



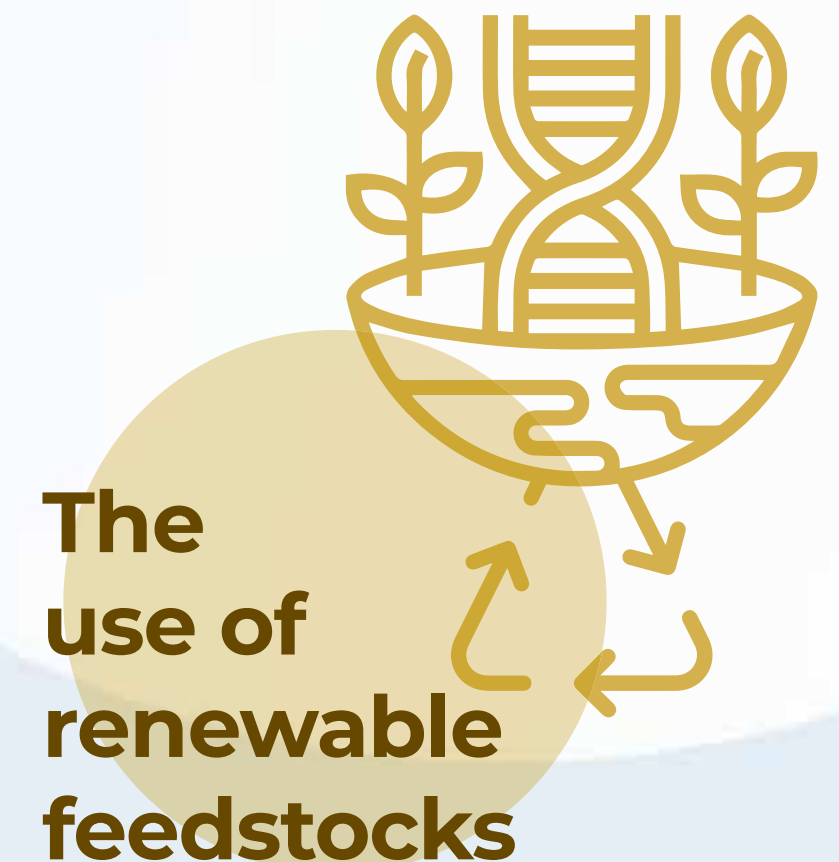
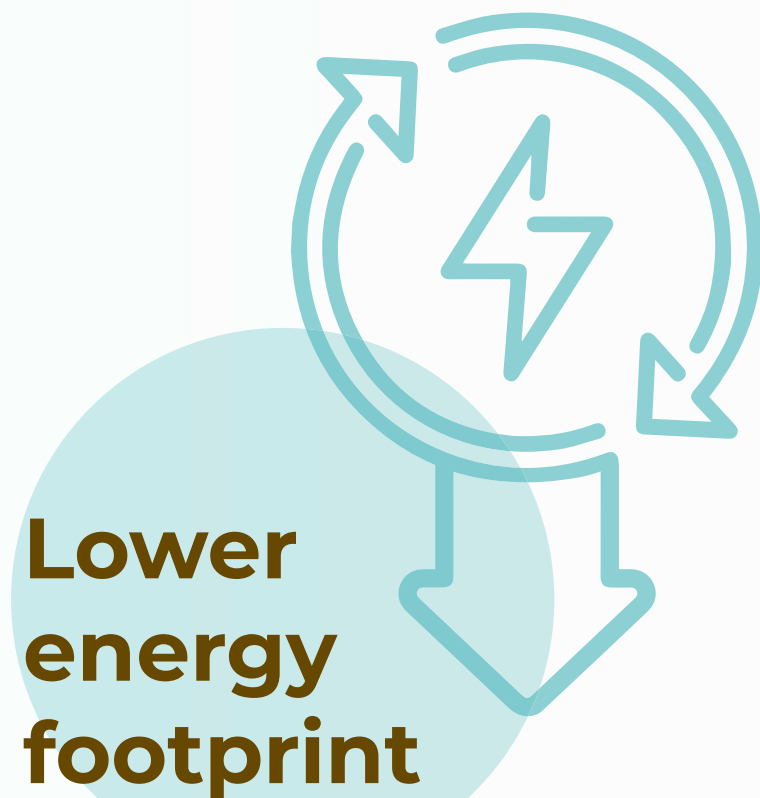
FuturEnzyme. Technologies of
the FUTURE for low-cost ENZYMEs
for environment-friendly products



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Enzymes for sustainable everyday products: benefits and challenges

In a world facing major environmental threats, **enzymes, as green catalysts**, can help alleviate global-warming problems and create consumer products that are more respectful for the environment. The pivotal assets provided by enzymes in industrial processes and consumer products include:



However, several bottlenecks hinder the economic competitiveness and environmental sustainability of enzyme-based consumer products:

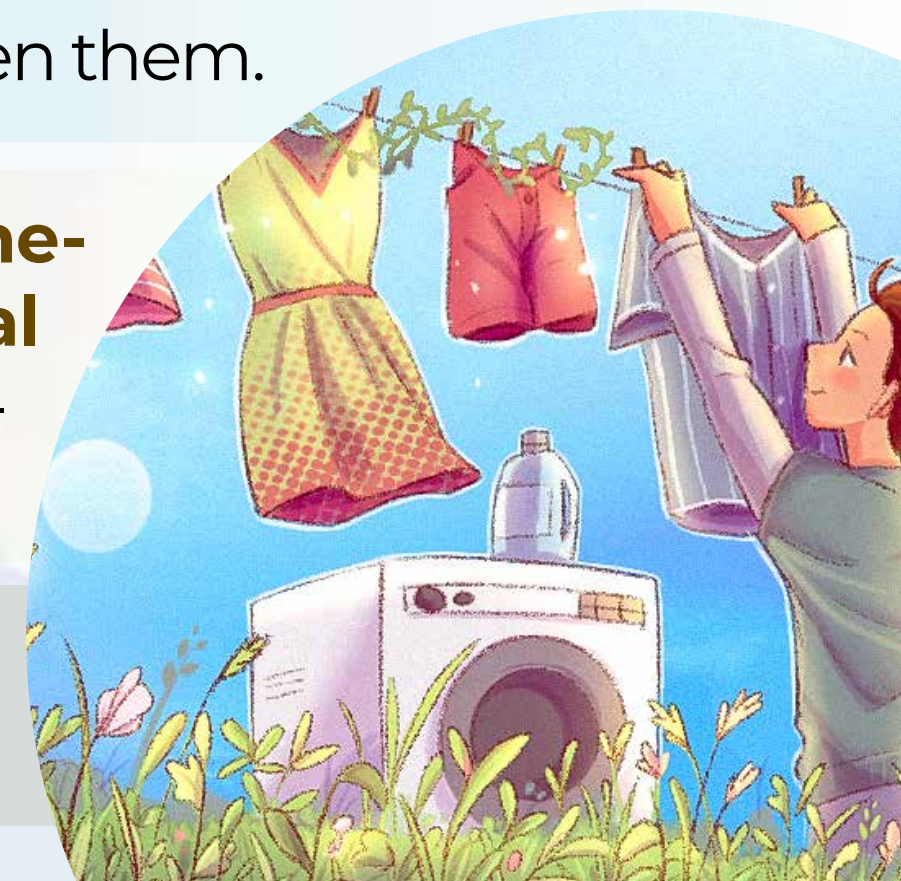
Limited repertoire of available enzymes with the characteristics suitable for use in everyday consumer products.

The inability to bio-prospect enzymes fitting manufacturers' specifications. Indeed, finding and producing a single novel enzyme requires multiple **costly** (approx. 30,000 €) **and time-consuming** (approx. 15 months) iterative cycles.

The limited incorporation of artificial intelligence for enzyme discovery. As example, a wealth of more than 280 million sequences (each representing an enzyme) are available in public databases and new sequences can be obtained at low price, but little use has been made of it so far because the absence of advanced computational resources (hardware, software) to screen them.

Enzymes often need **gradual improvements**. However, **most current engineering efforts applied to known enzymes come up short to meet industrial needs**, and concerns remain about using current machine learning algorithms to improve new enzymes.

Poor enzyme productivity along with high development, production, and formulation costs once an enzyme is selected and further implemented.





All together, the major challenge and biggest hurdle when approaching the bio-processing of consumer products with enzymes is to develop the new enzymes in timescales short enough to meet the needs of consumers and the climate and circular bioeconomy objectives.

FuturEnzyme project

FuturEnzyme's ambition is to develop **“intelligent” enzymes** that meet the characteristics of efficiency and stability required by industry. This will be achieved through a massive bio-prospecting of enzymes from microorganisms, including those from remote and inaccessible places, and their massive analysis with the help of supercomputers. On the other hand, a number of techniques will be applied to improve, both technically and economically, the performance and productivity of the best enzymes. We strongly believe that with these enzymes, that themselves are **eco-ingredients**, we will guarantee not only **high ecological standards** (reduction of water pollution and consumption, chemical usage, waste production and energy consumption) but also **high performance** of three consumer products (cosmetics, textiles and detergents) already in the market.

Expected results: experimentation and digitalization for enzymes bio-prospecting

FuturEnzyme project has the ambition to develop **2 web-based resources** to screen for enzymes meeting the manufacturers' specifications required by detergent, textile and cosmetic sectors:

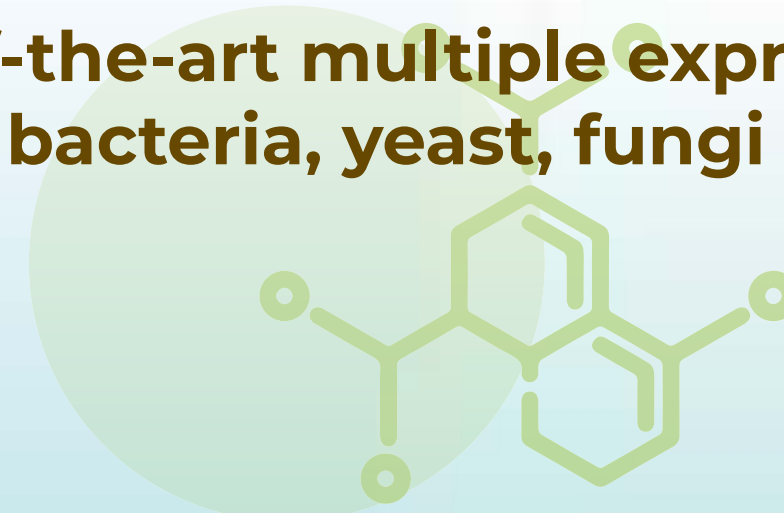
- **An online semi-automatic Hidden Markov Model based search tool**
- **An online machine learning-based predictive search tool**

The development of these tools will be based on two main points. First, detailed **knowledge of the characteristics** that enzymes must meet for inclusion in liquid detergents and the bio-processing of anti-ageing cosmetic ingredients and textiles. Second, the detailed analysis of a large number of enzymes to help us **associate sequences with properties** desired by industry. The FuturEnzyme high-tech platform will be also based on different technologies, including:

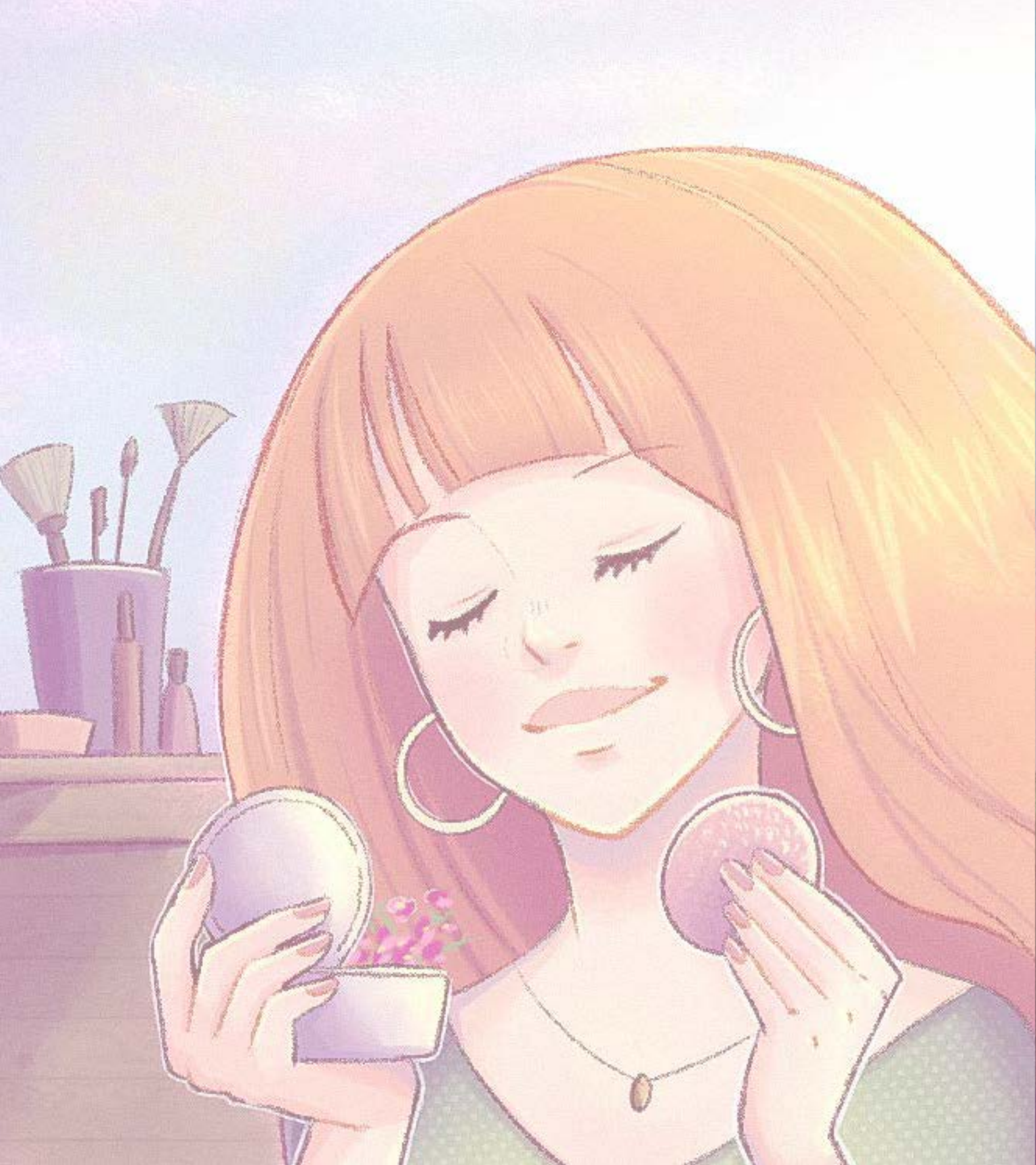
- **Activity-based enzyme bio-prospecting**
- **Cultivation of novel microbes**
- **Disruptive enzyme engineering approaches**
- **Enzyme implementation through immobilisation and shielding technology**

- **Beyond state-of-the-art multiple expression technologies in bacteria, yeast, fungi and archaea**
- **Biocatalysis**

Starting from 1,000 enzymes pre-selected by using computer- and functional-based screens, the project will select 180 enzymes with validated manufacturer requirements, of which 18 will be engineered to obtain a 100-fold more effectiveness compared to the existing ones in the market. **At the end, 9 enzymes** with verified features will be developed to improve 3 consumer products (cosmetics, textiles and detergents) already in the market.







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