The presented research project titled *"Role of Renewable Antioxidants in the Thermal and Thermo-Oxidative Performance of Thermoplastic Bio-Polyurethanes Subjected to Multiple Recycle Cycles"* is a direct response to the current demand in the plastics market for materials with favorable properties, a reduced environmental footprint, and suitability for a circular economy. This topic is highly relevant in the context of both waste management challenges and the search for new, sustainable industrial solutions. The project aims to develop a bio-based thermoplastic polyurethane (bio-TPU) with a high content of bio-components that can also undergo multiple mechanical recycling cycles. Research within the project focuses on the use of a bio-based processing additive—renewable antioxidants—to protect the material from degradation during processing.

This project addresses the growing issues of plastic waste and its environmental impact. While plastics play a crucial role in the economy—owing to their wide applications in construction, automotive, medical, electronics, and sporting goods—they are also highly durable, which can be both an advantage and a disadvantage. Without proper recycling, they become an environmental burden. Consequently, increasing attention is being devoted to materials with a lower carbon footprint and proven recyclability. The introduction of bio-based plastics to the market can reduce greenhouse gas emissions and curb the consumption of fossil resources. Moreover, their production using biomass and plants enhances the role of agriculture in the economy.

The project proposes three main research pathways. The first involves the synthesis of bio-TPU using bio-based components—bio-polyols, bio-diisocyanates, and bio-chain extenders—to achieve a high content of plant-based ingredients exceeding 75%. The second pathway includes multiple mechanical recycling cycles, which do not require additional reagents and utilize the unique feature of thermoplastics: their ability to melt and be reprocessed. The third research area focuses on the use of natural and sustainable antioxidants, such as ferulic acid, vitamin E, caffeic acid, and vanillin. The addition of these compounds aims to prevent the degradation of bio-TPU during recycling cycles. For comparison purposes, recycling will also be performed on bio-TPU without additives and with synthetic antioxidants (such as butylated hydroxytoluene—BHT).

The subject matter of the project is innovative, as although the mechanical recycling processes for olefin-based plastics (like polyethylene or polypropylene) are well understood, they have not been extensively studied for thermoplastic polyurethanes. Meanwhile, TPU is used in many industrial applications, including shoe soles, belts, bags, electronic cases, and more. During mechanical recycling, TPU is exposed to elevated temperatures, oxygen, and shear forces, which can lead to oxidation and deterioration of its properties. Adding antioxidants during processing can limit degradation processes, extend the material's lifespan, and improve recycling efficiency.

The most important anticipated outcome of the project is to demonstrate that it is possible to design and manufacture a bio-based thermoplastic polyurethane and subject it to multiple processing cycles without a significant loss of its key mechanical and thermal properties. Additionally, the use of renewable, bio-based antioxidants will protect it from thermal and thermo-oxidative degradation. The results obtained could fill the existing gap in scientific reports on plastics recycling and shed new light on ecological and efficient alternatives to commercial synthetic TPUs. The use of plant-based components and natural antioxidants aligns with the principles of green chemistry and may open new industrial and economic perspectives in the field of modern materials. The project supports national, European, and global efforts to reduce waste and protect the natural environment.