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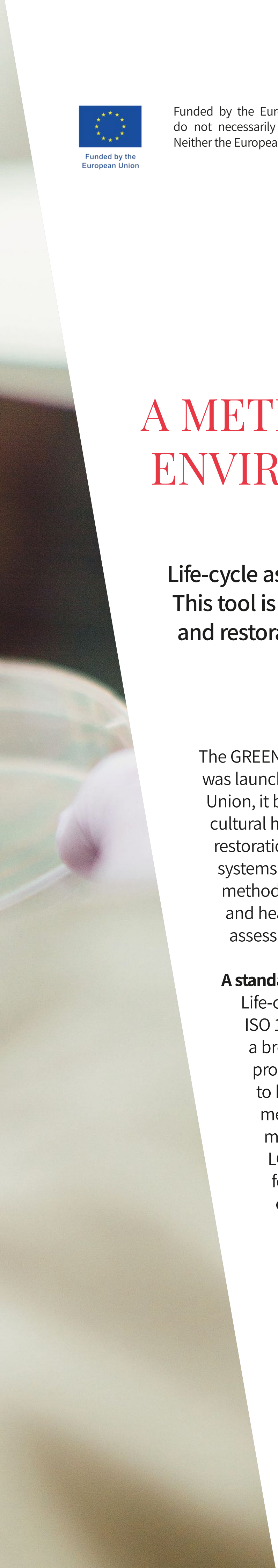

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A METHODOLOGY FOR ENVIRONMENTAL SUSTAINABILITY

Life-cycle assessment measures the environmental impacts of a product or service. This tool is used to evaluate the new green products for art conservation and restoration developed by GREENART researchers.

The GREENART project — or Green Endeavor in Art Restoration — was launched on 1st October 2022. Financed by the European Union, it brings together researchers working towards sustainable cultural heritage by developing new environmentally friendly restoration and conservation products in art. To rethink existing systems and formulate new ones, researchers rely on various methodologies to assess their efficiency, environmental impact, and health risks. One of these methodologies, life-cycle assessment (LCA), is crucial. What are its principles?

A standard framework for LCA

Life-cycle assessment is standardised according to ISO 14040:2021 and 14044:2021. These standards belong to a broader system assigned to environmental management, providing a framework for organisations and companies to harmonise their ecological approach through shared measurement tools and standards. After decades of methodological development and practical application, LCA has been adopted by the European framework for the assessment of “Safe and Sustainable by Design chemicals and materials” (EC SSbD), established in December 2022 by the Joint Research Centre, the scientific and technical research laboratory of the European Union. This framework works towards defining criteria and evaluation procedures for chemicals and materials, while advocating a hierarchical approach.

This approach guides GREENART researchers in developing new conservation and restoration products. Elena Semenzin is an associate professor in environmental chemistry; she assesses environmental risks and impacts related to traditional and emerging pollutants. Alex Zabeo, one of the founders of GreenDecision, is an expert in computer science and software development for decision support, including LCA. Involved in the safe and sustainable design of products developed by GREENART, they explain: “The first three steps of the EC SSbD framework primarily consider security aspects, covered by hazard and risk assessment approaches. The environmental aspect, the fourth step, must be assessed through the measurement of environmental sustainability covering the entire life cycle of the products.” This is where they use the LCA method, conducted on their innovative products.

The fifth step of the EC SSbD approach includes the evaluation of socio-economic aspects related to the production of chemicals and materials, aided by the methodologies of social life-cycle assessment (LCA-S) and life-cycle costing (LCC).

— Diotima Schuck

Analysing the life cycle of a product

Analysing the life cycle of a product is necessarily done from an environmental perspective. It involves understanding each stage of its life, from the extraction of raw materials — which can be minerals, metals, fossil fuels, wood, etc. — to its production phase. But this analysis doesn't stop there because it also considers distribution, use, maintenance, and repair until the end of the product's life. The product then becomes waste that can be reused, recycled, or disposed of depending on the possibilities it offers. And in a life-cycle assessment, all these stages are taken into account, each with factors that must be distinguished, analysed, and interpreted.

To conduct this analysis, researchers proceed in four phases, standardised by ISO 14040:2021 and 14044:2021 standards. The first involves defining the objective and scope of the study. For GREENART, it's about comparing new conservation and restoration products to those used today to verify whether they are characterised by reduced environmental impacts. The inventory comes next, meaning recording the inputs and outputs of each elementary process of the system (meaning, the study object delimited for analysis, here the innovative products of GREENART). Inputs include resources, raw materials, or energies, i.e., each element entering the system during one of the life cycle stages. Outputs are the results or waste generated by the system, manifested through atmospheric emissions, solid waste, or water discharges. This inventory of flows is then translated into environmental impacts. Finally, the results obtained are interpreted in the last phase of analysis, with the aim of identifying potential further improvements.

Through these steps, the environmental impact of the product will be evaluated and quantified, taking into consideration various elements. The two researchers explain: "A life-cycle assessment allows for the calculation of several impact categories, such as climate change, acidification, eutrophication, or toxicity to human health. This calculation is based on data collected in the environment, including the presence of oil or chemicals, energy or water consumption, and the emission of greenhouse gases or other substances into the air, water, and soil." They add: "We use relevant references to establish our goals for reducing environmental impacts."

Environmental Footprint (EF) method

In the context of the life-cycle assessment of GREENART's new products, researchers use a specific life-cycle impact assessment (LCIA) method proposed by the European Union, the Environmental Footprint (EF) method. "It is the most reliable, comparable, and verifiable method for measuring environmental performance," explain Elena Semenzin and Alex Zabeo. "The use of EF method is already planned within the framework of EU policies and legislation, such as the Taxonomy Regulation. The EF method considers sixteen impact categories that cover a broad range of relevant environmental issues and are related to several policy objectives such as protection of human and ecosystems health."

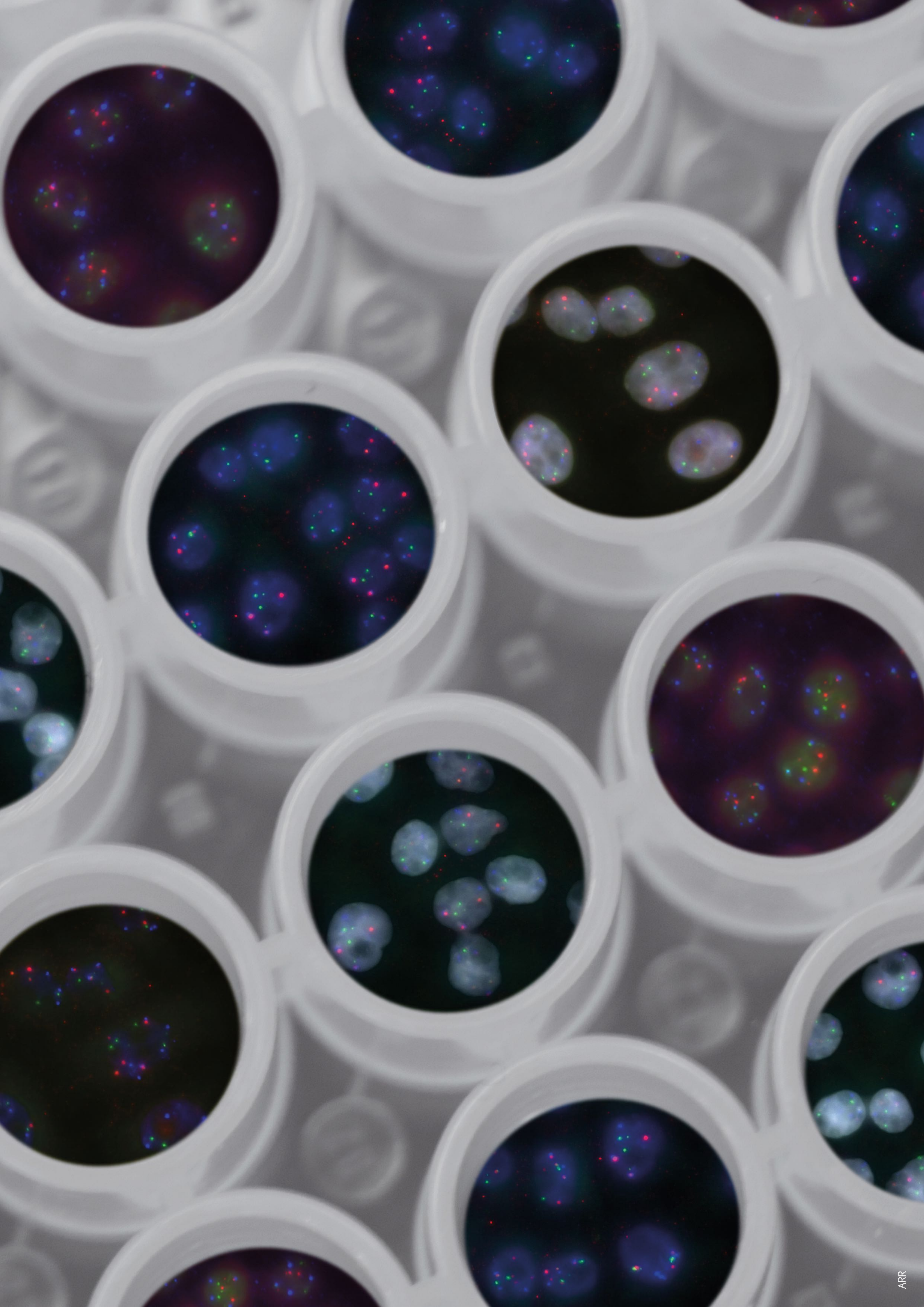
Are there relevant differences among different LCIA methods? The researchers clarify: "Different life-cycle assessment methodologies include different impact categories calculated using specific algorithms. The use of different methods makes it difficult to compare between different studies. For this reason, at the European level, there has been a significant effort towards harmonisation. The EF method is the main result of these efforts. Additionally, alongside this method, an EF database has been developed."

Beyond the evaluation of new products, it is also about measuring the impact of products in use today. Indeed, LCA measures and allows communication on the environmental performance of products developed by organisations through comparative studies. Companies can thus establish comparisons between similar products. "The identification and evaluation of benchmarks are crucial because life-cycle assessment is a comparative tool. And in the EC SSbD methodology, these benchmarks are necessary to establish goals for reducing environmental impact for different impact categories," explain the GREENART researchers, who will work on establishing these benchmark data targeting existing conservation-restoration products in the third year of the project, "alongside the life-cycle assessment of innovative GREENART products."

Methodological limits?

In the EC SSbD methodology, the fifth step, which evaluates the socio-economic impact of chemicals and materials, contains the most uncertainties. Fundamental components of the sustainability concept, social and economic dimensions are "less frequently integrated into the practical application of sustainability assessment", expose the researchers. Unlike life-cycle assessment, social life-cycle assessment (S-LCA) and life-cycle costing (LCC) are not yet standardised internationally. "For this reason, the analysis is characterised by more assumptions. Moreover, during the phase of designing new products, there is generally a lack of data at the industrial scale, so the analysis will necessarily be a preliminary analysis and should be iterated as soon as more complete datasets and information become available."

However, these limitations and needs for iterative application also affect LCA due to the complexity of



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accurately collecting all the incoming and outgoing flows of a product's life cycle.

"Life-cycle inventory data — collected in the second step of life-cycle assessment — represent the backbone of LCA because they transform a product system into unit processes and quantifiable input and output flows to assess their environmental impacts. And the evaluation of the quality of this data is crucial," comment Elena Semenzin and Alex Zabeo. "Another limitation is associated with the comparability of life-cycle assessment studies. This is due to the high degree of subjectivity inherent in life-cycle assessment, mainly arising from the wide range of choices and assumptions that the practitioner must make when modelling the studied system, as well as the vast variety of available databases and calculation methods. For this reason, the main efforts are directed towards the harmonisation of the methodology."

As a relative method, life-cycle assessment can primarily establish whether the impacts of the evaluated product are above or below a selected reference. Thus, the GREENART researchers explain: "Ongoing efforts are focused on absolute life-cycle assessment, which, based on planetary boundaries, aims to provide environmental impact scores that are objective and absolute."

For now, GREENART implemented the first step of the EC SSbD framework by conducting evaluations of the human health, environmental and physical hazards of products under development. "We are currently working to finalise the safety aspects evaluation, and it is only in the final year, for the most promising products that are positively evaluated in the preceding stages, that we will proceed with life-cycle assessment, life-cycle costing, and social life-cycle assessment," conclude the researchers.


Photo Marvin von Hagen

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