European Cluster
Enzymes for Greener Products
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Enzyme technologies for more sustainable consumer products

Key Messages

- Global greenhouse gas emissions (CO_2) are now at 38 Gt and may reach 60 Gt by 2050.[1] Certain industry sectors significantly contribute to CO_2 emissions. Our success in reducing these emissions can be increased through better integration of enzymatic solutions in targeted sectors.
- The integration of enzyme technologies in certain products, namely detergents, textiles, cosmetics, and nutraceuticals, has a proven potential to increase their sustainability. Greening textiles, detergents and cosmetics with enzymes can reduce the carbon demand by 42 million tons per year, according to recent estimates.[2]
- A new EU Cluster - Enzymes for Greener Products - brings together the knowledge, expertise, and technological capacity of 56 research, industry, and innovation organisations across 17 countries to take on the challenge of applying enzymes to boost the development of greener products, fast-tracking them to market, and enhancing climate neutrality.

Enzymes are proteins that act as biological catalysts and help speed up chemical reactions

Consumer concerns about the environment

Currently, 63% of people across 17 countries say that climate change is “very serious” and are concerned about the state of the environment[3] and particularly resource use and depletion: according to a European Commission survey,[4] 56% of EU consumers care about the environmental impact of goods and services. Eco-consumerism is on the rise, as are concerns about the impact of specific products such as household detergents, cosmetics, food, and clothes. European consumers are also willing to pay more for consumer products that are environmentally friendly.[5]

The enzyme solution

Growing environmental concerns have contributed to the rapid growth of the enzyme market as well as their use in various industrial and speciality applications. Enzymes can be ‘domesticated’ in such a way that they are now key actors in the circular economy with the potential to support sustainability, reduce environmental pollution, lower processing costs, and enhance product performance and functionality. Enzyme technologies have the potential to annually decrease CO2 emissions by 1 to 2.5 billion tons, the carbon demand to synthesise artificial chemicals (currently 140,000) by 200 million tons, and chemical waste by 90 million tons.[6] Hence, to meet this need for the production and supply of greener, more sustainable products, the Enzymes for Greener Products Cluster is leveraging the power of enzymes in the processing phases and in the formulation of consumer products, such as washing agents, textiles, personal care, cosmetics, and nutraceuticals.

Supporting and informing policies for industry

The results and findings from the Enzymes for Greener Products Cluster will provide new scientific insights to support and inform EC policy areas affecting specific industry sectors:

Textiles

Textiles have an annual worldwide production of 119 million tons,[7] but are manufactured using large chemical processes that emit 1291 million tons of CO_2, and bleaching processes that generate high biological and chemical oxygen demands. However, enzymes function at low temperatures, and being biodegradable there is no negative impact. Particularly important is the contribution of enzymes to the removal of residual spinning oils, acrylic acids, and dyes. Developing greener manufacturing practices, such as circular bio-bleaching processes, combined with efficient management of production and post-consumer textile waste generation, better recycling, and increasing textile lifespans will reduce the carbon footprint, add value, and make the industry more competitive. Enzymes applied in any of the steps in the textile production chain: fibre spinning; weaving and knitting; solvent cleaning; dyeing; washing; finishing; and cutting and sewing, can achieve an overall reduction of about 50-119 million tons of CO_2.[8]

Detergents

Laundering detergents and processes create annual emissions exceeding 62 million tons of CO_2 and account for 25% of the carbon footprint of the clothing industry due to high levels of energy and water use.[9] Owing to demands for hygienisation, further adverse effects are caused by detergents releasing antimicrobial chemical agents into our water systems, threatening aquatic life, and leading to antibiotic resistance. By enhancing the industry products and processes with enzyme technologies, we can enable laundering at lower washing temperatures with increased hygienisation and odour control. This reduces the need for frequent washing, leading to greater textile longevity. Life cycle assessments show that this effectively reduces the industry's carbon footprint.[10] Moreover, using enzyme technologies to replace some of the required surfactants will help decrease CO_2 emissions by 5.9 to 15 million tons of CO_2 per year in the EU.[11]

Cosmetics and personal care products

This sector is currently highly fossil-dependent due to the use of large volumes of petroleum-derived synthetic polymers. The production and extraction of active ingredients are notable sources of environmental impact, accounting for about 20% of the total. Recent estimates foresee a global production of about 10,000 tons of cosmetics and personal care products contributing to a total of 8-23 million tons CO_2. There is also the environmental cost when chemicals from these products reach our aquatic systems. The development of natural, biobased, and biodegradable products is therefore fundamental to competitive growth and reducing environmental impact. Enzyme technologies will replace the use of non-biodegradable polymers in the production of cosmetics. In sunscreens, enzymes will reduce the quantities of chemicals and pollutants being released in the environment while enhancing the UV properties. If eco-ingredients are produced with water- and low-temperature enzymatic processes, the industry's emissions could be lowered by 23%.[12]

Nutraceuticals

CO_2 emissions from nutraceutical production remain unquantified due to the industry's diversity and complexity. At the same time, there is considerable underutilisation of potential resources for nutraceutical products, such as anti-inflammatories, gut modulators, and nutritional supplements, which can be extracted from by-products from process side streams in other sectors, including the biomass and nutrient-rich waste from the fishing industry. Enzyme technologies can address both issues of underutilisation and waste. Two types of enzymes can broaden the scope of biobased ingredients and feedstocks for nutraceutical use: Xylans can be developed for digestive aids, anti-inflammatory and anti-microbial supplements, while oxidoreductases can improve the sensory qualities of proteins and omega 3. Enzymes can thus open new pathways in nutraceuticals, increasing the potential of supplements, and enabling product quality to be customized for targeted end users with specific requirements.

Delivering results to inform policy

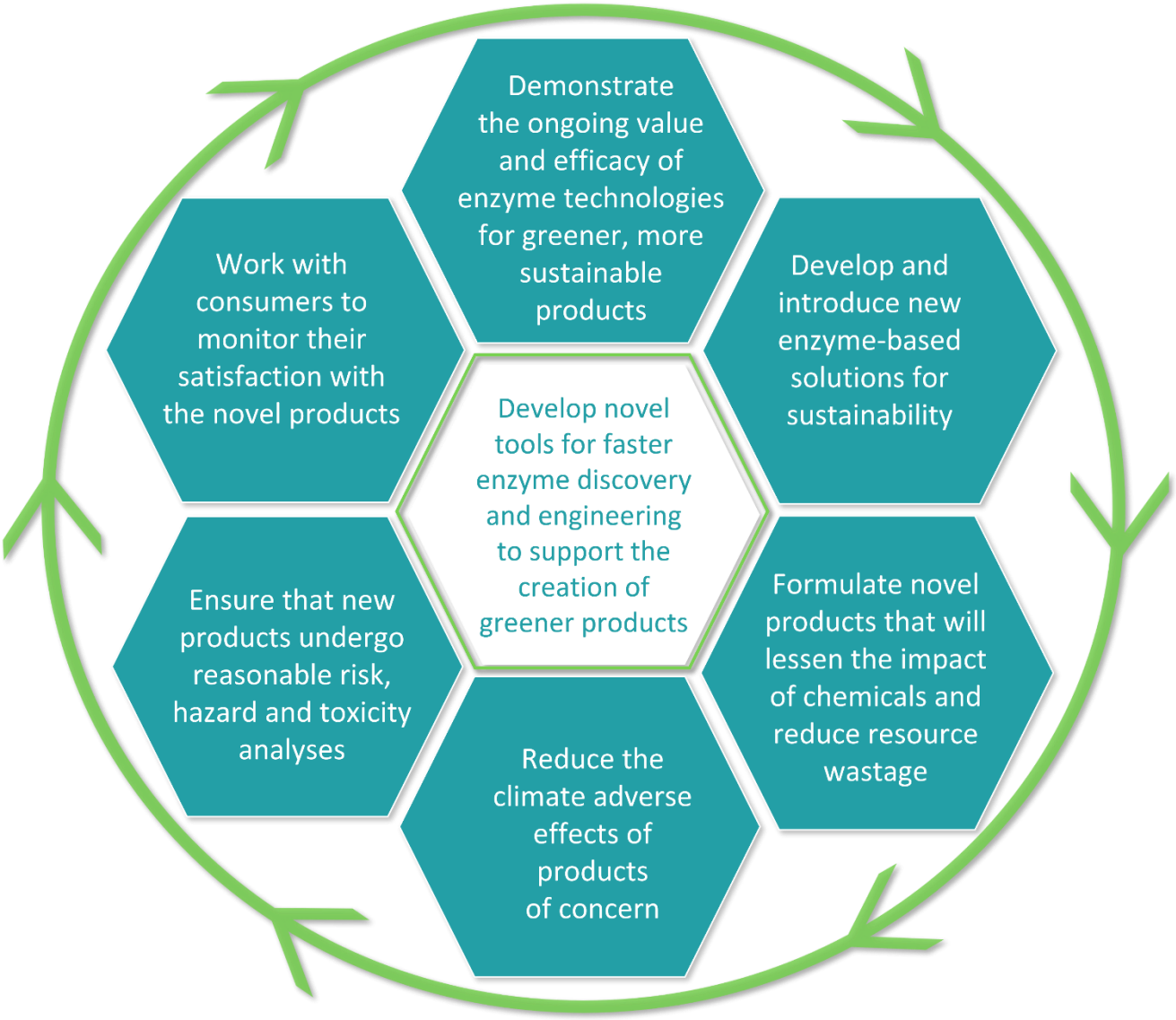
The research output of the four projects closely aligns with key priorities of the EU, and the results and findings of the Cluster will support and inform EC policy areas that address the environment, climate change, the growth of the bioeconomy and sustainable development (Table 1).

Table 1 *EC priorities and expected Enzyme Cluster research output that aligns with these*

EU Bioeconomy Strategy 2018[13]	Enzyme technologies will drive future solutions for the bioeconomy transition and support the sustainability of biomass use as a resource. They can enable the exploitation of agriculture, forestry, and agro-processing residues which are otherwise used inefficiently and poorly valorised. Supporting greener industrial bioprocessing in this way will generate more sustainable bio-based products, enhance the bioeconomy, and contribute to the European Green Deal.
European Green Deal[14]	Climate neutrality can be achieved using enzymes to reduce resource use and carbon footprints from current production processes. Novel products can be cascaded to interested parties to support long-term competitiveness. Training and information will be given to facilitate their uptake.
Circular Economy Action Plan[15]	Enzyme technologies will provide new sustainable production processes and consumer products, thus increasing possibilities for circularisation of biomass. Wastewater generated from the use of novel biopolymers can be effectively treated by existing waste-water plants.
8th Environmental Action Program[16]	Enzymes can help develop a toxic-free environment (air, water, soil), and protect, preserve, and restore biodiversity by boosting eco-innovation and its uptake. They can improve the environmental performance of products; boost demand for better resource-efficient products and production technologies and enable consumers to make informed choices.
Sustainable Consumption and Production Action Plan[17] Farm to Fork[18]	The use of specific enzymes will facilitate the development of simple low-energy and lower-water consumption processes to convert biomass. The use of non-edible resources (xylans and oxidoreductases) in supplementing food and nutraceutical products will be demonstrated.
Sustainable Blue Economy[19]	The novel technologies will support the protection of marine and aquatic resources by reducing the quantities of pollutants being released in the environment. They will also increase and transform value chains with new enzyme processes for transforming waste from the fishing industry.
EU Strategy on Adaptation to Climate Change[20] Zero Pollution Action Plan[21]	The reduction or removal of harsh processing conditions will render current methods more environmentally friendly. Products and processes are thus being created for zero environment toxicity, for example by developing biodegradable polymers, and reducing CO_2 emissions as well as decreasing the consumption of chemicals, water, and energy in a number of cases.
EU Industrial Strategy[22]	Enzyme-enhanced processes and products will enable a paradigm shift to relevant bioprospecting supported by digitalisation. User-friendly algorithms for enzyme discovery underpins the digital transition of EU industry, and evolved enzymes and microbes can help generate more technically and economically feasible applications in diverse value chains in industrial biotechnology. The output will help the diversification of international partnerships and support the recovery of Europe's industry and economy by fast-tracking new market opportunities.
2030 Agenda and Sustainable Development Goals[23]	The development and deployment of enzyme technologies will support and influence the transformation from non-renewable to renewable products, strengthening EU competitiveness, and creating jobs in science, industry, and consumer sectors.

Recommendations

In taking up the challenge of harnessing enzymes to enhance the sustainability and environmental friendliness of the target products and bring them to the consumers, the four Enzyme Cluster projects recommend strong support from all sectors for the courses of action shown here:



EnXylaScope
Unleashing xylan's potential with enzymes to make it a key ingredient for a scope of bio-based consumer products

FuturEnzyme
Developing future technologies for low-cost enzymes for more sustainable and environmentally friendly consumer products

OXIPRO
Harnessing the power of novel oxidoreductases - diversifying enzymes for environment friendly consumer products

RadicalZ
Developing novel tools for faster enzyme discovery and engineering to support the creation of greener products

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EnXylaScope	101000831
FuturEnzyme	101000327
OXIPRO	101000607
RadicalZ	101000560