ANNUAL REPORTING

2020-2021

TECHNICAL REPORT

Three types of membranes will be optimized in this project:

- Hybrid polymer- CA enzyme (CA carbonic anhydrase) membranes
- Surface modified membranes with amine functionalities
- Bulk modified new materials.

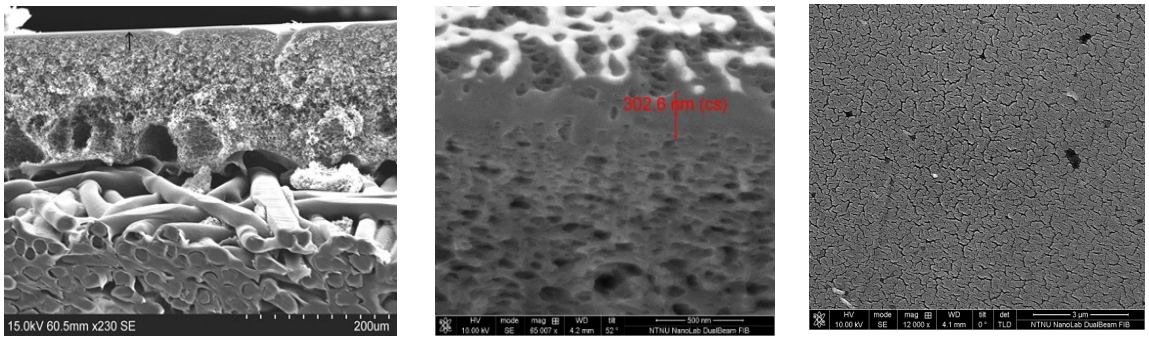


Figure 1. SEM pictures of polysulfone (PSf) membrane. From left to right: cross-section entire membrane, cross-section at surface and top view (surface)

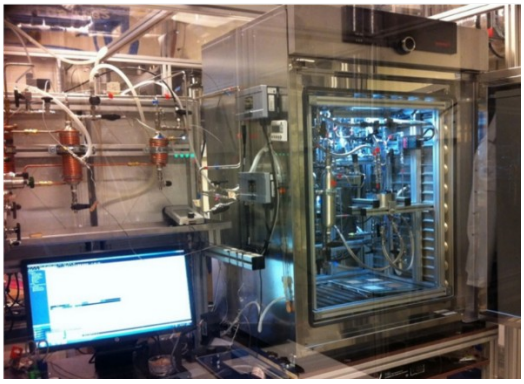
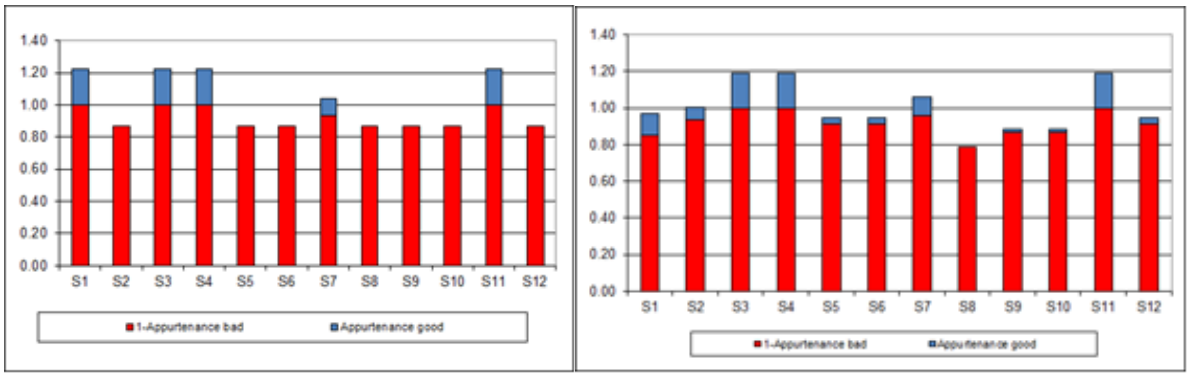


Figure 2. One of the test rigs for mixed gas permeation

The 11 selected solvents were analysed to determine their performance from a technical, economic and energy perspective.



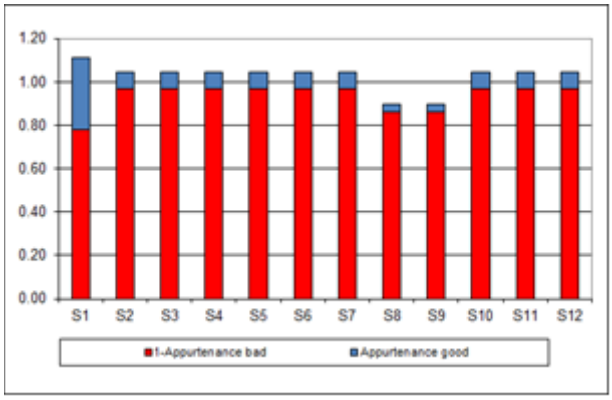


Figure 3. Evaluation of solutions by technical, environmental and economical criteria

The proposed hybrid CO_2 capture process, illustrated in Error: Reference source not found4, consists of a standard absorber - stripper configuration which produce high purity CO_2 for liquefaction and storage.

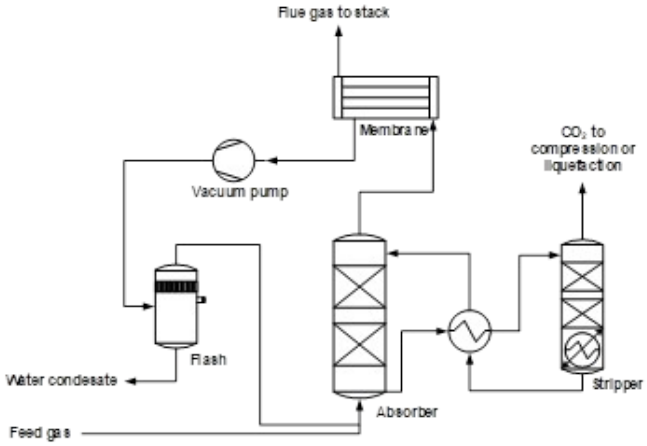
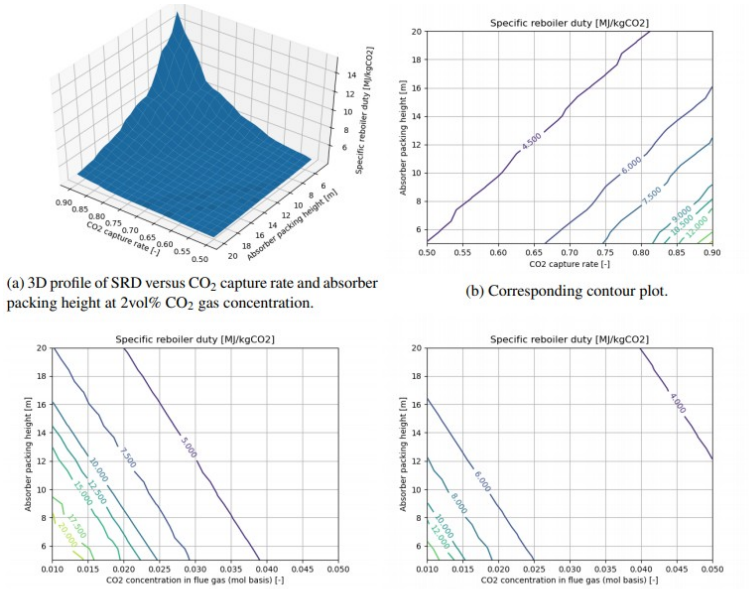


Figure 4. Conceptual illustration of a proposed hybrid absorption - membrane process for post combustion CO_2 capture

Error: Reference source not found5 a-b) shows how the energy demand for solvent regeneration varies with CO_2 capture rate. Figure 5 c-d) shows the SRD impact of feed gas composition and absorber packing height.



(a) 3D profile of SRD versus CO_2 capture rate and absorber packing height at 2vol% CO_2 gas concentration.

(b) Corresponding contour plot.

(c) SRD versus CO_2 gas concentration and absorber packing height at 90% capture rate.

(d) SRD versus CO_2 gas concentration and absorber packing height at 75% capture rate.

Figure 5. Minimum specific reboiler duty, SRD for a conventional 30 wt% MEA

The conceptual layout of a Synthetic Natural Gas (SNG) plant is presented in Figure 6.

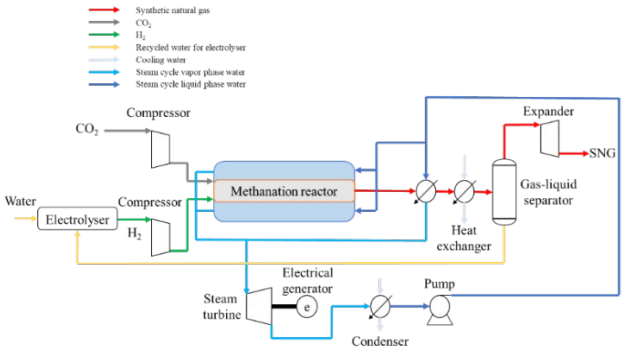


Figure 6. Conceptual layout of a SNG plant

Figure 7 shows the influence of operating temperature (left) and pressure (right) on the gas composition resulted from CO_2 methanation reactor.

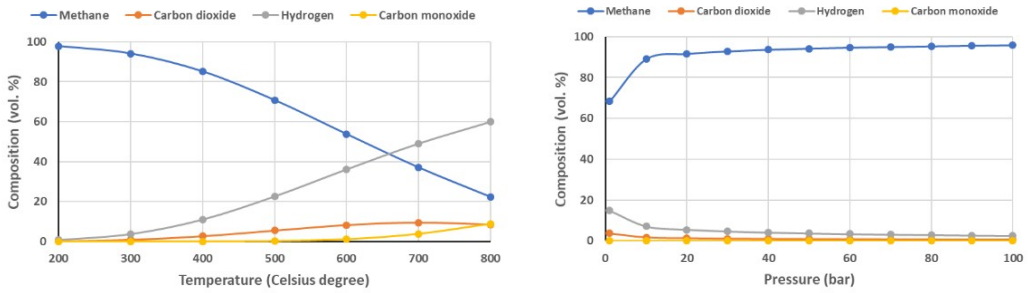


Figure 7. Influence of temperature (left) and pressure (right) to CO_2 methanation process

Gas permeation properties. Figure 8 shows a schematic drawing and picture of the mixed gas permeation set-up.

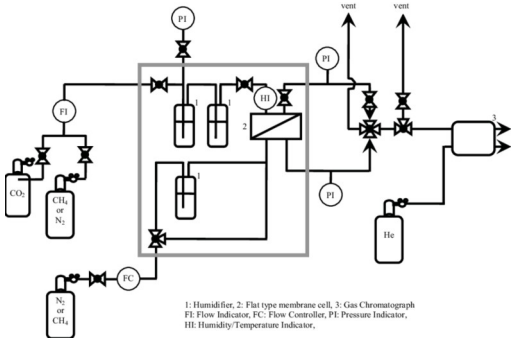


Figure 8. Schematic representation of experimental set-up for mixed gas permeation testing

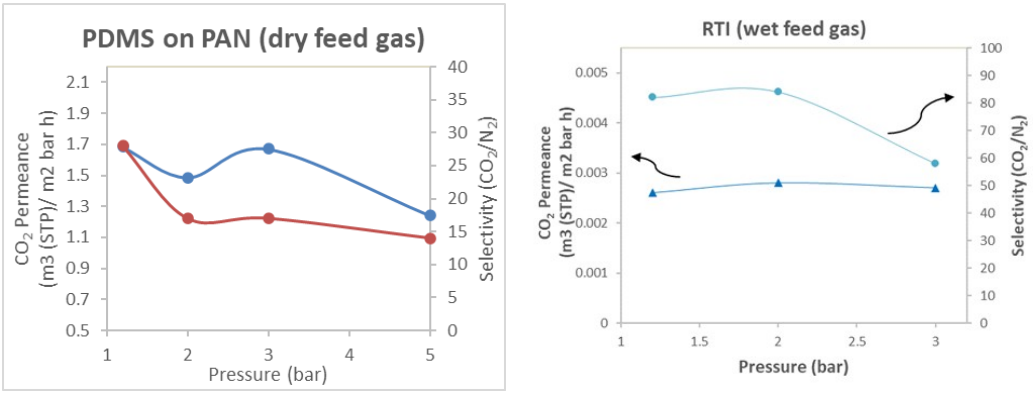


Figure 9. Gas permeation of unmodified PDMS on porous PAN support (left) and gas permeation for wet feed gas (right)

The pilot installation uses one of the latest technologies for burning coal – circulating fluidized bed combustion (CFBC) (Figure 10).

Figure 10. Experimental part on CFBC unit

Table 1. Flue gases composition from lignite combustion (TESTO analyzer)

T_{gaz}, [°C]	CO, [ppm]	NO, [ppm]	NO_x, [ppm]	SO_2, [ppm]	CO_2, [%]	O_2, [%]	λ
49.4	759	227	238	887	8.84	10.91	2.04
46.2	250	211	222	855	7.99	11.91	2.27
44.2	193	226	237	988	7.79	12.14	2.33
….							

A CO_2 capture efficiency of 85% with a CO_2 purity of 98% was considered in all cases analysed. The results obtained for the flue gas compression separation processes (Configurations 1-6) are shown in Table 2.

Table 2. Main results for the cases when compression process was integrated

Cases studied		**1**	**2**	**3**	**4**	**5**	**6**
Molar flow, [kmol/s]	19.83	4.05	3.83	3.09	3.09	2.77	2.68
Temperature, [^{0}C]	40	40	40	40	40	40	40
Pressure, [bar]	1.013	1.013	1.013	1.013	1.013	1.013	1.013
CO_2 efficiency, [%]		85	85	85	85	85	85
Surface required, [ha]		11.1	11.1	20.3	8.2	20.8	14.4
Electric power compressor, [MW_e]		263.2	275.1	292.2	294.8	334.6	318.6
Electric power generated, [MW_e]		-59.1	-60.3	-62.5	-65.5	-68.7	-71.3
Net electric power used, [MW_e]		204.1	214.8	229.7	229.3	265.9	247.3

Hollow fiber upscaling. Two types of hollow fibre were planned to be used in the project: polyphenylene oxide (PPO) and polysulfone (PSF). Upscaled area module will contain up to 200 HF and area up to 600-800 cm^2.

Figure 11. PPO hollow fibers and head of a module with 10 HF with a length of 30 cm

Catalysts selection, preparation, structural and functional characterization. X-Ray Diffraction (XRD) at small angles was used to confirm the materials structure and XRD on broad angle to confirm the presence of Ni and to estimate the Ni nanoparticle size ($D_{Ni\text{-}XRD}$) (Figure 12).

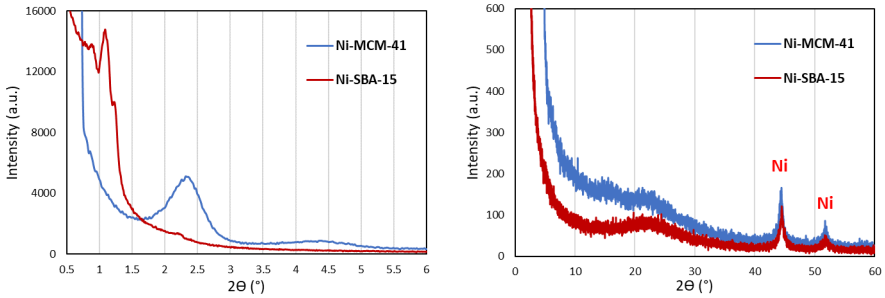
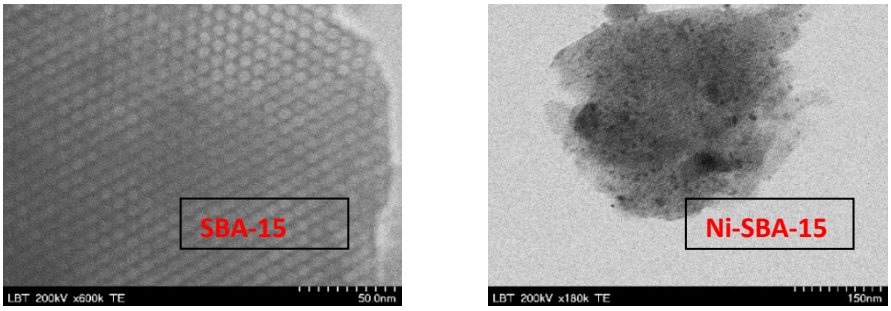


Figure 12. X-Ray Diffraction patterns of Ni-SBA-15 and Ni-MCM-41 catalysts

Electronic microscopy images of prepared catalysts. The images of Ni-SBA-15 and Ni-MCM-41 are presented in Figure 13.



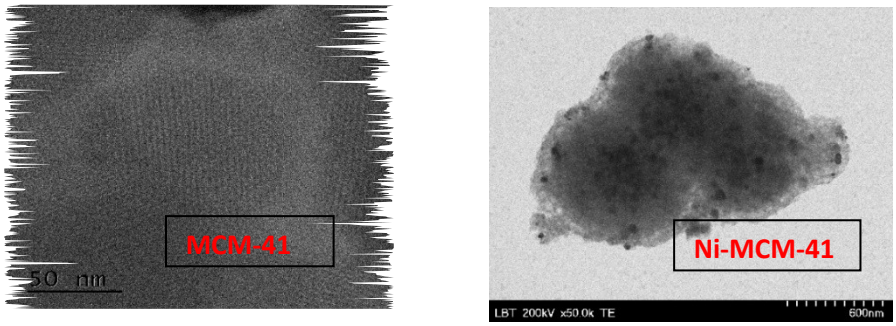


Figure 13. **TEM images of the prepared materials**

The best sinks for CO_2-EOR are considered to be Triassic and Sarmatian. The characteristics of Brădești structure are presented in Table 3.

Table 3. Characteristics of Brădești structure

Productive formation	**Triassic**	**Dogger**	**Sarmatian**
Depth, H (m)	2580	2400	2200
Effective thickness, h (m)	10-30	20-40	10-20
Porosity, m (%)	15	15	16
Permeability abs., k(mD)	150-350	150-350	150-350
Oil density, D (kg/mc)	830	840	850
Oil viscosity – standard conditions, v (cP)	2,5	3,5	3,5
Initial/present pressure, P (at)	240/180	220	210
Reservoir temperature, Tz (0C)	85	82	80
Anisotropy			
Clay content, % volumetric	16-28		21-32
Water salinity, kg. salt/wagon	320-760		550-760
Initial oil saturation, %	75-63	81	82

Dissemination of the results

In the period 2020-2021 the results of the project were disseminated through the publication of **16 articles in journals and conference papers**. These are listed below:

1. Mihet, M., Dan, M., Barbu-Tudoran, L., & Lazar, M. D. (2021). CO_2 Methanation Using Multimodal Ni/SiO_2 Catalysts: Effect of Support Modification by MgO, CeO_2, and La2O3. Catalysts, 11(4), 443.
2. Szima, S., & Cormos, C. C. (2021). CO_2 Utilization Technologies: A Techno-Economic Analysis for Synthetic Natural Gas Production. Energies, 14(5), 1258.
3. Cormos, C. C., & Dinca, C. (2021). Techno-economic and environmental implications of decarbonization process applied for Romanian fossil-based power generation sector. Energy, 220, 119734.
4. Luca, A. V., & Petrescu, L. (2021). Membrane technology applied to steel production: Investigation based on process modelling and environmental tools. Journal of Cleaner Production, 294, 126256.
5. Galusnyak, S., Petrescu, L., & Cormos, C. C. (2020). TECHNO-ECONOMIC AND ENVIRONMENTAL ASSESSMENT OF HYDROGEN PRODUCTION BASED ON NATURAL GAS STEAM REFORMING PROCESS. Studia Universitatis Babes-Bolyai, Chemia, 65(4).

6. Petrescu, L., Dinca, C., & Cormos, C. C. (2020). ASSESSMENT OF FLEXIBLE CARBON CAPTURE AND UTILIZATION OPTIONS APPLIED TO GASIFICATION PLANTS. Studia Universitatis Babes-Bolyai, Chemia, 65(4).
7. MIHĂILĂ, E. G., Aruxandei, D. C., DONCEA, S., Oancea, F., & DINCĂ, C. (2021). DEEP EUTECTIC SOLVENTS FOR CO_2 CAPTURE IN POST-COMBUSTION PROCESSES. Studia Universitatis Babes-Bolyai, Chemia, 66(2).
8. Cormos, A. M., Dragan, S., & Cormos, C. C. (2022). Integration of membrane technology for decarbonization of gasification power plants: A techno-economic and environmental investigation. Applied Thermal Engineering, 118078.
9. Cormos, C. C., Cormos, A. M., & Dinca, C. (2021). Techno-economic Assessment of Load Following Operation for Super-critical Power Plants Equipped with Carbon Capture Feature. In Computer Aided Chemical Engineering (Vol. 50, pp. 1479-1484). Elsevier.
10. Dinca, C., Slavu, N., Cormos, C. C., & Mihaila, E. G. (2021). Negative CO_2 emissions in biomass gasification process with hybrid amine-deep eutectic solvents. In Computer Aided Chemical Engineering (Vol. 50, pp. 1665-1670). Elsevier.
11. Tanase, A. I., Banica, C. K., & Dinca, C. (2021, October). Technical And Economical Assessment Of IGCC Plant Equipped With Chemical Absorption Process. In 2021 10th International Conference on ENERGY and ENVIRONMENT (CIEM) (pp. 1-5). IEEE.
12. Dinca, I. V., & Dinca , C. F. (2021, October). Technical and Economical Assessment of Membrane Integration in IGCC. In 2021 10th International Conference on ENERGY and ENVIRONMENT (CIEM) (pp. 1-5). IEEE.
13. Mihaila, E. G., Slavu, N., Popa, D. G., & Dinca, C. F. (2021, October). Novel Technology for CO_2 Capture Using Green Solvents. In 2021 10th International Conference on ENERGY and ENVIRONMENT (CIEM) (pp. 1-5). IEEE.
14. Bozonc, A.C & Cormos, A. M. Modeling and simulation of CO_2 capture using MEA in hollow fiber membrane contactors. Monograph, 9th European Young Engineering Conference, 19-21 April 2021.
15. Dinca, C., Slavu, N. & Cormos, C.C. Clean energy from poplar and plastic mix valorisation in a gas turbine with CO2 capture process. 13th International Conference On Sustainable Energy & Environmental Protection Seep2021, 13 September-16 September 2021.
16. Dinca, C., Slavu, N. & Cormos, C.C. Hybrid solvents based on DES and amines for CO2 capture. Authors:. Journal: 16th Conference on Sustainable Development of Energy, Water and Environment Systems (SDEWES), October 10-15, 2021, Dubrovnik, Croatia.