



FuturEnzyme

Legacy

A Science-Policy Brief on
Advancing Enzyme Technology
for Greener Consumer Products



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the European Union**

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Introduction

Stablished in 2021, the FUTURENZYME project¹ is dedicated to developing enzyme-based innovations for the real-world production of consumer goods.

By embracing enzyme technology, we can build a world where industrial progress goes hand-in-hand with environmental responsibility, leading to cleaner products, more efficient processes, and a healthier planet for all. These innovations directly align with the European Union's (EU) safety goals under the European Green Deal², Circular Economy Action Plan³, Safe and Sustainable by Design framework (SSbD)⁴, and the Clean Industrial Deal⁵.

What is the power of enzyme technology, and how does the FUTURENZYME project contribute?

Enzymes are proteins with a superpower. Found in all living organisms, they help speed up natural chemical reactions, and offer a promising alternative to synthetic chemicals in manufacturing process and product ingredients⁶.

Demand for sustainable, eco-friendly products is skyrocketing, especially when it comes to items used around the home, meaning that using enzymes in their production and use represents a great opportunity to meet those needs, without sacrificing product effectiveness. If industries could drastically reduce their environmental impact by replacing traditional chemical processes with biodegradable enzymatic solutions, consumers could easily choose products made with fewer chemicals, less waste, and greater care for the environment, driving to truly sustainable production and consumption. The FuturEnzyme project has the aim of developing enzyme-based innovations for the production of more sustainable and environmentally responsible consumer goods, such as a liquid detergent, a specific group of fabrics, and a cosmetic formulated with hyaluronic acid.

FUTURENZYME: Towards cleaner products and more efficient processes for a healthier planet

The **FUTURENZYME project** has developed an innovative enzymatic technology for more sustainable industrial production, which is well on its way to market readiness in three sectors.



In detergents, enzymes are a key ingredient in the formulation enabling the break down and removal of stains at lower temperatures. This significantly reduces energy and water consumption and minimises chemical waste.

In textiles and fashion, enzymes are added to the aqueous solution that is applied to the fabric to provide a sustainable alternative for removing polluting chemicals that are introduced during fabric production.



"The development/application of enzymes in the textile industry will be used even more and, above all, the very high-water consumption will be reduced. This means that textiles can be produced more efficiently and in a more environmentally friendly way through shorter and less aggressive pre-treatment processes so that the textile is less damaged and therefore more durable in clothing for end consumers"

Nazanin Ansari
(Schoeller Textil AG), project partner.



In cosmetic and personal care, enzymes are used to break the polymer hyaluronic acid into fragments of the specific size. This process has lower energy costs in comparison with conventional production methods and no chemical additives are used.



These sectors have a high environmental impact due to the intensive use of water, energy, and chemicals. For example, a washing cycle for 7 kg of clothes, the cleaning process of chemicals introduced during the production of 1 kg of polyester fabric, and the production of 1 kg of hyaluronic acid for cosmetic products result in a total of 16.3 kg of CO₂ eq in the 'climate change' category and 8.24 m³ eq of water in the 'water use' category. Enzyme technology innovations not only help reduce the intensive use of water, energy, and chemicals but also pave the way for more sustainable consumer goods that can meet the rising demand for environmentally friendly and effective options.

Feedback from consumers



Consumer interest in sustainability is becoming increasingly central to purchasing decisions, particularly in the household products sector. The growing commitment to reducing environmental impact and adopting more responsible practices by companies responds to increasing consumer demand for sustainable solutions, with many willing to pay a premium for eco-friendly alternatives.

The introduction of enzymes into the usage or production steps of consumer products represents a significant opportunity to meet these sustainability needs. This aspect is particularly relevant, as consumers seek ecological solutions but prioritize product effectiveness.

Making technological innovation with enzymes an easy and accessible option for businesses committed to adopting eco-friendly practices, consumers can also benefit by having a choice of sustainable products.

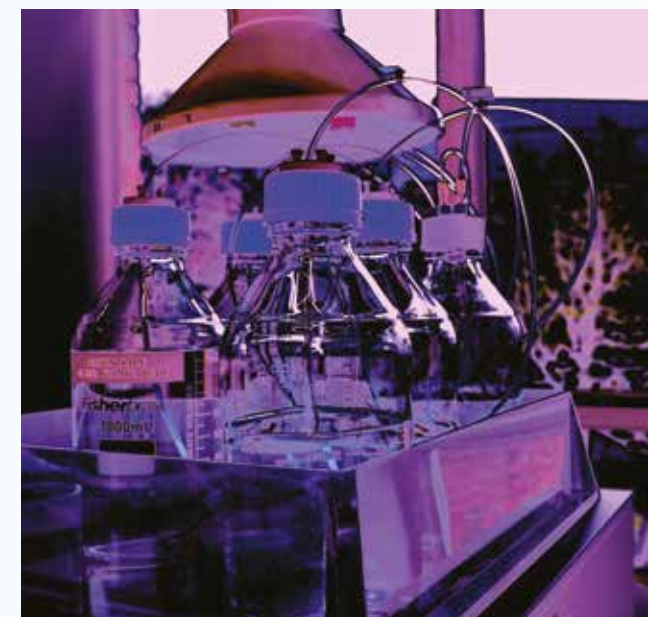
FUTURENZYME: Making viable enzyme solutions

Despite the enormous potential of this technology, enzymes have been underutilized in many industries to date, with challenges in efficiency, scalability, and affordability hindering their adoption in real-world production of consumer products.

One of the biggest challenges is finding and producing the right enzyme for each job, process and product.

"Not all detergents, textiles, or cosmetics on the market have the same composition or characteristics. Therefore, the enzymes used to make these products greener and more sustainable must have properties tailored to each specific product"

Manuel Ferrer
(CSIC), project coordinator.



For an enzyme to be widely adopted by producers and consumers, it must be both effective and cost-efficient. However, when do producers decide to use an enzyme supplement in their products or processes? Or when do consumers decide to purchase a product that integrates enzymes in the processing or final product? The answer is simple: only when it is both effective and cost-efficient; providing sustainability and innovation is a bonus.

With leading scientists, industry partners, and sustainability specialists, teaming up to discover new and effective microbial enzymes, the FUTURENZYME team handled innovative discovery, and supercomputing and machine learning platforms that optimize enzyme properties based on product needs.

Collaboration across the discovery and production system is necessary for these breakthroughs to make an impact.

**Developing safe enzymes
for a greener world!**





The production and use of biodegradable enzymes make the world greener and safer!

An extensive body of research demonstrates the health and environmental safety of enzymes. The enzymes are fully biodegradable in short time periods without any remnants.

By selecting enzymes from safe microbial and fungal sources, we ensure that the production and use of our enzymes is safe for customers and the environment. The enzymes are obtained by fermentation of “generally recognized as safe” (GRAS) microbial host strains using natural ingredients in closed systems so that harmful contaminations in the enzyme products can be prevented. The microbial production strains are derived from natural bacterial, fungal, and yeast strains modified to overproduce the enzyme of choice. This allows us to obtain enzymes in the desired quality and quantity in an environmentally friendly way to meet and exceed all regulatory requirements for pharmaceutical, food, cosmetics, and other applications.

The future is enzymatic

The technology and enzyme developments made in the **FUTURENZYME project** have provide industries and policy makers with powerful tools to make sustainability a reality for all.

“Imagine if industries could drastically reduce their environmental impact by replacing traditional chemical processes with biodegradable enzyme-based solutions. In addition, imagine if consumers were empowered to easily choose products made with the least chemicals, the least waste, and the most care for the environment – that could truly drive more sustainable consumption,”

Luisa Crisigiovanni
(Altroconsumo), a member of the
FUTURENZYME Advisory Board⁷.



Findings and facts

- **Consumers value ecological solutions but prioritize product effectiveness.** Consumer surveys show that while consumers seek ecological solutions and adopt more responsible practices, they prioritize product effectiveness. Customer orientation is key to success.
- **Enzymes are safe and compliant, meeting the highest regulatory standards with no health nor environmental risks.** No allergic reactions were reported during this project, and the enzymes entering the market are thoroughly assessed according to their corresponding Material Safety Data Sheets.
- **Despite their benefits, enzymes still contribute to environmental impact.** Environmental impacts range from 4.5% to 19.0%, depending on the impact category, when integrated into consumer products and processes. Evaluating these harmonise impacts ensures that innovation meets real needs.
- **Enzyme innovation reached Technology Readiness Level (TRL) 4–5.** Limited project timelines hindered complete safety and efficacy validation, especially for final product prototypes entering the market.
- **The enzyme technology is well on its way towards market readiness.** A relevant example is the use of enzymes to produce hyaluronic acid fragments, which has led to advancements in the cosmetics industry, offering more sustainable and effective solutions, with 30% less emissions during production.
- **The search for new enzymes did not significantly translate into industrial developments.** Despite advances in biodiscovery, enzyme innovation still requires extensive testing, as no single screening method can address the unique needs of each industrial product and process.
- **The enzyme portfolio is highly versatile with cross-sector potential.** The versatility of enzyme candidates exceeded expectations beyond the scope of the project. Out of ~1200 candidates, 0.1% met the needs for our targeted industrial applications., but all others not intended for commercial use by the project’s industrial partners remain available for business in thousands of other applications.

Policy takeaways

Based on these findings, the **FUTURENZYME team** recommends that key stakeholders promote enzyme technology. In brief, governments can use policy levers to incentivize and support sustainable practices, businesses can embrace enzyme technology in their discovery and production methods, and consumers need transparent information to support them in making eco-friendly choices.

To make this possible, we need clear information on the benefits of enzymes, their safety, how they improve these products in a more sustainable manner, and how they contribute to innovative functional properties.



"I envision regulatory measures that incentivize to promote enzyme-based technologies. May their decisions reflect an understanding of the interconnectedness of economic growth, environmental integrity, and social equity, fostering a sustainable and resilient future for all"

Monica Desiree van Logchem
(Evonik Operations GmbH), project partner.

"The main wish is that this kind of projects and cooperations would be supported more often to sensitize the public opinion and policy makers about the benefits of green biotechnology. We would wish that more projects like FuturEnzyme would be funded by the EU because such project provides companies "fresh" energy in R&D to move from routine R&D process to more risky and innovative ones, which would not be possible without a public stakeholder taking certain risks for a greener future"

Jan Modregger
(Biosynth GmbH), project partner.



"Policy makers should encourage industries to adopt greener practices by offering tax incentives, subsidies, or grants. Also, by streamlining regulatory pathways, policy makers could facilitate faster approval and integration of eco-friendly approaches into industrial applications"

Anne Timm
(INOFEA AG), project partner.

"Create and ensure a regulatory environment that allows for easy and unbureaucratic development of enzyme innovations to transform the European industry into a sustainable bioeconomy so that Europe can maintain and extend its pioneering role in enzyme-based industrial processes"

Markus Müller
(CLIB – Cluster Industrial Biotechnology), project partner.



- **Update Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH)⁸.** We propose to reflect enzyme-specific properties and differentiate enzymes from conventional chemical substances in classification and risk evaluation. Labelling enzymes as 'hazardous by default' could raise public concern despite their long history of safe use and without clear evidence of health risks. It could also discourage industry adoption of technologies that support a healthier planet.
- **Offer funding, streamline regulations, and introduce fast-track procedures with reduced administrative burdens to boost enzyme technology.** This may accelerate the commercialization of enzymes, benefiting large industries, SMEs, and start-ups to deliver enzyme-based solutions to the market.
- **Establish dedicated assessment criteria that consider enzyme biodegradability and low toxicity during the production and use phase in industries.** Foster shared acceptance of enzyme safety assessments by various regulatory agencies. Incentivise case-by-case enzyme formats—like liquids, granules, or immobilized or encapsulated enzymes—instead of fine powders to fully exempt enzymes from Category 1 Respiratory Sensitisers.
- **Financial incentives to promote sustainable enzyme innovation through collaborative research and impact assessments.** Initiatives which integrate environmental impact assessments of enzymes themselves—such as carbon, water, and life cycle footprints—will drive sustainability across various industries.
- **Support biotech innovation through funding and partnerships, and streamline regulations to speed up enzyme commercialization.** Strengthen public-private partnerships to drive short-term enzyme commercialisation and long-term biotech innovation, focusing on high-potential enzymes beyond isolated projects, especially those at TRL 4–5.
- **Financial incentives to support pilot projects and demonstration plants for new products.** Establish a procedure to identify and overcome legal, administrative, or other constraints that prevent the market launch of new products accessible through new enzyme technologies.

- **Support the establishment of EU-wide enzyme innovation hubs.** These hubs, uniting diverse stakeholders, would drive innovation and growth by developing reports and market roadmaps for priority enzyme technologies aligned with the EU Green Deal² and its climate and industry goals.
- **Develop information initiatives and awareness campaigns highlighting the safe use of enzymes and their benefits.** Support campaigns to make public opinion and policymakers aware of the benefits of building a large-scale movement for environmental responsibility and green innovation. Inform citizens about tax outcomes in green tech, including enzymatic solutions.

Conclusions

The FUTURENZYME project demonstrates the potential of enzymes to drive more sustainable production in industries such as detergents, textiles, and cosmetics, offering cleaner products and more efficient processes. As consumer demand for eco-friendly products continues to grow, it remains essential that these products also meet performance standards. Enzyme-based solutions can address this by providing both effective and environmentally friendly alternatives. However, despite their potential, enzymes have been underutilized due to challenges related to efficiency, scalability, and affordability. For enzymes to be widely adopted, they must be both effective and cost-efficient.

Fortunately, enzymes are safe, biodegradable, and meet high regulatory standards, making them environmentally friendly and supporting the transition to greener industries. To accelerate the adoption of enzyme technologies, policy makers should incentivize sustainable enzyme innovations, simplify regulatory processes, and foster public-private partnerships. Additionally, public awareness campaigns should emphasize the environmental benefits of enzyme-based solutions, helping to increase their acceptance and use.

The findings and recommendations detailed in this document complement those of the sister FNR-16 projects EnXylaScope, OXIPRO, and RadicalZ, with which we have closely collaborated over the past four years around the R&D theme ‘Enzymes for more environment-friendly consumer products’⁹.

FuturEnzyme's work has revolutionised the model for discovering novel microbial enzymes and their host organisms based on product needs, as well as their design and optimisation using advanced supramolecular engineering, supercomputing, and machine learning platforms. As a publicly funded project involving industrial partners, it has clearly demonstrated value creation within its lifetime. However, its impact will go well beyond the project's end, with many enzymes produced at industrial scale currently under evaluation for commercialisation, and some technological innovations expected to reach the market.

References

- ¹ <https://www.futureenzyme.eu/>
- ² <https://ec.europa.eu/green-deal>
- ³ <https://ec.europa.eu/circular-economy-action-plan>
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- ⁷ <https://www.euroconsumers.org/futureenzyme-tech-greener-consumer-products/>
- ⁸ <https://echa.europa.eu/regulations/reach>
- ⁹ <https://radicalz.eu/cluster/>

Learn more about FuturEnzyme

- **Video Byte.**
<https://vimeocom/1070381049?share=copy> Password: AJE_Enzyme
- **Animated video.**
https://www.futureenzyme.eu/video-by-design_cells/
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<https://www.futureenzyme.eu/comic-by-ainhoa-quiros/>
- **Brochures.**
<https://www.futureenzyme.eu/news/#brochuresen>
- **Zenodo (project's scientific articles).**
<https://zenodo.org/communities/futureenzyme/records>
- **Scientific article on consumers.**
<https://www.mdpi.com/2071-1050/15/17/13183>

The partners of the FUTURENZYME project:



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