth II Summer School ATHENS (TelCo) | 29/09 – 01/10/2020 | CERTH | - |

| | Type of publication | Author | Title | Reference | Date | Partners involved | Others |
|---|---|---|---|---|---|---|---|
| **11.** | **O** | A. Asimakopoulou (CERTH) | CCUS researchers knowledge exchange session: The case of membrane-based mineralization<br><br>*Linkage to MemCCSea project: Presentation of WP2 & WP3 results* | CO2oling the Earth II Summer School ATHENS (TelCo) | 29/09 – 01/10/2020 | CERTH | - |
| **12.** | **Po** | A. G. Asimakopoulou, D. Koutsonikolas, G. Skevis (CERTH). | Membrane-based technologies for $CO_2$ capture and mineralization from energy-intensive Industries.<br><br>*Linkage to MemCCSea project: Presentation of WP2 & WP3 results* | Low Carbon Combustion, Lille, France | 5-6/11/2020 | CERTH | - |
| **13.** | **O** | George Skevis (CERTH) | MemCCSea - Membrane systems for $CO_2$ capture and storage at sea (http://www.act-ccs.eu/archive)<br><br>*Linkage to MemCCSea project: Presentation of project concept and goals* | ACT 5th Knowledge Sharing Workshop 2020 | 16/11/2020 | CERTH, DNV, IKTS, NETL, NTNU, DBI | - |
| **14.** | **O** | Mouratidis M., Koutsonikolas D., Pantoleontos G., Asimakopoulou A., Skevis G. (CERTH) | Process simulation tools for a novel carbon capture and mineralization concept<br><br>*Linkage to MemCCSea project: Presentation of WP4 results* | Sustainable Process Integration Laboratory (SPIL) Scientific Conference (TelCo) | 18-20/11/2020 | CERTH | - |
| **15.** | **O** | A. Asimakopoulou, D. Koutsonikolas, G. Kastrinaki, G. Skevis (CERTH) | Membrane-based technologies for $CO_2$ capture and conversion to value-added chemicals<br><br>*Linkage to MemCCSea project: Presentation of WP2 & WP3 results* | International Congress on Membranes & Membrane Processes 2020 (TelCo) | 7/12 – 11/12/2020 | CERTH | - |

| | Type of publication | Author | Title | Reference | Date | Partners involved | Others |
|---|---|---|---|---|---|---|---|
| **16.** | **Other (Website post)** | A. Asimakopoulou, D. Koutsonikolas, G. Skevis (CERTH) | Innovative filters “made in Thessaloniki” will capture pollutants emitted by ships (in greek)<br><br>*Linkage to MemCCSea project: Presentation of project concept and goals* | http://greenagenda.gr/ | 17/12/2020 | CERTH, DNV, IKTS, NETL, NTNU, DBI | - |
| **17.** | **Po** | E. Piperidou, D. Koutsonikolas, A. Asimakopoulou, G. Karagiannakis, G. Skevis (CERTH). | Hydrophobic modification of commercial ceramic membranes with immersion and CVD methods<br><br>*Linkage to MemCCSea project: Presentation of WP2 results* | World Online Conference on Sustainable Technologies | 17-19/03/2021 | CERTH | - |
| **18.** | **Po** | A. Asimakopoulou, D. Koutsonikolas, M. Mouratidis, G. Skevis (CERTH). | Novel membrane contactor processes for post-combustion gas pollutants removal in the maritime sector<br><br>*Linkage to MemCCSea project: Presentation of WP3 results* | 10th European Combustion Meeting – Virtual edition | 14-16/04/2021 | CERTH | - |
| **19.** | **O** | G. Dimopoulos (DNV) | Carbon Capture Storage / Utilisation (CCUS) Technology & Market from a Maritime Point of View<br><br>*Linkage to MemCCSea project: Presentation of project concept, goals and main results* | MARine TEChnical Managers Association Meeting (MARTECMA) 2021 | 22/04/2021 | CERTH, DNV, IKTS, NETL, NTNU, DBI | - |
| **20.** | **Other** | G. Skevis, A. Asimakopoulou, D. Koutsonikolas (CERTH) | MemCCSea Project presentation in CERTH Newsletter - March 2021<br><br>*Linkage to MemCCSea project: Presentation of project concept, goals and main results* | https://www.certh.gr/certh_newsletter.el.aspx | 27/04/2021 | CERTH, DNV, IKTS, NETL, NTNU, DBI | - |

| | Type of publication | Author | Title | Reference | Date | Partners involved | Others |
|---|---|---|---|---|---|---|---|
| **21.** | **O** | G. Skevis, G. Karagiannakis, A. Asimakopoulou, P. Baltzopoulou, D. Koutsonikolas (CERTH) | Waste Valorization for a Sustainable Future: CCS and the Circular Economy<br><br>*Linkage to MemCCSea project: Presentation of project concept, goals and main results* | Conference on Waste Biorefinery towards Decarbonization, Portuguese Presidency of the Council of the EU | 24/05/2021 | CERTH | - |
| **22.** | **O** | H. Richter (IKTS) | Powerful separators: Carbon membranes for $H_2$- and $CO_2$-separation from different gas streams<br><br>*Linkage to MemCCSea project: Presentation of project concept, goals and main results* | Exibitor Pitch ACHEMA Pulse, ACHEMA<br>Online event | 15/06/2021 | DBI | - |
| **23.** | **Other** | G. Skevis, A. Asimakopoulou, D. Koutsonikolas, Th. Damartzis, M. Mouratidis (CERTH) | MemCCSea Project presentation in the 85$^{th}$ Thessaloniki International Fair through a virtual reality tool 'Ship VR'.<br><br>*Linkage to MemCCSea project: Presentation of project concept, goals and main results* | 85$^{th}$ Thessaloniki International Fair | 11-19/09/2021 | CERTH, DNV, IKTS, NETL, NTNU, DBI | |
| **24.** | **Other** | G. Skevis (CERTH)<br>G. Dimopoulos (DNV) | Round Table Discussion on Novel CCS Technologies for Industry and Marine Transportation<br><br>*Linkage to MemCCSea project: Presentation of project concept, goals and main results* | 85$^{th}$ Thessaloniki International Fair<br><br>Invitation to the round table | 18/09/2021 | CERTH, DNV, IKTS, NETL, NTNU, DBI | |
| **25.** | **Po** | D. Koutsonikolas, A. Asimakopoulou, G. Karagiannakis and G. Skevis (CERTH). | Membrane Gas Absorption (MGA) for acid gas treatment<br><br>*Linkage to MemCCSea project: Presentation of WP3 results* | EUROMEMBRANE 2021<br>Copenhagen, Denmark<br>LIVE EVENT | 28/11-02/12/2021 | CERTH | - |

| | Type of publication | Author | Title | Reference | Date | Partners involved | Others |
|---|---|---|---|---|---|---|---|
| **26.** | **O** | A, Asimakopoulou, D. Koutsonikolas, G. Pachidis, G. Karagiannakis, G. Skevis (CERTH) | Gas-Liquid membrane contactors in CCUS applications<br><br>*Linkage to MemCCSea project: Presentation of WP3 results* | CA18224 GREENERING Scientific meeting<br>Coimbra, Portugal | 28/2-02/03/2022 | CERTH | - |
| **27.** | **Oth (MSc Thesis)** | E. Bintoutdi (CERTH) | The Dawn of a Maritime Revolution: On-board Carbon Capture & Storage – A Review"<br><br>*Linkage to MemCCSea project: Presentation of WP1 results* | Master of Science (MSc) Thesis in Environmental Management & Sustainability, IHU, Greece | 04/2022 | CERTH | - |
| **28.** | **O** | A. Asimakopoulou, G. Kastrinaki, D. Koutsonikolas, G. Skevis (CERTH) | Hybrid Membrane Gas Absorption Technology for the Decarbonization of the Maritime and Energy Intensive Industries | International Conference on Water, Energy, Food and Sustainability (ICoWEFS 2022) | 10-12/05/2022 | CERTH | - |
| **29.** | **Oth (journal publication)** | T. Damartzis, A. Asimakopoulou, D. Koutsonikolas, G. Skevis (CERTH), C. Georgopoulou, G. Dimopoulos (DNV), L. Nikolopoulos, K. Bougiouris (EURONAV), H. Richter (IKTS), U. Lubenau (DBI), S. Economopoulos, C. Perinu (NTNU), D. Hopkinson, G. Panagakos (NETL) | Solvents for Membrane-Based Post-Combustion $CO_2$ Capture for Potential Application in the Marine Environment<br><br>*Linkage to MemCCSea project: Presentation of WP1 results* | Appl. Sci. 2022, 12, 6100. https://doi.org/10.3390/app12126100 | 05/2022 | CERTH, DNV, EURONAV, IKTS, DBI, NTNU, NETL | |
| **30.** | **O** | Δ. Κουτσονικόλας, Α. Ασημακοπούλου, Γ. Παντολέοντος, Ι. | ΔΕΣΜΕΥΣΗ $CO_2$ ΜΕ ΜΕΜΒΡΑΝΕΣ ΕΠΑΦΗΣ ΥΓΡΟΥ-ΑΕΡΙΟΥ | 13ο Πανελλήνιο Επιστημονικό Συνέδριο Χημικής Μηχανικής, Πάτρα | 02-04/6/2022 | CERTH | - |

| | Type of publication | Author | Title | Reference | Date | Partners involved | Others |
|---|---|---|---|---|---|---|---|
| | | Παχίδης, Γ. Καραγιαννάκης, Γ. Σκεύης | *Linkage to MemCCSea project: Presentation of project concept, goals and main results* | https://pesxm13.chemeng.upatras.gr/ | | | |
| **31.** | **O** | S.P Oikonomopoulos | MemCCSea – Project summary and progress<br><br>*Linkage to MemCCSea project: Presentation of project concept, goals and main results* | CSLF - Carbon Sequestration Leadership Forum on CDR – Carbon Dioxide Reduction, Bergen, Norway | 27/6-30/6/2022 | NTNU | - |
| **32.** | **Oth (Social media)** | T. Damartzis, A. Asimakopoulou, D. Koutsonikolas, G. Skevis (CERTH), C. Georgopoulou, G. Dimopoulos (DNV), L. Nikolopoulos, K. Bougiouris (EURONAV), H. Richter (IKTS), U. Lubenau (DBI), S. Economopoulos, C. Perinu (NTNU), D. Hopkinson, G. Panagakos (NETL) | Numerous posts for "MemCCSea Final Dissemination and Networking Event"<br><br>*Linkage to MemCCSea project: Presentation of project concept, goals and main results* | Linkedin, Facebook, Twitter | 5/10/2022 | CERTH, DNV, EURONAV, IKTS, DBI, NTNU, NETL | - |
| **33.** | **Oth (Press release)** | T. Damartzis, A. Asimakopoulou, D. Koutsonikolas, G. Skevis (CERTH), C. Georgopoulou, G. Dimopoulos (DNV), L. Nikolopoulos, K. Bougiouris (EURONAV), H. Richter (IKTS), U. | MemCCSea Final Dissemination and Networking Event<br>Opportunities and Challenges for the Decarbonization of the Maritime Sector<br><br>*Linkage to MemCCSea project: Presentation of project concept, goals and main results* | https://www.certh.gr/D94DC6A9.el.aspx | 06/10/2022 | CERTH | - |

| | Type of publication | Author | Title | Reference | Date | Partners involved | Others |
|---|---|---|---|---|---|---|---|
| | | Lubenau (DBI), S. Economopoulos, C. Perinu (NTNU), D. Hopkinson, G. Panagakos (NETL) | | | | | |
| **34.** | **O** | R. Ronneberg | The ACT Initiative: A successful funding scheme for CCUS projects<br><br>*Linkage to MemCCSea project: Presentation of project concept, goals and main results* | MemCCSea Final Dissemination and Networking Event<br>Opportunities and Challenges for the Decarbonization of the Maritime Sector | 14/10/2022 | RCN, ACT Coordinator | |
| **35.** | **O** | A. Asimakopoulou | The MemCCSea Project: An overview<br><br>*Linkage to MemCCSea project: Presentation of project concept, goals and main results* | MemCCSea Final Dissemination and Networking Event<br>Opportunities and Challenges for the Decarbonization of the Maritime Sector | 14/10/2022 | CERTH | - |
| **36.** | **O** | D. Koutsonikolas | Membrane-based CCS<br><br>*Linkage to MemCCSea project: Presentation of project concept, goals and main results* | MemCCSea Final Dissemination and Networking Event<br>Opportunities and Challenges for the Decarbonization of the Maritime Sector | 14/10/2022 | CERTH | - |
| **37.** | **O** | D. Hopkinson | Innovative Membrane Materials for Onboard CCS<br><br>*Linkage to MemCCSea project: Presentation of project concept, goals and main results* | MemCCSea Final Dissemination and Networking Event<br>Opportunities and Challenges for the Decarbonization of the Maritime Sector | 14/10/2022 | NETL | - |
| **38.** | **O** | C. Georgopoulou | Membrane CCS Marinization and Onboard Integration | MemCCSea Final Dissemination and Networking Event<br>Opportunities and Challenges for the Decarbonization of the Maritime Sector | 14/10/2022 | DNV | - |

| | Type of publication | Author | Title | Reference | Date | Partners involved | Others |
|---|---|---|---|---|---|---|---|
| | | | *Linkage to MemCCSea project: Presentation of project concept, goals and main results* | | | | |
| **39.** | **Other (Website post)** | A. Asimakopoulou | Akrivi Asimakopoulou: Innovative carbon Capture technologies from CERTH<br><br>*Linkage to MemCCSea project: Presentation of project concept, goals and main results* | https://maritimes.gr/el/ | 17/10/2022 | CERTH | - |
| **40.** | **Other (radio interview)** | A. Asimakopoulou | Innovative carbon Capture technologies from CERTH<br><br>*Linkage to MemCCSea project: Presentation of project concept, goals and main results* | | 17/10/2022 | CERTH | - |
| **41.** | **Other (Website post)** | T. Damartzis, A. Asimakopoulou, D. Koutsonikolas, G. Skevis (CERTH), C. Georgopoulou, G. Dimopoulos (DNV), L. Nikolopoulos, K. Bougiouris (EURONAV), H. Richter (IKTS), U. Lubenau (DBI), S. Economopoulos, C. Perinu (NTNU), D. Hopkinson, G. Panagakos (NETL) | MemCCSea Final Dissemination & Networking Event<br><br>*Linkage to MemCCSea project: Presentation of project concept, goals and main results* | http://memccsea.certh.gr/component/content/article/13-news/21-memccsea-final-dissemination-networking-event?Itemid=101 | 14/11/2022 | CERTH, DNV, IKTS, NETL, NTNU, DBI | - |

| | Type of publication | Author | Title | Reference | Date | Partners involved | Others |
|---|---|---|---|---|---|---|---|
| **42.** | **Oth (Thesis)** | K.Papoutsis (CERTH) | *STUDY OF CARBON DIOXIDE CAPTURE TECHNOLOGY USING LIQUID-GAS CONTACT MEMBRANES*<br><br>*Linkage to MemCCSea project: Presentation of project WP3 results* | Diploma Thesis<br>Department of Chemical Engineering, Polytechnic School,<br>Aristotle University of Thessaloniki | 15/07/2023 | CERTH | - |
| **43.** | **O** | A. Asimakopoulou (CERTH), D. Koutsonikolas (CERTH), T. Damartzis (CERTH), G. Pantoleontos (CERTH), G. Skevis (CERTH), C. Georgopoulou, G. Dimopoulos (DNV), K. Bougiouris (EURONAV), H. Richter (IKTS), U. Lubenau (DBI), S. Economopoulos (NTNU), C. Perinu (NTNU), D. Hopkinson (NETL) and G. Panagakos (NETL) | Innovative membrane systems for CO2 capture and storage at sea (MemCCSea ACT-ERANET project)<br><br>*Linkage to MemCCSea project: Presentation of project concept, goals and main results* | Euromembrane 2022<br>Sorento, Naples, Italy | 20-24/11/2022 | CERTH, DNV, EURONAV, IKTS, NETL, NTNU, DBI | - |