

# Measuring sustainability: life cycle assessments drive green innovation in OXIPRO

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Sustainability is a buzzword in today's world, but for real progress to happen, it must be backed by science and thorough analysis. The EU-funded OXIPRO project is a recent example of this approach, using innovative enzyme-based solutions to create more sustainable consumer products. One of its key tools in measuring and improving sustainability is **life cycle assessment (LCA)**. But what exactly is LCA, and why does it matter?

LCA is a method used to evaluate the sustainability impacts of a product or process from its beginning to its end—a 'cradle-to-grave' analysis. By integrating LCA at an early stage of development and at lower technology readiness levels (TRLs), OXIPRO is exemplifying responsible innovation.

## Why LCA matters in OXIPRO

The OXIPRO project focuses on developing oxidoreductase enzymes for applications in detergents, textiles, cosmetics and nutraceuticals. Each of these sectors has significant environmental challenges, from chemical pollution to excessive energy and water consumption. LCA helps quantify these environmental impacts and compare new enzyme-based processes to traditional methods. This way, OXIPRO can demonstrate not only environmental benefits but also identify potential drawbacks early on so that they can be tackled efficiently.

To fully understand why OXIPRO's research incorporates LCAs as a fundamental part of the process, it helps to crystallise the benefits of oxidoreductase enzymes. Enzymes are biological molecules, typically proteins, that act as catalysts to speed up chemical reactions. They are essential for life, enabling biological processes to occur efficiently. Unlike many conventional chemical catalysts, enzymes work under moderate temperatures and pressures, making them more environmentally friendly.

The innovation cases in OXIPRO rely on the use of oxidoreductases. Oxidoreductases are a specific class of enzymes that facilitate oxidation-reduction (redox) reactions. These reactions involve the transfer of electrons between molecules, which is a fundamental process in many biological and industrial applications. Oxidoreductases can replace traditional chemical processes that often rely on harsh solvents, high energy input and environmentally damaging reagents. By introducing these natural catalysts into various consumer product formulations, OXIPRO aims to make industrial

processes cleaner, safer and more efficient.

However, simply replacing a chemical with an enzyme does not automatically guarantee a lower environmental footprint. This is where LCA becomes crucial. LCA allows us to assess whether the new products relying on OXIPRO enzyme production and application are genuinely more sustainable than existing conventional products. It evaluates multiple environmental and social aspects in addition to assessing factors contributing to the economic sustainability of developed applications. By performing LCAs early in the research and development process, OXIPRO aims to ensure that its innovations actually contribute to sustainability rather than merely shifting the environmental burden elsewhere.

One of the unique aspects of OXIPRO's approach is applying LCA at the research and development (R&D) stage rather than waiting until the technology is fully developed. This means that sustainability is considered from the outset, allowing for adjustments before the technology is commercialised. This is particularly important for novel enzyme applications, where potential environmental benefits need to be balanced against factors like production methods and raw material sourcing.

## Different types of LCA applied in OXIPRO

Not all LCAs are the same. The OXIPRO project employs multiple types of LCA to get a well-rounded picture:

- **Environmental LCA (ISO 14040/44)**  
This assesses factors such as carbon footprint, water use and chemical emissions throughout the value chain. It helps determine if the new enzyme-based processes truly reduce environmental impacts.
- **Social LCA (S-LCA)**  
This goes beyond the environment to consider how the new processes affect people, including workers, consumers and local communities.
- **Economic LCA (E-LCC)**  
Sustainability isn't just about being

green—it also must be economically viable. This type of LCA looks at cost factors throughout the product life cycle to ensure long-term feasibility.

By combining these different approaches, OXIPRO exploits **life cycle sustainability assessment (LCSA)**, which provides a broad, holistic view of the impact of its innovations.

## Examples from the OXIPRO innovation cases

LCAs are not just a theoretical exercise—they have real-world applications in the OXIPRO innovation cases:

### Textile biobleaching

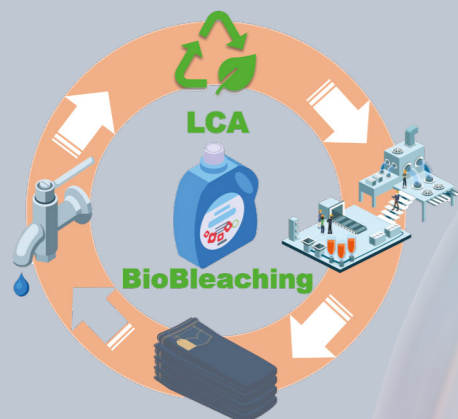
Traditional textile bleaching relies on harsh chemicals that can harm both human health and the environment. OXIPRO is developing an enzyme-based biobleaching process that could replace these chemicals while reducing water and energy use. The LCAs conducted on this process help highlight the potential reductions in emissions and resource consumption compared to conventional bleaching methods. This process has the potential to make textile production more circular by enabling more sustainable material processing while reducing pollution from industrial wastewater.

### Nutraceuticals from fish by-products

The seafood industry produces significant waste, much of which could be re-purposed for human consumption. OXIPRO is investigating how enzymes can be used to transform fish by-products into high-value nutraceuticals (such as protein supplements). Here, LCAs help determine whether the process is genuinely beneficial from an environmental perspective. This innovation could contribute to a more sustainable food system by promoting the upcycling of marine resources into valuable ingredients for human health.

### Low-temperature laundry detergents

Washing clothes at lower temperatures saves energy but requires detergents that are effective in cold water. OXIPRO



is developing enzyme-based detergent formulations that work efficiently at lower temperatures, potentially reducing household energy use. LCA is used to compare these new detergents to traditional formulations, assessing whether they really make a difference in energy consumption and overall sustainability. The adoption of these detergents could lead to lower carbon emissions from household laundry while maintaining high cleaning efficiency.

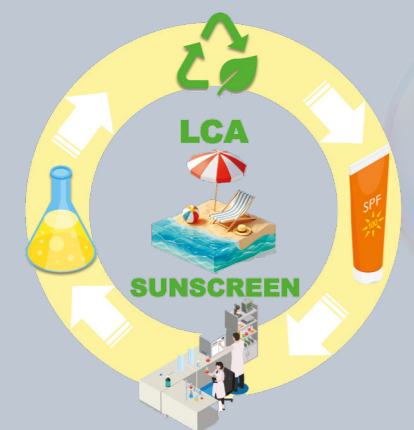


The environmental analysis showed that the determining factor for environmental gains is the lower electricity use due to lower washing temperature. However, considerable environmental savings are only reached when the detergent is used in areas where electricity is generated with fossil fuels. If low-emission electricity is available in use locations, the impact of the production of raw detergent materials will become more relevant.

### Sunscreens with sustainable UV filters



Many conventional UV filters in sunscreens are harmful to marine ecosystems. OXIPRO is developing enzyme-derived UV filters that could be a safer alternative. However, LCA results have shown that while the new filters may be less toxic, other ingredients in the sunscreen formula still have significant environmental impacts. This highlights the importance of considering the entire product, not just one ingredient. The research also points toward the need for further ingredient innovation in the cosmetic industry to create genuinely sustainable formulations.



### Sustainability assessment in the early stages of innovation

One of the unique aspects of OXIPRO's approach is applying LCA at the R&D stage and not only when the technology is fully developed. This means that sustainability is considered from the outset, allowing for adjustments before the technology is commercialised. Typically, there is limited room for environmental improvement in the rest of the life cycle. However, in the design phase, access to robust process data is not easy.

Assessing sustainability performance at different design stages demands vast amounts of information. Traditional process design already requires extensive data, including physicochemical properties, unit operation models, costs and market details. Adding environmental and social dimensions significantly increases data needs, including environmental impacts, health and safety, resource use, emissions, regulations and social statistics (Bhander, Hauschild and McAloone, 2003).

A key challenge in assessing the sustainability of (chemical) processes is the link between information availability, quality and the impact of decisions made at each design stage. Figure 1 illustrates how various factors evolve in evaluating process sustainability throughout the design stages. Early stages, such as product and process design and conceptual engineering, are characterised by limited and low-quality information with high uncertainty. Despite this, early decisions—guided by available data and expert knowledge—play a crucial role in shaping the process's overall sustainability.

According to Katri Behm, OXIPRO's sustainability assessment leading expert at VTT: "Integrating LCA from the earliest stages of R&D ensures that we identify and address sustainability challenges before they become locked into a product's design. This approach allows us to fine-tune innovations, making sure they fully contribute to a greener future."

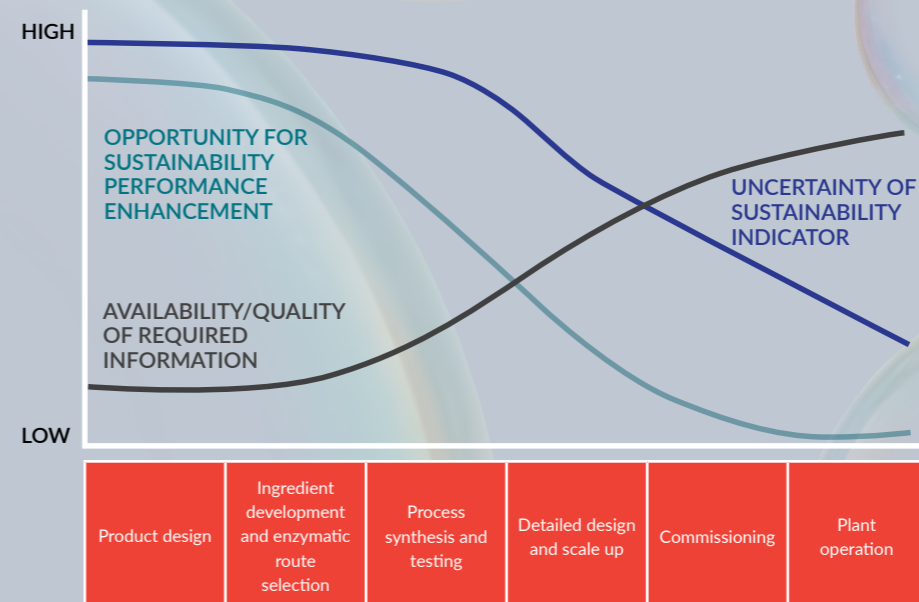


Figure 1: Sustainability assessment of a chemical process at various stages of process development. Modified from Argoti, Orjuela and Narváez (2021).

### Conclusion and recommendations

The OXIPRO project is a valid example of how sustainability should be approached—not as an afterthought but as an integral part of innovation. By using LCA at an early stage, the project can ensure that its enzyme-based solutions are not just scientifically sound but also genuinely sustainable.

LCA offers more than just data—it influences decision-making. By integrating LCA early in the process, OXIPRO can refine its innovations to maximise their environmental benefits while avoiding unintended consequences. The insights gained from LCA studies help:

- guide research priorities by identifying environmental hotspots and ensuring that innovation efforts focus on areas with the most impact

- inform policymakers through robust LCA data that supports regulatory approvals and policy development
- attract investors and consumers by providing credible evidence to verify sustainability claims.

As OXIPRO progresses, the continued use of LCA will help fine-tune its developments, proving that sustainability and innovation can go hand in hand. By setting this precedent, OXIPRO is not only creating greener products but also paving the way for a more responsible approach to scientific research and technological advancement.

### References

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### PROJECT NAME

OXIPRO

### PROJECT SUMMARY

OXIPRO is developing sustainable, enzyme-based solutions for greener consumer products in four sectors: detergents, textiles, sunscreens and nutraceuticals. By harnessing oxidoreductases, a versatile unexploited class of enzyme, its technologies promise to reduce energy, water, and harsh chemical use, enhancing product quality while minimising environmental impact and upcycling waste into valuable products, driving the transition to a circular, eco-friendly economy.

### PROJECT PARTNERS

NORCE, Norway (Project Coordinator)  
VTT, Finland  
LEITAT, Spain  
Universitat Autònoma de Barcelona, Spain  
Barcelona Supercomputing Center, Spain  
Calyxia, France  
Gecco Biotech BV, Netherlands  
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Biocatalysts Ltd, United Kingdom  
Rijksuniversiteit Groningen, Netherlands  
SB Science Management UG, Germany  
CRB, Netherlands

### PROJECT LEAD PROFILE

Dr Gro Bjerga, the OXIPRO Project Coordinator at NORCE Norwegian Research Center AS, has a distinguished career in marine biotechnology and enzyme development. Specialising in enzyme discovery, protein production and bioprospecting, Dr Bjerga's research focuses on creating biotechnological solutions for the bio-based marine industry. With expertise in optimising enzymes for industrial applications, she leads projects using advanced molecular biology techniques, including recombinant cloning, heterologous protein expression and enzyme activity assays. Her work is instrumental in driving innovation for greener, more sustainable industrial processes.

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