The CALIMERO Project concludes with novel approaches to Life Cycle Sustainability Assessment

- *The CALIMERO project pioneered tailored Life Cycle Sustainability Assessment methodologies to enhance environmental, social, and economic performance across Europe's bio-based industries.*
- *CALIMERO improved assessments through advanced industrial simulations, new biodiversity and toxicity indicators, and multi-objective optimization.*

Madrid, Spain. 21 October 2025 – After developing a sustainability assessment for Europe's bio-based sectors for four years, the CALIMERO project comes to an end. CALIMERO has significantly improved sector-specific and cross-cutting sustainability metrics by implementing Life Cycle Sustainability Assessment (LCSA) methods across actual industrial case studies, representing the construction, textile, pulp and paper, biochemical, and woodworking industries. The project's efforts improve ecotoxicity, biodiversity, and circularity assessments, opening the door for more relevant Product Environmental Footprint (PEF) calculations inside the EU.

CALIMERO developed advanced simulation models across multiple sectors, enabling industries to better understand emissions, energy use, and resource flows, and supporting more sustainable decision-making. These simulations enabled a sector-specific understanding of emissions, energy efficiency, and resource flows, guiding improvements through comprehensive sensitivity and uncertainty analyses.

To improve the modeling of bio-based material sustainability, CALIMERO developed the Land-use Impact on Landscape Connectivity (LILaC) indicator, which introduces spatial modeling of biodiversity into life cycle analysis, to better measure ecological impacts. Additionally, the project used two sets of characterization factors, for human toxicity and ecotoxicity, assessing prediction modeling when data is challenging to acquire.

CALIMERO also integrated Social Life Cycle Assessment (S-LCA) and Life Cycle Costing (LCC) into its methodology, using high-fidelity industrial simulations and machine learning approaches. The S-LCA framework enables the quantification of social impacts such as job creation and occupational health across simulated manufacturing scenarios. Meanwhile, LCC details economic outcomes, evaluating profitability, operating expenses, and investment returns. The project used advanced simulations and machine learning algorithms to enable European industries to include data-driven social and economic assessments of sustainability.

Regarding the enhancement of circularity measurement in bio-based goods, CALIMERO has made significant progress. CALIMERO compared different methods, highlighted their limitations, and explained when each is most suitable. LCA approaches are also contrasted with circularity indicators to identify effective combinations of indicators for assessing circularity strategies, like increasing the recycled content, better collection, or improved energy recovery. The project also created a methodical approach to evaluating potential supply risks for bio-based products, via a novel criticality framework and tool. Additionally, by adding time-dependent process data to databases, CALIMERO improved the dynamic evaluation of carbon footprints by capturing important elements like carbon storage and postponed emissions from bio-based products.

To balance competing sustainability objectives, like social benefits, cost, and environmental impact, CALIMERO used Multi-Objective Optimization (MOO), tested in case studies. Specifically, a Python metaheuristic evolutionary

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algorithm was used for the woodworking industry, and a discrete epsilon-constrained method was used for the textile industry. These examples show how MOO can be used to identify optimal processes and explore trade-offs in LCSA~~,~~ via advanced computational tools.

With these Life Cycle Sustainability Assessment (LCSA) techniques, CALIMERO was able to demonstrate~~,~~ real decreases in greenhouse gas emissions, toxic impacts, and operating costs of bio-based companies, along with increased job creation potential.

CALIMERO then identified sector-specific and cross-sectoral opportunities for industrial symbiosis and circular resource use, such as textile waste serving as feedstock for construction materials or pulp and paper by-products supporting biochemical production. This underscores the untapped potential for cascading use, resource recovery, and economic resilience within bio-based industries.

A set of final guidelines and monitoring frameworks was produced by CALIMERO for sector stakeholders, LCSA practitioners, and policymakers to track sustainability progress effectively. By integrating monitoring frameworks aligned with the EU Bioeconomy Monitoring System and encouraging improvements in the Product Environmental Footprint method, CALIMERO enables progress in the bio-based industry of Europe, aligned with the EU Green Deal's vision for a fair and circular bioeconomy.

The activities carried out by CALIMERO have guided the development of its Theory of Change, a strategic framework that explains how theory of change, a strategic framework that maps out how targeted actions in process optimization, data transparency, collaboration, and balanced demand for bio-based products can drive transformative changes across Europe's bioeconomy sectors. It contains four key pathways (regenerative optimization, integration of comprehensive life cycle sustainability assessments, collaboration and adaptive governance, and balancing economic viability with environmental and social responsibility). The Theory of Change will inform and enable stakeholders in the bio-based industries assessed and beyond to understand the changes, incentives, penalties, and feedback loops that influence industry behavior. This promotes circular and sustainable progress after the end of the CALIMERO project.

About CALIMERO

CALIMERO is a European Project whose goal is to **create a common framework for the Life Cycle Assessment methodologies** of certain bio-based industries' sectors. Assessing their processes will help identify the main sources of pollutants and **analyze potential solutions**.

The CALIMERO Consortium, composed of 12 partners from seven countries, brings together expertise from across research, industry, and policy sectors. Coordinated by Contactica, the project covers five critical sectors: construction, woodworking, textiles, pulp and paper, and biochemicals. With a total budget of €3,518,900, the project will conclude in 2025, having built a foundation of improved sustainability practices and tools that will continue to guide and strengthen bio-based industries across Europe.

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