The awareness of the climate catastrophe resulting from human impact and the increasing sense of responsibility within modern society for the environment have spurrednew initiatives in researching and developing innovative material and technological solutions. One of the most important endeavors in materials science involves the introduction of innovative bio-based polymeric materials. They aim to diminish environmental impact compared to their petrochemical equivalents, with a defined product life-cycle, and properties that enable comprehensive and safe application. At the same time, the rising prevalence of novel biodegradable and bio-based polymers within the overall plastics market creates the need to develop dedicated/specialized methods for processing their mixtures and the use of technologically difficult-to-separate polymeric grades resulting from the chemical similarity of the materials.

The most effective method of reusing polymer waste is mechanical recycling. It involves grinding and re-processing mostly thermoplastic polymers in the molten state into new full-value products. In the case of processing immiscible and non-separable polymers of various types, the properties of the final products are often characterized by deteriorated functional properties, including mechanical ones, in relation to each component. Hence, a primary scientific concern in the field of recycling involves the exploration of new methods of compatibilization and enhancement of polymer miscibility. In the case of the packaging industry, two of the most promising alternatives to petrochemical polymers like poly(ethylene terephthalate) (PET) or polypropylene (PP) are polylactide (PLA) and poly(ethylene 2,5-furandicarboxylate) (PEF). Both of these polymers belong to the group of bio-based polyesters: PLA is the most frequently processed compostable thermoplastic polymer, while PEF, due to its favorable barrier and mechanical properties, is a real alternative to PET. The literature describes the production of PLA-PEF mixtures, and the problem of deterioration of their properties resulting from the incompatibility poses a threat to the purity of the post-consumer polymer stream intended for further use. At the same time, achieving miscibility in a PLA-PEF system may yield materials with favorable technological and functional properties. As a result, the development of a miscible PLA-PEF system is expected to bring about not only the introduction of a new type of material but also the establishment of novel methods for a sustainable and conscious approach to closing the life cycle of products and materials already present on the market.

As part of the **siliCOMP** project, activities will be undertaken to develop a new process-oriented approach to the compatibilization of immiscible thermoplastic biopolyesters (PLA, PEF). This involves the use of innovative and highly effective hybrid organic-inorganic silicon nanomodifiers (silsesquioxanes - SQs) through a dedicated processing path. The approach to employing SQs as coupling agents in the PLA-PEF mixture will involve describing interactions. This includes incorporating a suitably functional SQs (relative to PLA) as part of the PEF macromolecule during its synthesis, producing PEF-SQs nanodispersions through in-situ processes, or using SQs as a reactive additive introduced in the molten state during the shaping of PLA-PEF mixtures. Beyond the current research implementation patterns, we aim to increase the process scale and explore structural changes in blends. These changes result from chemical and physical interactions between their components, now compatibilized with a new generation of coupling agents (SQs), and are further influenced by shear forces under real technological process conditions. The impact of process conditions will be diverse, shaping the blends with varying chemical compositions through three distinct methods: an almost shear-free system (rotational molding), intense shear conditions (twin-screw extrusion), and the utilization of a specially designed cavity transfer mixer (CTM) with ultra-high shear forces. A comprehensive approach to the process of creating interactions in complex two- and three-phase systems based on PLA and PEF biopolyesters will enable the identification of the most advantageous modification and processing routes. As a result, new and environmentally friendly materials will be developed with high potential for use in the packaging and food industries. The entire process will be guided by environmental impact analysis through Life Cycle Assessment (LCA), facilitating the optimization of synthesis and processing processes to produce a polymer mixture with the most favorable functional properties and the smallest carbon footprint.