MemCCSea

Innovative membrane systems for CO_2 capture and storage at sea

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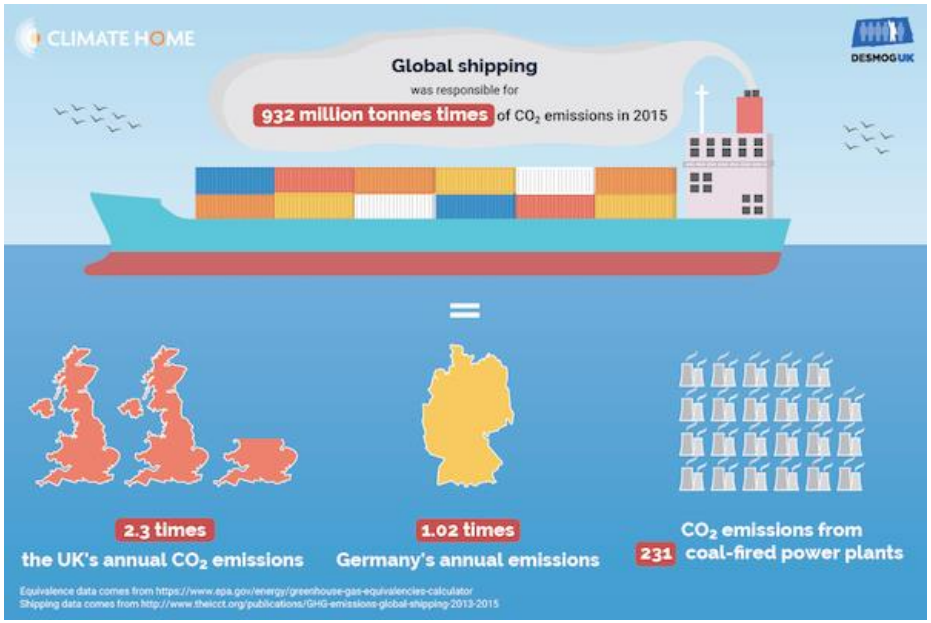
The MemCCSea project No 299690 has received funding from GSRT (GR), FZJ/PtJ (DE), RCN (NO), DoE (USA) and is co-funded by the European Commission under the Horizon 2020 Programme, ACT Grant Agreement No XXXX.

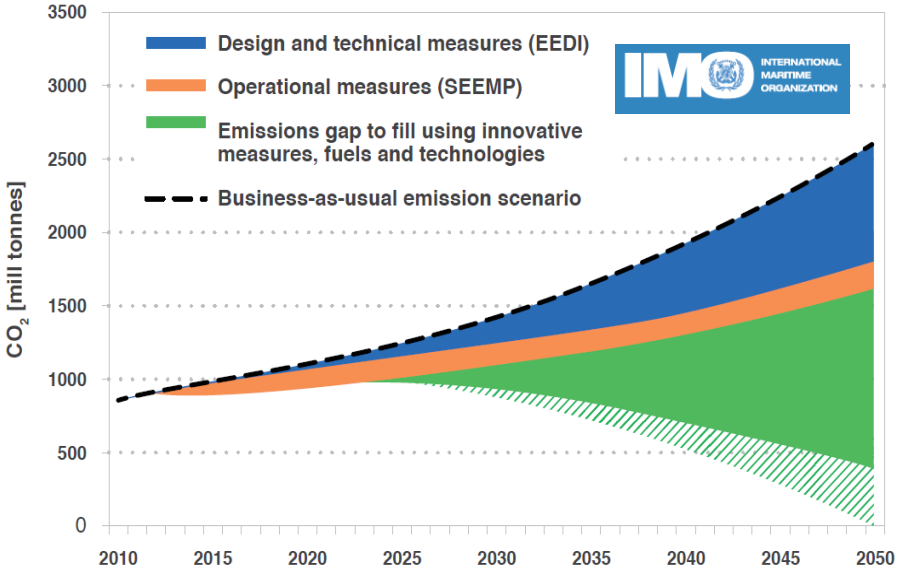
4th ACT Knowledge Sharing Workshop
6-7 November 2019
Athens, Greece

CCS & The Maritime Industry

The global share of CO_2 emissions from the shipping industry is expected to reach **17%** by 2050 from approx. **2.5%** currently.

At least 50% reduction of total annual GHG emissions (requires approximately **85% CO_2 reduction per ship**) by 2050.





For the shipping industry to deliver [CO_2] mitigation in line with the Paris Agreement, virtually **full decarbonization needs to be achieved** (Traut et al., 2018)

CCS & The Maritime Industry

- **No alternative to large diesel engines at least for long-distance shipping**

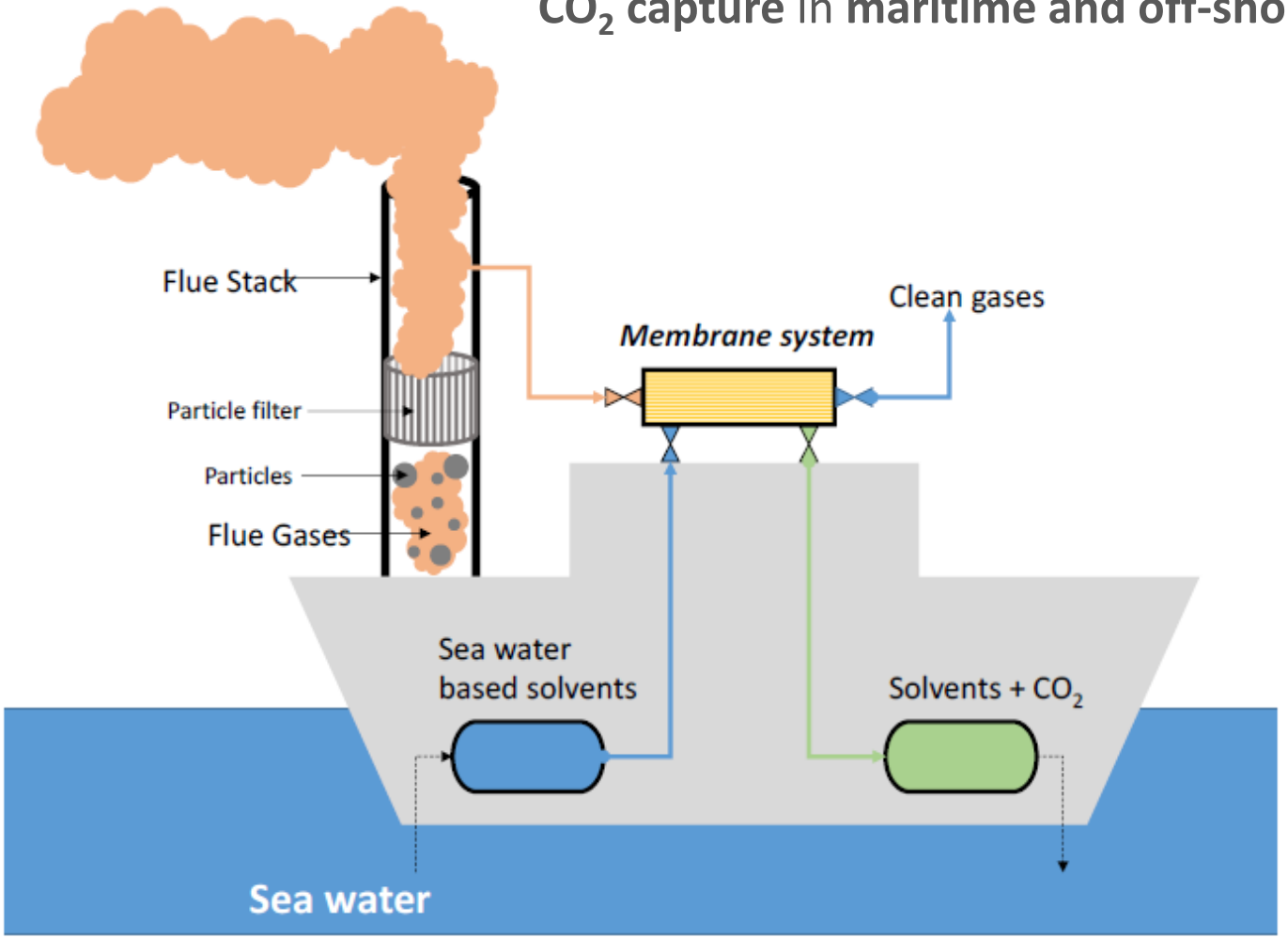
- Switching 50% of the international marine bunker fuel mix to LNG reduces GHG emissions by only 10% (IEA, 2017)

- Non-carbon fuels (hydrogen, ammonia): Need for low-carbon hydrogen production, Global refueling infrastructure network, Safety issues (hydrogen), Poor combustion properties (ammonia)

- Potential for carbon capture on-board ships needs to take into account (energy) costs and space limitations.

The MemCCSea Concept

Development of **hyper compact membrane systems** for flexible operational and cost-effective **post-combustion CO_2 capture** in **maritime and off-shore applications.**



The MemCCSea Consortium

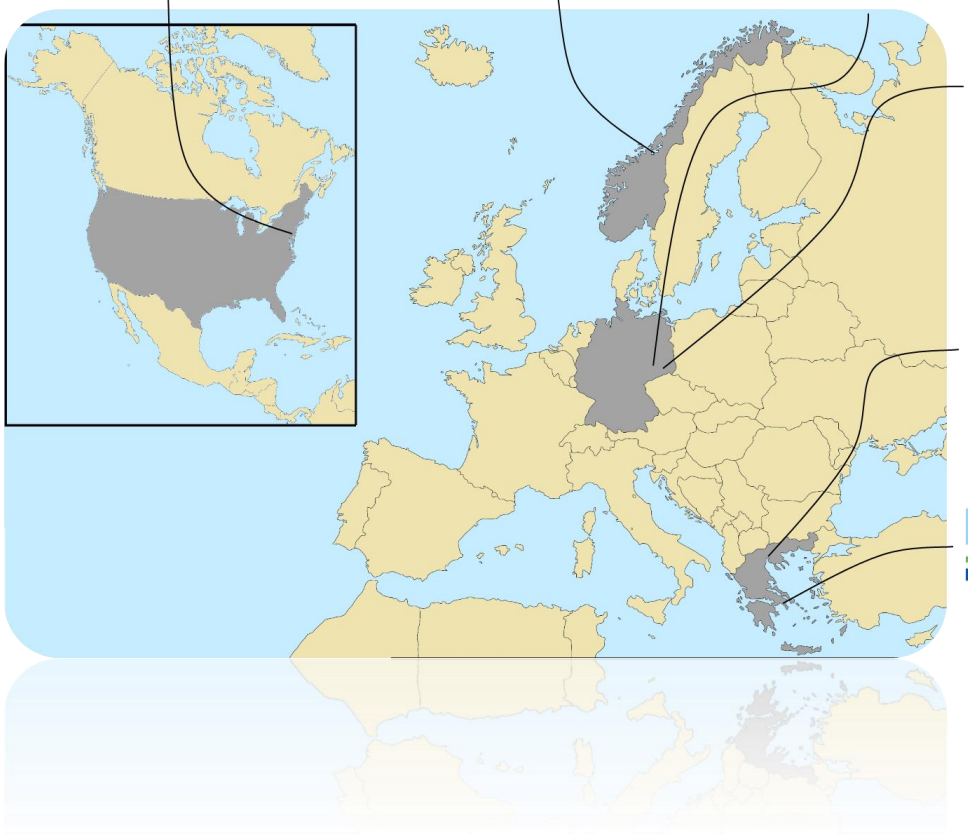
Project duration
1/11/2019 – 30/4/2022 (30M)

Budget
1.98 M€

NATIONAL ENERGY TECHNOLOGY LABORATORY

NTNU

DBI GUT
Gas- und Umwelttechnik GmbH



Fraunhofer
IKTS

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CENTRE FOR RESEARCH & TECHNOLOGY HELLAS

CPERI
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DNV·GL

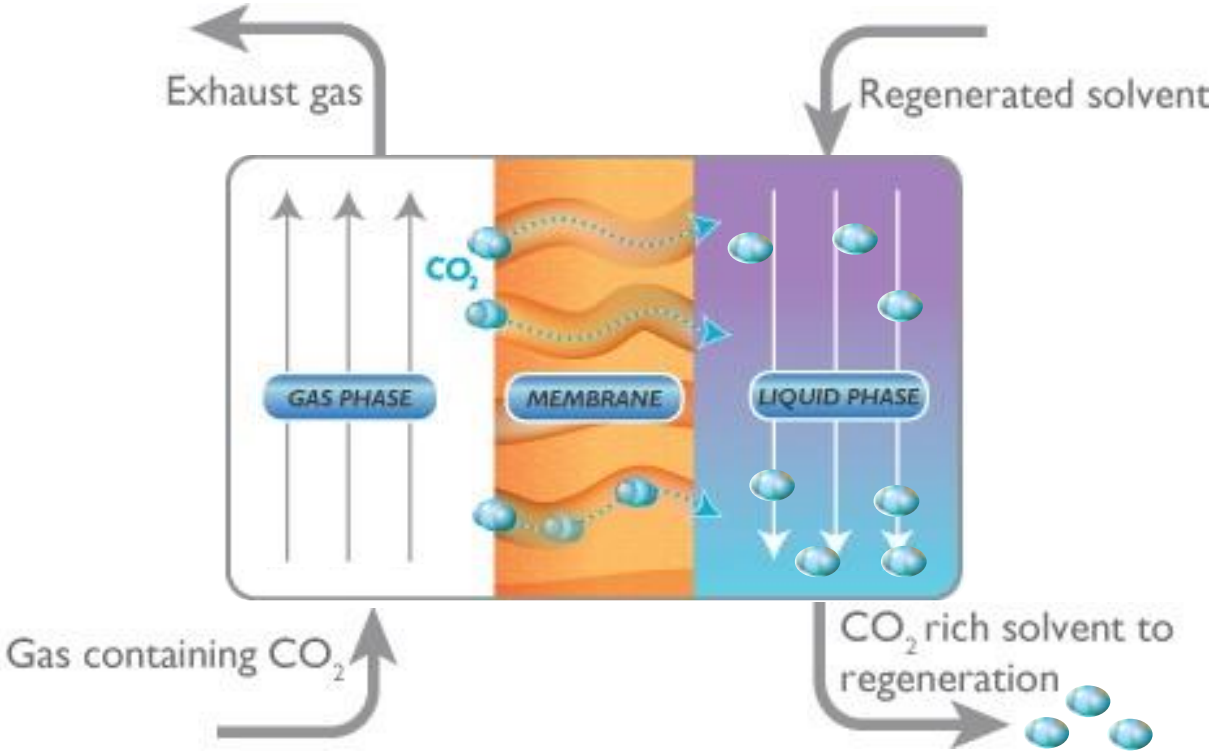
Project website
http://memccsea.certh.gr

The MemCCSea Project – Key Targets

MemCCSea will provide a **feasible design** and **pilot demonstration**, optimized for maritime applications, capable to achieve **higher than the state-of-the-art performance**, meeting the following key targets

- Recovery of the **main engine CO_2 emissions greater than 90%**
- **Overall CO_2 emissions reduction** (including added emissions by the capture plant and utilities **greater than 50%**
- **A 10-fold reduction of system volume** and a **reduction of operating costs greater than 25%** compared to a conventional amine-based scrubbing system.

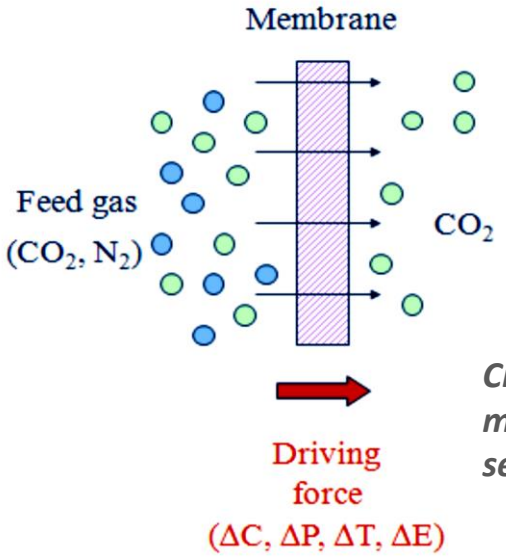
Membrane Technology – Gas-Liquid Contactors



Cross section of a porous hollow fiber wall

- An immobilized gas-liquid interface is created at the pores mouth where reaction takes place
- No dispersion of one phase in the other
- Very high and well defined surface areas can be obtained
- Easy and modular scale up of the process

Membrane Technology – Permeators

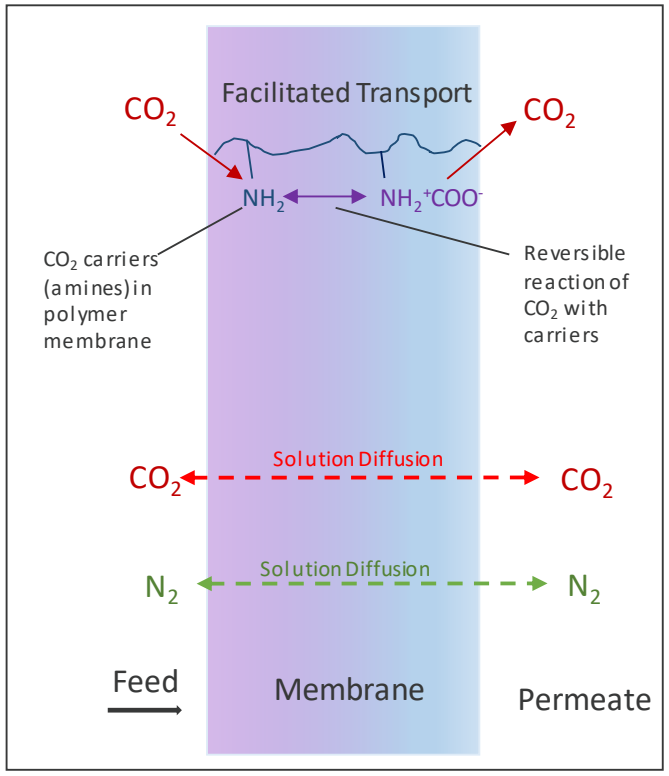


The driving force for CO_2 permeation can be a difference in concentration (ΔC), pressure (ΔP), temperature (ΔT) and electric potential (ΔE) of CO_2 and N_2 at either side of the membrane.

Cross section of a dense membrane wall during CO_2 separation

Facilitated Transport Membranes for CO_2 separations

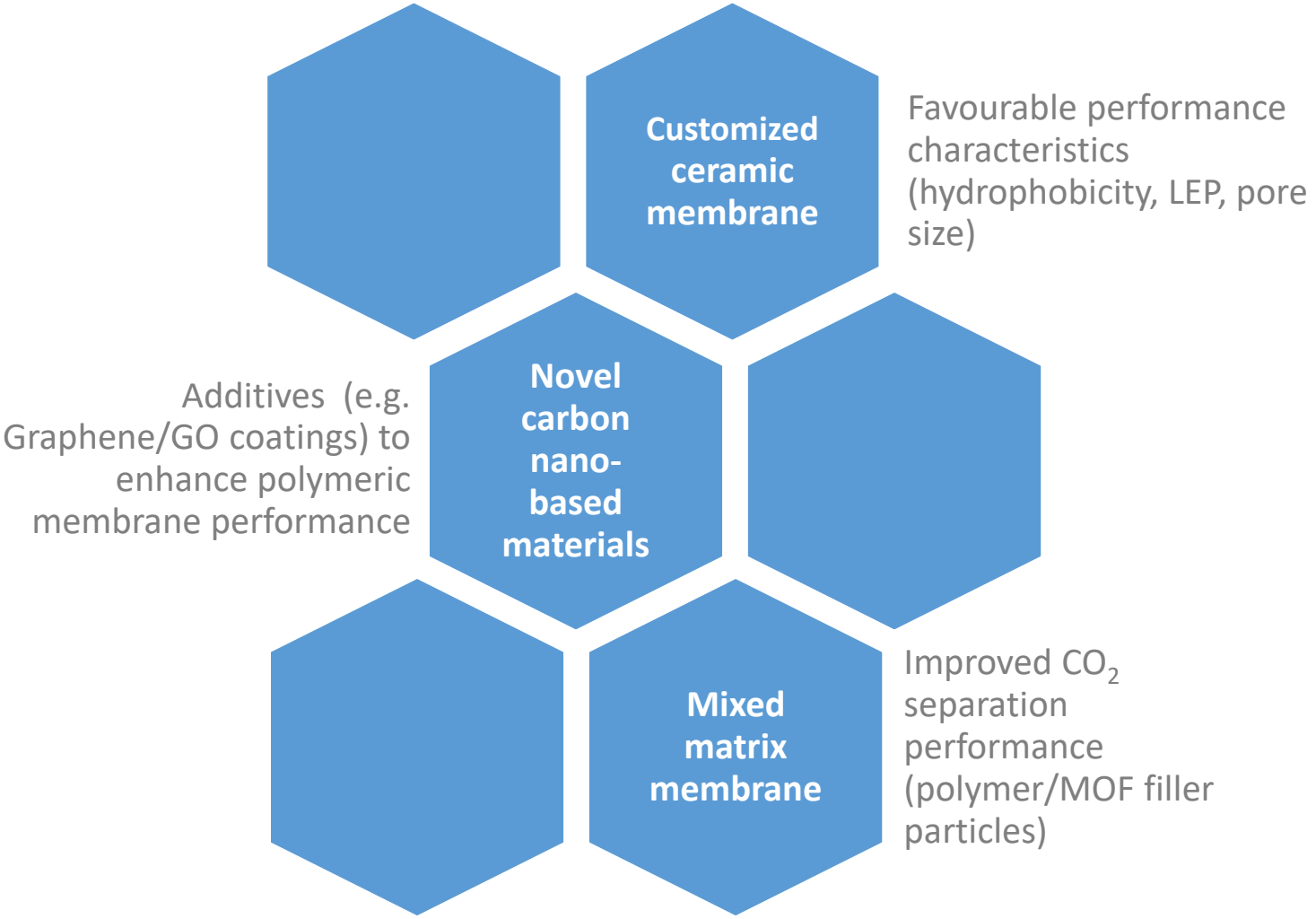
Simultaneous enhancement of both CO_2 permeability and selectivity – Not limited by the permeability/selectivity tradeoff observed in solution diffusion membranes (can exceed Robeson upper bound)



Aliphatic amine carrier for CO_2 - Reversible formation of carbamate

The MemCCSea Project – S&T Challenges

Re-design and optimization of membranes materials



The MemCCSea Project – S&T Challenges

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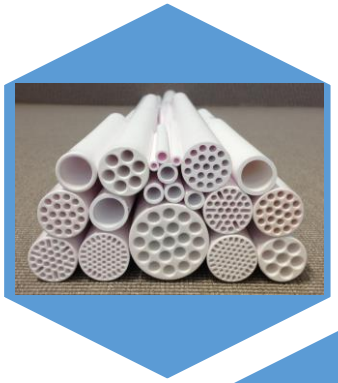
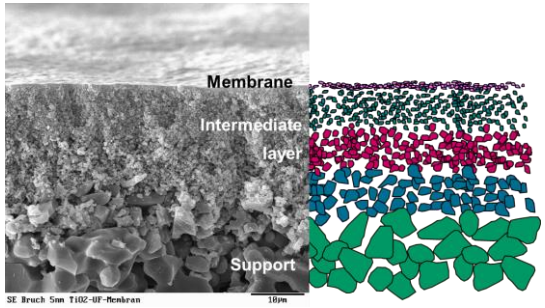
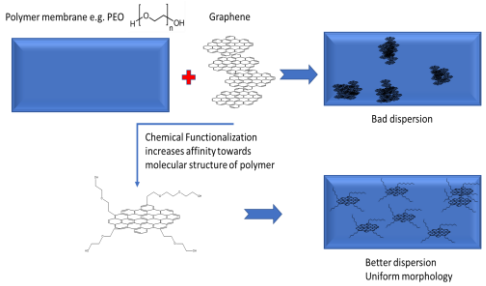


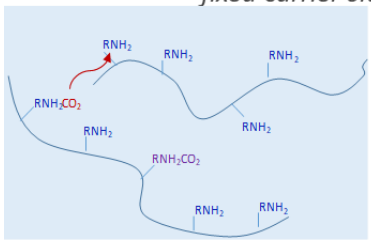
Customized ceramic membrane





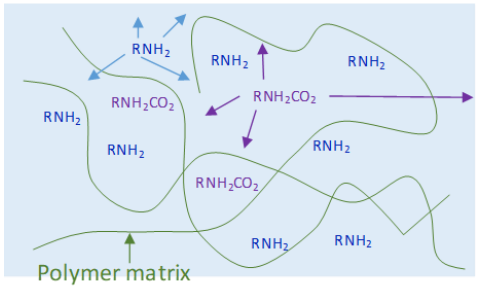
Novel carbon nano-based materials

CO_2 "hopping" between fixed carrier sites



Mixed matrix membrane

Carrier and Carrier-CO_2 complex are free to diffuse within membrane

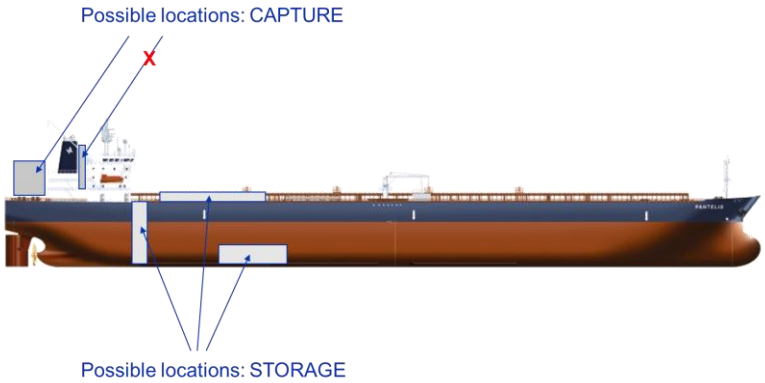


The MemCCSea Project – S&T Challenges

Process Marinization

Design and utilization of environmentally-friendly, **seawater-based solvents** modified with CO_2 capture promoters (e.g. CaO, NaOH)

Address **unique challenges of maritime environment** (operational and safety requirements, energy efficiency, on-site solvent regeneration etc)



Modelling and simulation

Modelling and simulation of **transport phenomena in CGL and MMP membranes** incorporating accurate material properties and properties of the solvent mixture.

Model-based assessment and optimization of the marine energy system with carbon capture (COSSMOS software).

Impact

User-friendly, cost-effective and environmentally-benign carbon-capture solution for the maritime industry

- GLC membranes have demonstrated their potential for CO_2 removal in energy-intensive industries. **CAPEX reductions may exceed 25%** (on the basis of biogas upgrading to biomethane) compared to conventional amine-based solutions.
- **Specific surface area** of membrane systems in excess of **1000 m^2/m^3** resulting to a **ten-fold decrease in absorber size** compared to conventional absorption packed columns.
- **Minimized environmental impact from seawater-based solvents**
- **Assessment of carbon storage options** (e.g. liquefaction, underwater storage, storage ashore)

MemCCSea Commercialization

- There are no commercially available *ceramic* membranes for CO_2 separation processes. **Innovative ceramic/polymeric/hybrid will open a new segment in a rapidly expanding market (expected size 2.6 billion USD by 2022 with an annual growth of 7.2%).**
- Over 65% of the global membrane market share is currently located outside the EU. **Investment in innovation can increase the market share of EU companies.**
- The MemCCSea membranes do not include any rare or unusual elements/components.
- The MemCCSea solutions (membrane synthesis, membrane evaluation protocols, solvent regeneration, system design) will be **fully transferable to other CO_2 capture applications.**

Dissemination & Outreach Activities

- MemCCSea partner countries (Greece (#2), Germany (#4), Norway (#6), US (#7)) collectively account for approx. 25% of the world merchant fleet (UNCTAD, 2018).
- Partners have close links with the CCUS community in the industrial sector (cross-fertilization).
  - **CERTH:** Participation in the CO2olingtheEarth EU initiative
  - **NETL:** Participation in the US, DoE, Carbon Capture and Carbon Capture Simulation for Industry Impact (CCSI2) Field Work Proposals (FWPs)

Planned Activities

- Mid-project and Final Workshops organized in the EU and the US aimed at the RTD and industrial/maritime community
- Targeted dissemination events towards policymakers (e.g. IMO, National and EU public bodies, etc)
- Links with other RTD projects in the EU and the US (e.g. organization of common events)
- Public Website & Quarterly Newsletters


MemCCSea