

*This is an Executive Summary of one of the ZEBRA-LIFE project deliverables.*

## **D.1.3. PROJECT ANNUAL REPORT (YEARS 1, 2, 3)**

---

An overview of ZEBRA-LIFE project activity from M1 to M36 to reach the project objective is summarized following the 8 specific objectives (SO), each one linked to a work package;

- SO1: Renewable bio-aromatics formulation optimized for cosmetics, food, fuels and lubricants and rubber applications.

The project successfully extracted 10 tons of lignin and assessed its potential as an antioxidant across various applications – food, rubber, cosmetics, fuel, and lubricants. Preliminary testing and formulation work were conducted, leading to the production of several lignin-derived antioxidant batches. These batches were tested in end-user products with promising initial results, particularly in rubber and, with formulation, in food and cosmetics. Research focused on improving lignin solubility led to a successful method for incorporating it into lubricants and fuels. The project culminated in optimized process conditions and a finalized production layout, informed by end-user feedback.

- SO2: Demonstration of online monitoring of antioxidant capacity during production process.

BQC developed an electrochemical sensor for real-time monitoring of antioxidant capacity during lignin processing. After optimizing cleaning and measurement techniques, the sensor successfully demonstrated its ability to measure antioxidant activity in lignin samples. Two sensor units were delivered to CENER for testing – first for initial process control, and then for use in a pilot plant setting – with positive results confirming its effectiveness as a control tool. Further integration and testing within the pilot plant are ongoing to enable immediate post-reaction antioxidant assessment.

- SO3: ZEBRA-LIFE Pilot plant fully operative.

The integrated pilot plant for lignin processing completed its engineering design in year one. Following a tendering process, all necessary equipment was contracted and installed within CENER's BIO2C facility, staying largely on schedule. The plant became fully operational in April 2025. To date, four production campaigns have been successfully completed, processing 3.5 tons of lignin. The plant is now functioning well and supporting antioxidant batch testing.

- SO4: ZEBRA- products ready to be used as ingredient at pilot scale for different selected applications.

Validation of pilot-scale produced antioxidants is showing no significant differences with their lab-scale counterparts produced in the first half of the project. So far, three samples of lignin derived antioxidants have been validated, both by CENER's quality control indicators and by the partners validation methods. In the following months, more samples will be produced for further validation.

- SO5: Demonstrate that ZEBRA-LIFE has a significant environmental impact in the EU circular economy.

A monitoring and reporting plan was established, defining key performance indicators (KPIs) to track the project's environmental and socio-economic impact both during project lifetime and five years after its completion. Mass balance calculations were performed to assess the process's environmental and economic feasibility within a pulp and paper plant context. Furthermore, a strategy for implementing an Environmental Management System (EMAS) at the pilot facility is underway, reinforcing the project's commitment to circular economy principles.

- SO6: Confirm economic feasibility and sustainability of the ZEBRA-LIFE processes and final applications.

A techno-economic analysis (TEA) has been updated using data from the pilot plant, providing a more accurate assessment of production costs and economic feasibility for various lignin applications. The analysis benchmarks lignin-derived products against fossil-based alternatives and incorporates preliminary findings from a study assessing potential customer willingness to pay. Full results will be detailed in a forthcoming deliverable.

- SO7: ZEBRA-LIFE processes and final applications ready to be scaled up.

Collaboration between CENER and Smurfit Westrock has established a shared understanding of the technical requirements for the ZEBRA-LIFE process and defined product/waste stream interfaces. Smurfit Kappa has investigated potential suppliers of lignin production plants to assess implementation feasibility for commercialization. Based on plant capacity and available technology, a lignin processing capacity of 10,000 tons/year is considered most realistic, and various exploitation scenarios are being evaluated based on the resulting products.

- SO8: All relevant stakeholders are aware of the beneficial impact offered by ZEBRA-LIFE.

The project has actively disseminated its progress through established communication channels, including a website, social media, newsletters, and marketing materials. Collaboration with other related EU projects is ongoing, with plans for a joint webinar and a working group focused on developing guidelines to facilitate end-of-waste status for valorized waste products.

The project has increased its visibility by presenting at relevant local and international events, conferences, and webinars. Proactive stakeholder engagement has broadened support and provided valuable perspectives. These efforts aim to ensure the project's relevance and impact within both local and European contexts.

The project is progressing as planned with effective communication between partners. Major efforts have focused on product development, pilot plant construction, and initial production campaigns. Twelve deliverables have been completed, and 21 consortium meetings held, with minor delays managed effectively. Key milestones, including website launch, pilot plant commissioning, and antioxidant capacity monitoring, have been achieved. Assessments relating to environmental and economic impacts are underway.

In conclusion, the project remains on track, demonstrating successful progress in both technical development and collaborative execution, with a slight delay on final deliverables to ensure thorough testing and validation.