

Decarbon3BIO - Bio-decarbonization Systems for Sustainable Biomass, Biofuel and Bioproduct Production



Over the past century, human activity has profoundly altered the natural environment, primarily through the continuous rise in atmospheric carbon dioxide (CO₂) concentrations. As one of the principal drivers of climate change, CO₂ emissions have contributed to global warming, ecosystem destabilization, ocean acidification, and the increasing frequency of extreme weather events. Addressing these challenges requires innovative, scalable, and economically viable approaches to carbon capture and sustainable resource utilization. In this context, microalgae have emerged as highly promising biological systems for carbon biosequestration and renewable biomass production. These unicellular photosynthetic organisms demonstrate exceptional CO₂ uptake efficiency, rapid growth rates, and adaptability to diverse and often harsh environmental conditions. Unlike terrestrial energy crops, microalgae can be cultivated in saline, brackish, or wastewater streams, eliminating competition for arable land and freshwater resources. Their cultivation can therefore be integrated into circular and industrial symbiosis models.

Beside carbon capture, microalgae represent also a versatile biofactory capable of synthesizing a broad spectrum of high-value compounds. Their biomass contains lipids, proteins, pigments, terpenes, terpenoids, polysaccharides, and other bioactive molecules with applications across multiple sectors, including bioenergy, pharmaceuticals, cosmetics, food and feed industries, and sustainable agriculture. Our project is designed to harness this metabolic potential through the development of advanced, integrated microalgae-based CO₂ capture systems. A central approach of Decarbon3BIO project involves the cultivation and comparative evaluation of selected microalgal strains in controlled photobioreactor systems. These closed cultivation platforms enable precise regulation of environmental parameters, ensuring stable growth conditions and allowing the identification of strains with superior carbon fixation capacity and biomass productivity.

In the next steps, we will focus on comprehensive biochemical profiling of the produced microalgal biomass in order to identify and quantify high-value fractions, including:

- **Lipids** – essential precursors for advanced biofuels such as sustainable aviation fuels (bio-jet fuel), as well as valuable sources of omega-3 and omega-6 polyunsaturated fatty acids (PUFAs);
- **Terpenes and terpenoids** – multifunctional organic compounds widely used in cosmetics and pharmaceutical formulations, including natural pigments such as chlorophylls and carotenoids applied in food products, feed additives, dietary supplements, and cosmeceuticals;
- **Organic fractions suitable for biofertilizer production**, supporting soil regeneration and sustainable crop cultivation.

By integrating advanced analytical techniques with principles of the circular economy, Decarbon3BIO aims to maximize environmental sustainability, economic feasibility, and full biomass valorization. The project adopts a holistic systems-based approach, combining localized environmental assessments with state-of-the-art biotechnological and chemical analyses to design “zero-waste” microalgal bioprocesses. Through interdisciplinary collaboration across biotechnology, chemistry, environmental engineering, and agricultural sciences, Decarbon3BIO will generate scientifically validated and scalable solutions for climate mitigation, renewable fuel development, and sustainable bioproduct manufacturing. The outcomes will form a robust foundation for large-scale international collaborative initiatives and strategic partnerships with industrial stakeholders, contributing to long-term decarbonization efforts and the advancement of environmentally responsible technologies.