**BIOCOMEM**

**BIO**-BASED **CO**POLYMERS FOR **MEM**BRANE END PRODUCTS FOR GAS SEPARATIONS

**H2020-BBI-JTI GRANT AGREEMENT NUMBER: 887075**

# NEWSLETTER Nr. 6

## 20th November 2023


**Figure 1:** Picture of the 5th Consortium Meeting held in TECNALIA, S. Sebastian, Spain, 19th - 20th of November 2023

Dear BioCoMem friends, I am glad to welcome you to the sixth project newsletter! As you can see from the picture, the last project meeting was held in presence (hybrid for those who could not travel) in November 2023, hosted by Tecnalia in S. Sebastian, Spain, allowing all the consortium members to thoroughly discuss, assess and coordinate project progress and final findings. In fact the BioCoMeM ends on November 30th 2023 – and yes, this was the last project meeting!

**Figure 2:** In presence and online participants at the 5th BIOCOMEM Consortium Meeting (top0) and visits to the TECNALIA's laboratory (bottom)

BioCoMem Project Newsletter is glad to inform you about the main results achieved so far: after suffering some delays due to covid-19, the project has boosted activities and has closed on-track. As an highlight of what flollows, we are trilled to announce that membrane modules for the final demonstration at TRL4 and TRL5 have been well received at the demo site and have been tested at TUE and DMT facilities, respectively.
Enjoy the newsletter reading!

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# Project Objectives

The overarching objective for the BIOCOMEM project is to demonstrate that membrane-based separation techniques using PEBA-type (Polyether block amide) copolymers are more efficient than their heat-based equivalent methods. This will reduce the overall environmental impact through some mechanisms. With this, the BIOCOMEM project has three specific objectives.

- First, to produce two new bio-based PEBA co-polymers at pilot scale. Each of these will be specifically designed to add value to three $CO_2$ separation market sectors: biogas upgrading, natural gas upgrading, and post-combustion flue gas treatment.
- Second, to validate – again at pilot-scale, in an industrially representative environment – a process for manufacturing three different gas separation hollow-fiber membranes that meet specific performance requirements.
- Third, to provide proof of the principle that bio-based membranes can genuinely bring value to the gas separation market.

# Partnership

The BioCoMem consortium gathers now 7 organizations from 4 countries including top-level European Research Institutes, Universities, and representative top industries in different sectors (3 SMEs and 1 IND).
The consortium brings together multidisciplinary expertise in catalysts synthesis, membranes development, chemical and process engineering development, and construction of turn-key solutions in the energy sector including operation and maintenance (i.e. biogas upgrading plants design), modeling and simulation, LCA, and industrial risk study.

# BioCoMem in progress

**Helmholtz-Zentrum Hereon** developed two additional multilayer thin-film composite membranes with the prototypes A1 and C bio-based PEBA copolymers as separation layers, following with their successful upscaling.

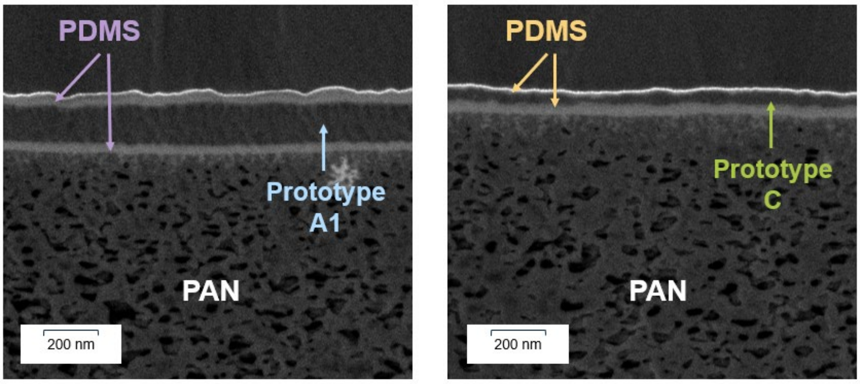



**Figure 3: Cross-sectional SEM images of the upscaled five-layered TFCMs developed at Hereon with the prototypes A1 and C bio-PEBAs.**

The upscaled membranes were integrated into membrane modules at two different scales:

1. A demonstrator module “K100 PN40” (prototype A1) containing 0.45 m² of membrane area, which will be tested at the DMT facilities in Netherlands for natural and biogas upgrading.
2. Two lab-scale modules “K100” (prototypes A1 and C) with 0.06 m² of total membrane area each, which will be further tested at TUE for diverse $CO_2$ separations.

The performance of all three membranes developed within the BioCoMem project can be summarized in the following Table 1.

**Table 1 Average single gas permeances and ideal selectivities measured for TFCMs developed at Hereon via the pressure increase method at 30 °C, $p_{feed}$= 800 mbar and Am= 8,3 cm².**

| TFCM | Permeance [GPU] | | | Selectivity [-] | |
|---|---|---|---|---|---|
| | $N_2$ | $CH_4$ | $CO_2$ | $CO_2/N_2$ | $CO_2/CH_4$ |
| Prototype A | 65 | 204 | 2027 | 31,0 | 9,9 |
| Prototype A1 | 46 | 142 | 1598 | 34,4 | 11,2 |
| Prototype C | 34 | 97 | 1019 | 29,9 | 10,5 |

In BIOCOMEM, **Maastricht University (UM)** developed two new classes of poly(ether-*b*-amide) (PEBA) polymers for gas separation membranes. The problem with commercial PEBA’s is that they are not soluble in solvents needed to make hollow fiber membranes, what hampers their processability.
UM developed two new classes of PEBA, prototype B and prototype C. The monomers used for the polyamide block are biobased and their introduction offers the potential to improve the PEBA solubility. In prototype B, the polyamide is based on biobased dimer fatty acid and in prototype C the polyamide is based on a sugar derivative. The prototype B and prototype C polymers could be processed into membranes by Tecnalia and Hereon. Screening experiments with flat sheet membranes show that the $CO_2$ permeability for prototype B and C even outperforms reference polymers. The selectivity e.g. $CO_2/N_2$ and $CO_2/CH_4$ is only slightly lower than for the reference polymers.
The best PEBA polymer compositions from prototype B were upscaled by Arkema and further used by Tecnalia and Hereon for making membrane modules. Prototype C was limited to lab scale synthesis, but the amount of polymer was enough for extensive membrane evaluation at Hereon.

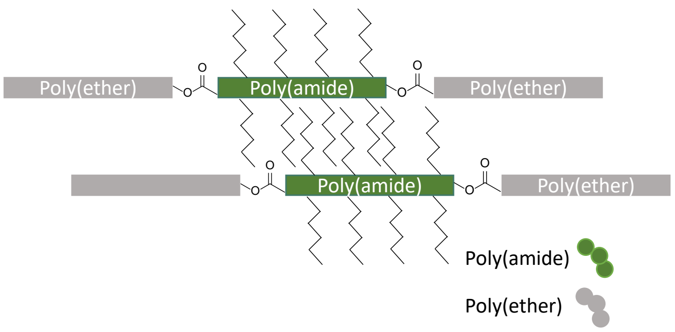



**Figure 4: Graphical representation of PEBA prototype B**

At **Tecnalia**, developed prototype B co-polymer has an intrinsic $CO_2$ permeability of 396 Barrer and CO2/N2 selectivity of 36. This co-polymer was processed into a hollow fiber membrane by a single step coextrusion with the same co-polymer at a higher polyamide content. Same chemical composition allowed good adhesion between the layers within the non- solvent induced phase separation step of the production process and higher polyamide content provided stable and improved porosity.
Scanning electron microscopy and porosity analysis (based on image processing) are provided below:

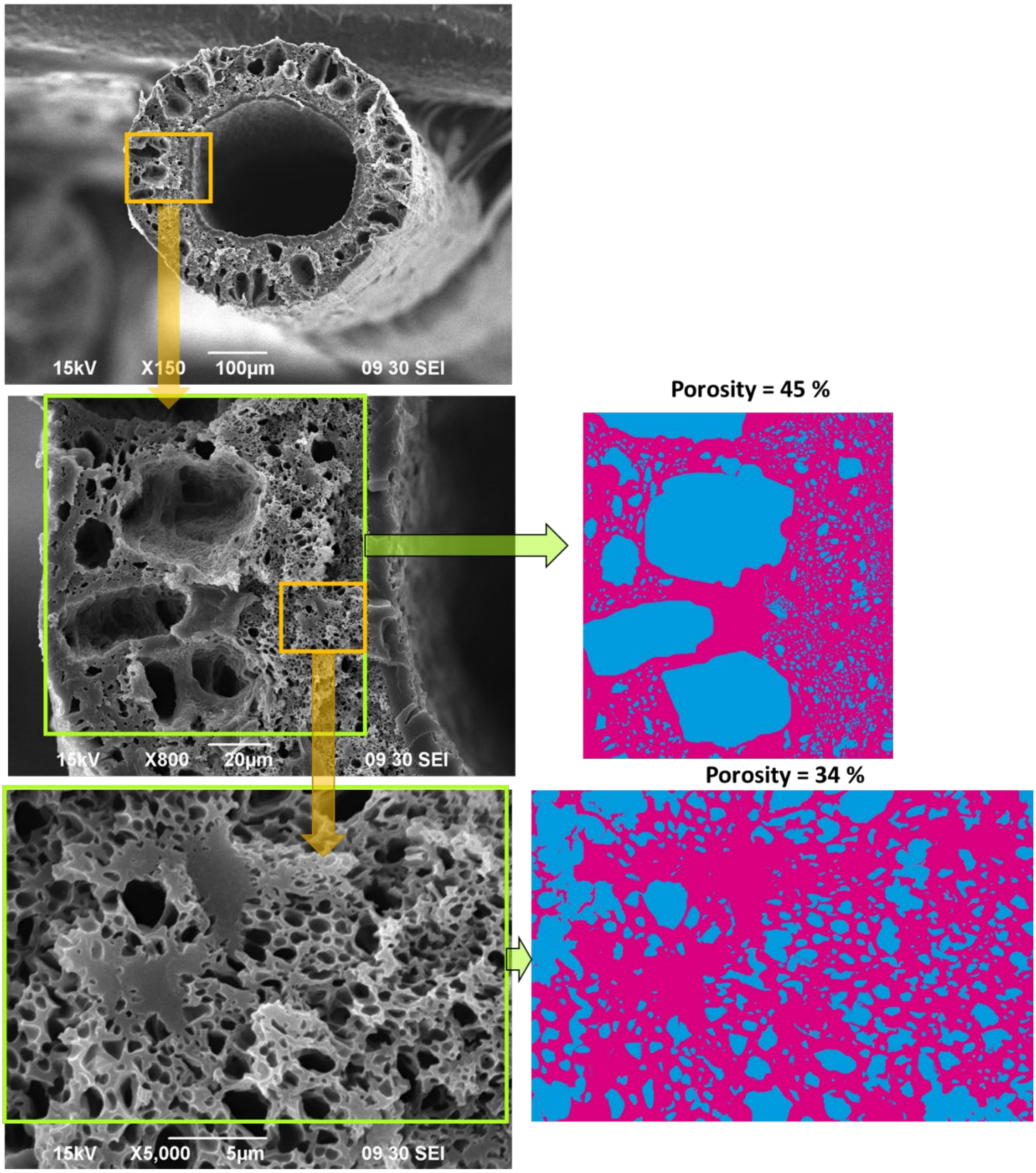



Figure 5: SEM and image-based porosity measurements at TECNALIA

The influence of fabrication parameters was evaluated at different quench bath temperatures, air gap heights and take up rates, keeping all the other parameters constant, i.e. 50 °C spinning temperature and 80/20 wt% H2O/solvent ratio. As shown in the table below main results are that Increasing the coagulation bath temperature determines an increase in the permeance and an increase in the take up rate increases the selectivity.

| Quench Bath Temp | Air gap height | Take up rate | 35 ºC 2 bar feed pressure 1 bar permeate pressure | | | | 50ºC 2 bar feed pressure 1 bar permeate pressure | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (ºC) | (cm) | (m/min) | PCO2 (GPU) | Standard error for PCO2 (GPU) | aCO2/N2 | Standard deviation for aCO2/N2 (GPU) | PCO2 (GPU) | Standard error for PCO2 (GPU) | aCO2/N2 | Standard error for aCO2/N2 |
| 22 | 10 | 5 | 38,51 | ±2,61 | 3,29 | ±0,13 | | | | |
| 21,5 | 1,5 | 5 | 29,63 | ±1,04 | 4,60 | ±0,25 | 33,30 | Only one module | 8,44 | |
| 21,5 | 1,5 | 10 | 37,10 | ±11,69 | 5,03 | ±0,16 | 69,60 | Only one module | 7,61 | |
| 39 | 10 | 5 | 74,43 | ±10,11 | 1,77 | ±0,29 | | | | |
| 38,8 | 1,5 | 8 | 67,92 | ±3,49 | 4,15 | ±0,06 | 87,12 | ±3,30 | 5,21 | 0,86 |

In more optimization runs is expected to achieve 400 GPU CO2 permeance and 30 CO2/N2 selectivity.

**Eindhoven University of Technology** has finalized the design of a superstructure-based mathematical model for the optimization of $CO_2$ removal in three applications including post-combustion $CO_2$ capture, natural gas sweetening and biogas upgrading. Two typical polymeric membranes prepared within the BIOCOMEM project, with different selectivities and gas permeabilities were studied to assess the potential of these membranes at a real industrial scale. Using a superstructure-based model, operating conditions, driving force distribution along each membrane stage, the use of feed compression and/or permeate vacuum, the number of stages and recycle options were simultaneously optimized, and then the most promising membrane-based process configuration was chosen. The multi-stage membrane process was investigated in terms of energy consumption, membrane area and gas processing cost. Additional sensitivity analyses were undertaken to characterize the influence of membrane properties and separation targets on the process layout, power consumption and membrane area. The results revealed that high purity and recovery at a minimum cost could be achieved by the three-stage process in post-combustion $CO_2$ capture and natural gas while in biogas upgrading the two-stage configuration exhibited the best performance. It was found that as membrane selectivity increases, power consumption decreases from 5338 kW to 4622 kW in natural gas, and from 2036 kW to 1298 kW in biogas upgrading. It was concluded that power consumption and membrane area are strongly depend on separation target. The optimization results indicated that total membrane area increases from about 550000 $m^2$ to 1220000 $m^2$ when separation target increases from $CO_2$ recovery and purity of 90% and 95% to CO2 recovery and purity of 95% and 98% in post-combustion $CO_2$ capture.

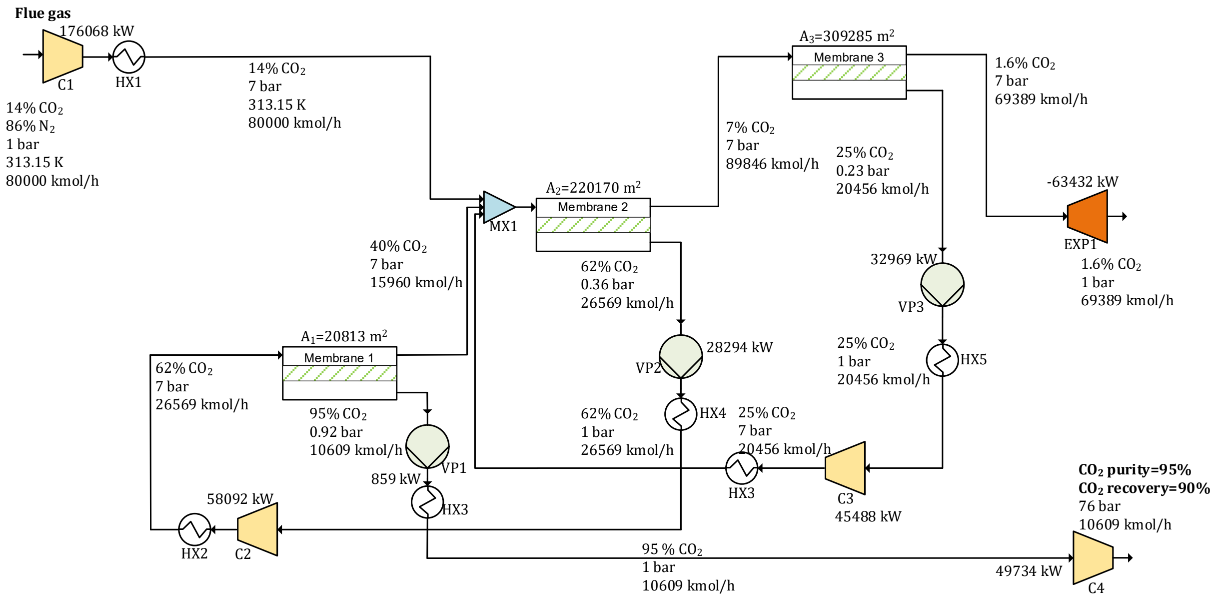
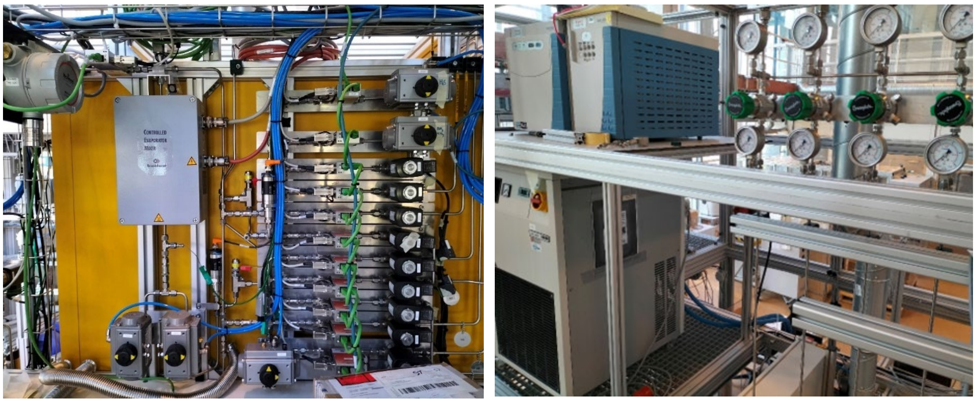



**Figure 6: An example of multi-stage membrane process scheme developed in BioCoMem**

In addition **Eindhoven University of Technology** has launched the TRL4 demonstration campaign at its own laboratories (Figure 7). Data will be shared in future open access scientific publications.

Two experimental campaigns in relevant environment has been successfully completed by **DMT Environmental Technology (**Figure 8**)**. $CO_2$ separation from biogas has been demonstrated at TRL5 during 2 x 240h of operation using the up-scaled thin-film composite membrane (TFCM) prepared by **Helmholtz-Zentrum Hereon**.

**B4Plastics** has gained valuable insights in the process of upscaling the foundational components necessary for the development of gas separation membranes.
This progress has paved the way for a subsequent project named **Cumeri**, where B4Plastics, Tecnalia and Uinversity of Maastricht aim to elevate the knowledge acquired from Biocomem to a higher Technology Readiness Level 7 (TRL7).
As a company participating in BioCoMem, it has been a very positive experience as we've adopted a broader perspective, recognizing the interplay between chemistry, scale-up processes, and the crucial properties required to meet specific criteria for successful gas separation



Mass flow controllers, CEM and pneumatic valves, chillers and pressure readers

Operator desk, GC, chiller, vessels with level sensors

**Figure 7: BioCoMem membrane separation set-up at Eindhoven University of Technology for TRL5 campaign**

**Figure 8: Hereon's installed membrane module tested at DMT premises**

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# The BioCoMem Dissemination Activities and Events

## 16th International Conference on Catalysis in Membrane Reactors

**Date:** 16th -18th October, 2023

The conference has been held in Donostia-San Sebastian (ES), hosted by TECNALIA. The aim of the ICCMR conferences is to promote the research and progress in the area of catalytic membrane systems by bringing together academic scientists and industry working in the membrane, catalysis and process engineering fields. The meeting highlighted recent developments, bring new ideas, help making contacts and create a platform for discussion between academics and practitioners. All the participants had great opportunity to make beneficial contacts and exchange ideas. The conference has addressed also young researchers who had a chance to interact closely with senior scientists. http://www.iccmr16.org/

BioCoMem was present at the ICCMR-16 event with the following oral presentation:
**Rouzbeh Ramezani (TU/e):** Process simulation and cost evaluation of membrane systems for CO2 removal using a superstructure approach

## Final BioCoMem Dissemination Video

A second video of the project has been released in October 2023.

The purpose of the dissemination video is to inform about the expertise of each partner and his contribution to the project during the path towards the demonstration of bio-based polymeric membrane technology for carbon capture purposes. The video targets not only stakeholders and potential end user, but also to a wider audience. For these reasons, the video has been published on all Biocomem platforms, including its website and social media platforms.

This is the second short video (~2 to 3 minutes) where the material has been created by each single partner under the supervision of the project coordinator and the communication manager. The video is available here

# Webinars

## "Biobased membranes for $CO_2$ separation"

**Date:** June 26th 2023 – 10:00-12:00

A first dedicated BioCoMem webinar to discuss the main methodologies, challenges and achievements of the BioCoMem project has been held on June 26th . Speakers have been Dr. Angeles Ramirez/ Dr. Sergey Shishatskiy (Hereon), Dr. Oana David (Tecnalia), Dr. Rouzbeh Ramezani (Eindhoven University of Technology), Stefan Frehland (Quantis).

Link to watch the registration here


## "Pathways to demonstrate the BIOCOMEM technology for future bio-based membranes deployment in industry"

**Date:** November 24th 2023 – 10:00 – 12:30

A second BioCoMem webinar has been held on November 24th to discuss about the main results achieved during the project, and included presentations from Dr. Oana David (Tecnalia), Dr. Sergey Shishatskly (Hereon), Dr. Rouzbeh Ramezani (Eindhoven University of Technology), Andrea Randon (Eindhoven University of Technology).

Link to watch the registration here

# BioCoMem final remarks by the Coordinator, Dr. Oana David

BIOCOMEM was a challenging project that aimed to go all the way from monomers to end products for three applications. Project was successful when thin film composite membranes were developed because this method can adapt to coating many polymers. The resulting membranes have competitive properties with market benchmark. Spinning of monolithic hollow fibers was more challenging and several new polymer synthesis strategies had to be developed in other to improve processability. Final hollow fiber membranes are not competitive with market benchmark from the point of view of their gas separation properties but have the advantage, respect to thin film composite membranes, that these use about 80 % of biobased polymer and have potential to be recyclable. In more process optimization trials these properties can improve.

Nevertheless, as results of the LCA assessment we arrive at the conclusion that the environmental impact of the production of the membranes themselves is insignificant (it represents less than 0,1 of the total carbon footprint over the life cycle) compared to their performance during the application (i.e., energy use during operation). This is because production operational aspects as power are so severe over the lifetime (estimated by us of 5 years) that the material production should is just a fraction of the foot print.

# BIOCOMEM Website

Visit the BIOCOMEM project at the address – www.biocomem.eu and follow the project on LinkedIn and YouTube.
Let us have your comments!
This is the last Newsletter of the BioCoMem project.

Biocomem H2020 Project GRANT AGREEMENT N°: 887075

*Biocomem 2020*

## BIOCOMEM in figures:

- ✓ ***7 partners***
- ✓ ***5 countries***
- ✓ *3.1 M€ project*
- ✓ *Start June 2020*
- ✓ *Duration: **42 months***
- ✓ *Key **Milestones:***
  - ❖ Development of two new PEBA co-polymers suitable for monolithic hollow fiber membrane production
  - ❖ Optimized recipe for HF membrane production by coating using reference bio-PEBA
  - ❖ Optimized recipe for HF membrane production by spinning using new aromatic/cycloaliphatic polyamide-b-polyether bio co-polymer
  - ❖ Optimized recipe for HF membrane production by spinning using new lignin-g-(polyether-b-polyamide 11) bio co-polymer
  - ❖ Demonstrate the Ciocomem technology at TRL5 and TRL6

Project Manager:
Dr. Oana David
Tecnalia
Oana.david@tecnalia.com

Project Innovation Manager:
Ass. Prof. Ketrien Bernaerts
University of Maastricht
Katrien.bernaerts@maastrichtuniversity.nl

Dissemination Manager:
Dr. Luca Di Felice
Eindhoven University of Tecnology
l.d.felice@tue.nl

Exploitaion Manager Manager:
Dr. Oana David
Tecnalia
Oana.david@tecnalia.com

More information on BIOCOMEM available at the project website:
https://www.biocomem.eu/