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The European Association for Bioindustries

How industrial biotechnology can tackle climate change

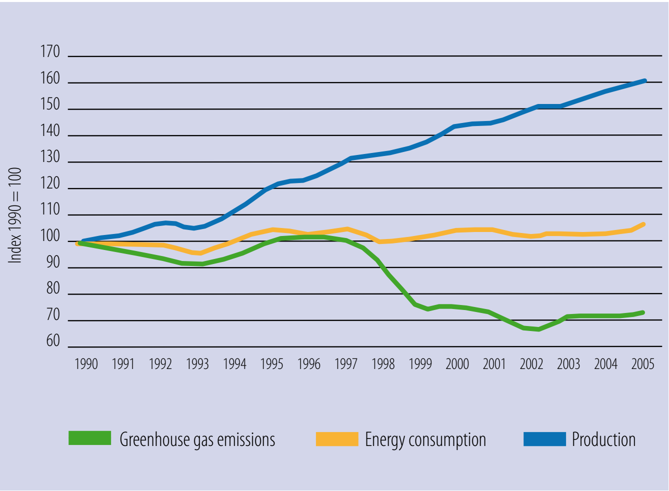
Climate change is "hot" right now, intensely discussed by politicians, business, society and the media.

Reducing the impact on the world's climate is a key element in sustainable development and of particular importance for industry. Discussions in the early days focused on finding the origin of climate change, now industry and other stakeholders are searching for solutions and ways to minimise climate change and its negative effects.

Industrial emissions have substantially fallen over the past 30 years in most western European countries (see figure). This is mainly due to technology improvements[1]. However, today's technologies will most probably not be sufficient and adequate to achieve the ambitious objective set by the European Union to become the world leader in combating climate change.

Industrial or white biotechnology is one of the most promising new approaches to pollution prevention, resource conservation, and cost reduction. Applications of white biotechnology can contribute to meet the EU's environmental objective to reduce greenhouse gas (GHG) emissions by 20% in 2020. This fact sheet provides some concrete examples.

EU chemical* industry greenhouse gas emissions, energy consumption and production 1990-2005



Sources:
Cefic Chemicals International and European Environment Agency (EEA)
** including pharmaceuticals*

Definition of Industrial Biotechnology

Industrial biotechnology is the application of biotechnology for the processing and production of chemicals, materials and energy. It uses enzymes and microorganisms to make products in sectors such as chemicals, food and feed, paper and pulp, textiles and energy. By using biotech processes, all these sectors can make significant contributions to mitigating climate change.

Industrial biotechnology can help prevent pollution and offers new ways to produce goods and services. Environmental benefits are often combined with increased economic efficiency, leading to cost savings in the production process while the production output and quality remains the same or increases. In summary, industrial biotechnology often delivers environmental and economic benefits at the same time.

The textile sector

Mankind and the environment benefit daily from industrial biotechnology without being aware of it, for example while doing a load of laundry. Enzymes have been used in detergents since the 1960s and since then have helped to reduce the amount of detergent released into the environment as well as decreasing the energy needed to do laundry. In fact detergent enzymes represent one of the largest and most successful applications of modern industrial biotechnology.

In addition to making clothes cleaner, one of the main environmental advantages of cold water enzymes is that clothes can be washed at a lower temperature. Washing machines are one of the biggest consumers of household electricity, and 80% of the electricity for washing laundry is used to heat the water. With the new generation of cold water enzymes, washing temperatures can be reduced from 40°C to 30°C, without sacrificing cleanliness, and saving 30% of the electricity used on the laundry. This one small step has not only had an impact on electricity bills but has also significantly reduced CO_2 emissions. Studies show that CO_2 emissions can be reduced by 100 g per wash by washing at 30°C rather than 40°C[2]. (See Graph)

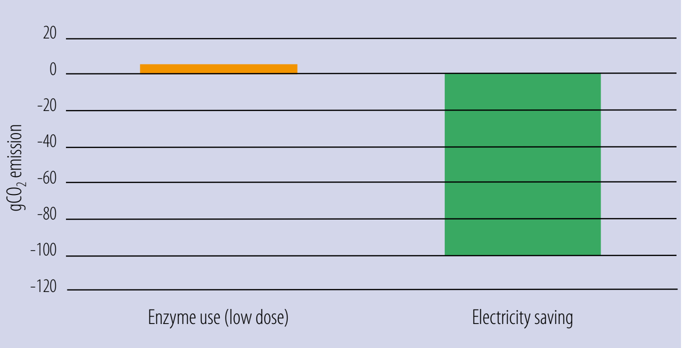
Enzymes partly replace other, often less desirable, chemicals in detergents and contribute to reducing both the duration of the washing cycle and water consumption. Enzymes are biodegradable, do not present risks to aquatic life, and so minimise the environmental impact of detergents. Use of enzymes in the laundering process leads to a reduction of eco-toxic substances of between 5% and 60% depending on the product [3].

Textile bleaching is usually done using hydrogen peroxide followed by at least two rinses in hot water (80-95°C). With the use of an enzyme that degrades residual peroxide during the second post-bleach rinse, water heated to 30-40°C can be used and less energy is needed[4].

Another application of enzymes in the textile industry is in the **treatment of cotton fibres**. Traditionally, before cotton can be dyed, it goes through numerous processes including a series of chemical treatments and rinsing in water. With a biotechnology process, it is possible to reduce the use of chemicals and therefore the amount of water needed to rinse the fibers by as much as 30-50%. Compared to the traditional chemical process, the enzymatic process reduces the pH (acidity) from 14 to 9 (7 = pH neutral) and temperature from 95°C to 55°C, meaning that there are important energy savings. Also, the rinse water required is reduced by half, which in combination with the energy savings makes the process cheaper. Finally, fibre strength and softness are improved and, because the process is milder on the cotton, a higher yield is achieved[7].


Thanks to enzymes, washing temperatures can be reduced, saving up to 30% of the electricity used on laundry

Emission of CO_2 per wash cycle using enzymes at 30°C instead of 40°C.



Enzymes in textile bleaching

A comparison of the amount of water used in the bleach clean-up process shows that by using a specific enzyme[5], 6300 to 19 000 liters of water per tonne of textiles are saved. By substituting the enzyme for a reducing agent in a hot rinse, additional savings of energy around 1,6 to 1,8 GJ/tonne of textiles can be made, and, owing to the reduced energy consumption, release of CO_2 is lowered by 100-120 kg/tonne of textiles produced[6].

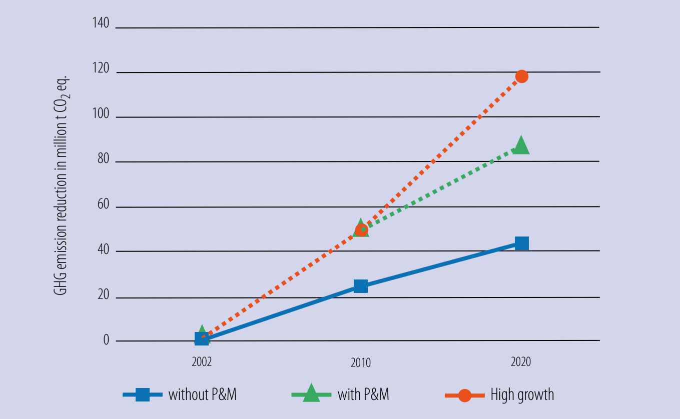
Plastics production

Plastics in general are important materials contributing significantly to environmental protection: due to their tailor-made properties (e.g. light weight, excellent insulation ability, tunable properties for for optimum food protection, etc.) they reduce already energy use by 26% and greenhouse gas emissions (GHG) by 56% across a variety of applications compared to alternatives[8]. Besides crude oil, natural gas and coal, biomass is an additional raw material source for plastics.

Today, biotech processes allow for the production of biobased plastics from renewable resources. Even though today biobased plastics make up only a small portion of all plastics produced, they contribute to a reduction of dependency on fossil fuel in some specific sectors. In many cases, the production of biobased polymers has a great potential to reduce greenhouse gases. Using biotechnology processes to produce plastics, less energy may be expended, few resources are consumed and global greenhouse gas (GHG) emissions are reduced.

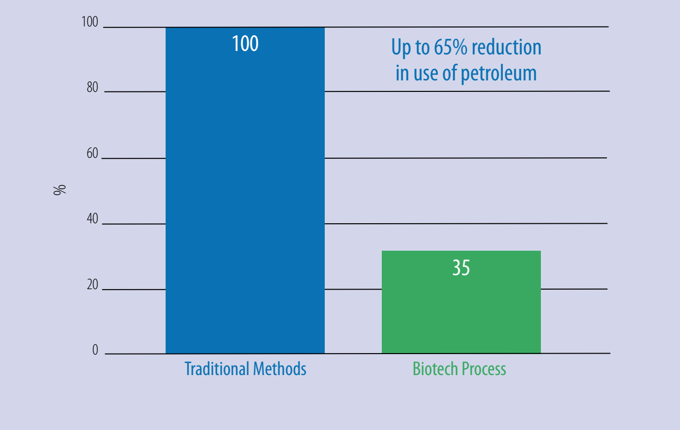
Depending on the type of bioplastic, biobased polymers may contribute up to a 50% decrease in terms of energy consumption and up to 67% savings of CO_2 emissions during the production process[9]. In the future, industry expects that less energy will be needed and GHG emissions will fall as the production processes are optimised and new feedstock and cheaper energy sources become available.

Potential GHG emission reduction from bio-based polymers



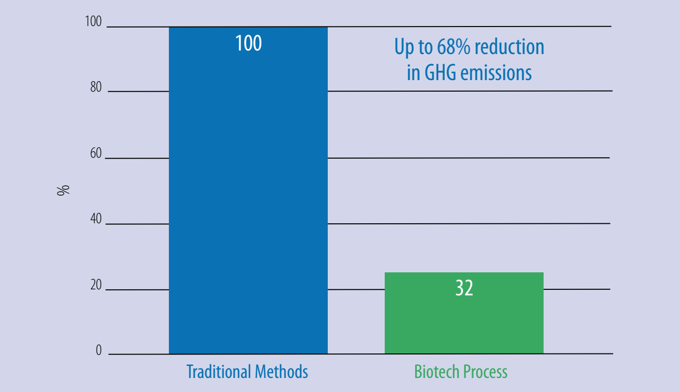
Depending on the extent to which policies and measures (P&M) supporting biobased plastics are implemented, the potential GHG emission reductions by 2010 range between 1.8 and 3.5 million t CO_2 eq. and by 2020 between 3.0 and 8.5 million t CO_2 eq[10].

Comparison of petroleum used by PLA and traditional plastics



Polylactic acid or PLA is made from 100% natural feedstock (corn) and its LCA (Life Cycle Assessment) indicates that in applications where it shows the same performance it uses up to 65% less petroleum and releases 68% less greenhouse gases to the atmosphere than traditional plastic materials[13].

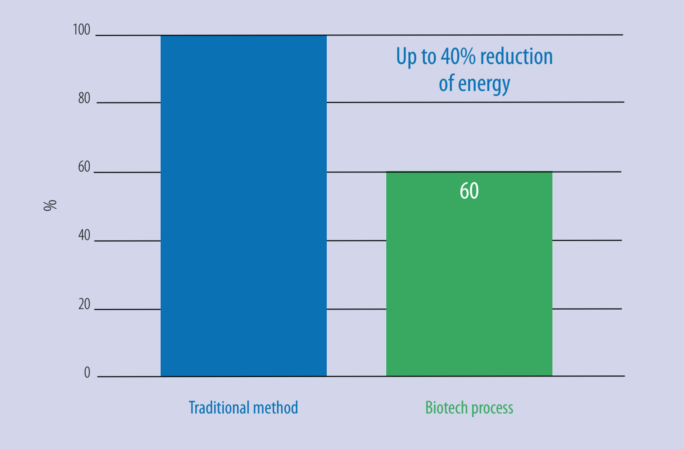
Comparison of emissions between plastics produced from petroleum and maize



Pulp and paper production and bleaching

Converting wood into paper is an energy, water and chemical intensive process. The conventional chemical process requires boiling wood chips at around 160°C before bleaching the pulp with chlorine dioxide. With the application of biotechnology processes, it is now possible to reduce the amount of chlorine chemicals by 10-15% and to cut the energy used during the bleaching process by 40% which means lower emissions during power generation[12].

GHG emissions reduction in pulp bleaching

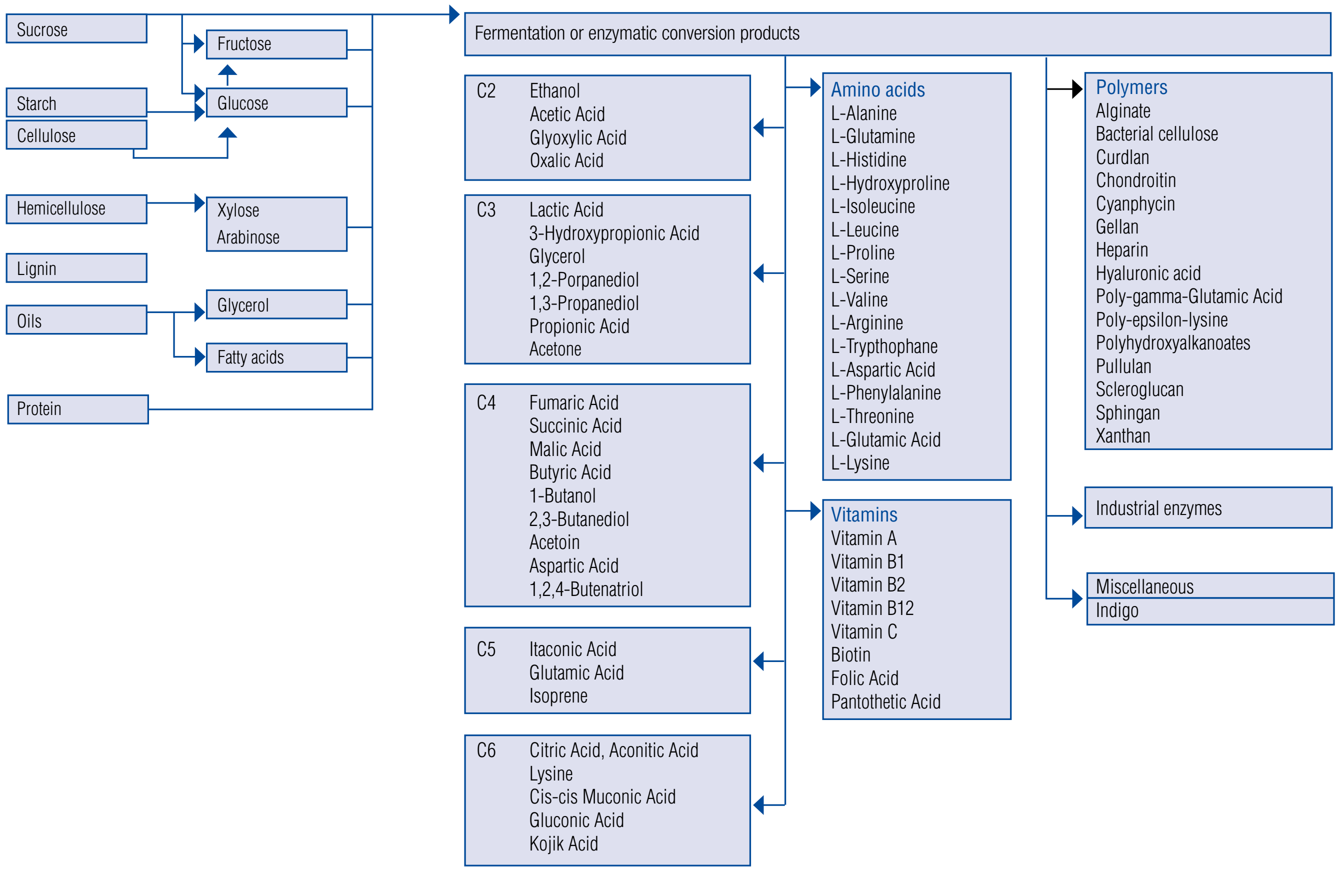


Enzyme technology can also be applied during the bleach boosting or refining processes of kraft pulp [pulp from wood chips], resulting in less CO_2 production[13].

Chemicals industry

Biotechnology can be used to produce various bulk and fine chemicals that are currently produced from fossil fuel based feedstocks. Biobased substances can also act as building blocks for many other materials provided that they are cost competitive.

Overview of chemicals that can be obtained from major biomass constituents by established or possible biotechnological processes[14]



C2
Ethanol
Acetic Acid
Glyoxylic Acid
Oxalic Acid

C3
Lactic Acid
3-Hydroxypropionic Acid
Glycerol
1,2-Porpanediol
1,3-Propanediol
Propionic Acid
Acetone

C4
Fumaric Acid
Succinic Acid
Malic Acid
Butyric Acid
1-Butanol
2,3-Butanediol
Acetoin
Aspartic Acid
1,2,4-Butenatriol

C5
Itaconic Acid
Glutamic Acid
Isoprene

C6
Citric Acid, Aconitic Acid
Lysine
Cis-cis Muconic Acid
Gluconic Acid
Kojik Acid

Amino acids
L-Alanine
L-Glutamine
L-Histidine
L-Hydroxyproline
L-Isoleucine
L-Leucine
L-Proline
L-Serine
L-Valine
L-Arginine
L-Trypthophane
L-Aspartic Acid
L-Phenylalanine
L-Threonine
L-Glutamic Acid
L-Lysine

Vitamins
Vitamin A
Vitamin B1
Vitamin B2
Vitamin B12
Vitamin C
Biotin
Folic Acid
Pantothetic Acid

Polymers
Alginate
Bacterial cellulose
Curdlan
Chondroitin
Cyanphycin
Gellan
Heparin
Hyaluronic acid
Poly-gamma-Glutamic Acid
Poly-epsilon-lysine
Polyhydroxyalkanoates
Pullulan
Scleroglucan
Sphingan
Xanthan

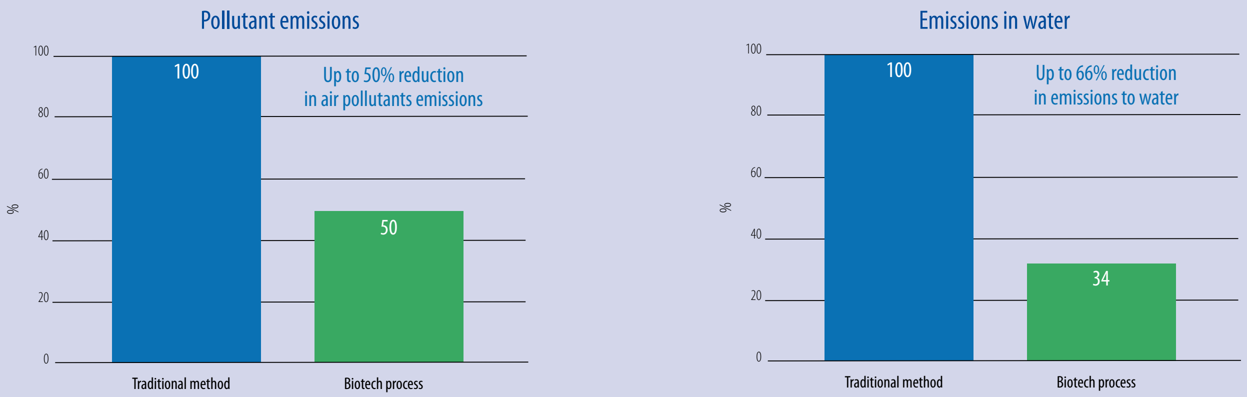
Industrial enzymes

Miscellaneous
Indigo

Traditionally, the vitamin B2 manufacturing process starts with glucose and is followed by a sequence of six chemical steps. Since 1990, most chemical processes have been replaced by fermentation. Producers now use yeasts or fungi in a single integrated biological process. The move to bioprocessing for production of vitamin B2 resulted in a 40% cost reduction and in a drastic reduction of wastes and pollutants.

The energy used in the chemical and the biotechnological processes is about equal: chemical synthesis uses more steam (energy) which comes from fossil fuels, but fermentation involves more electricity. However, compared to chemical synthesis, fermentation has reduced the use of non-renewable resources by 80%, volatile organic compounds by 50% and emissions to water by 66% while the residuals (34%) are inorganic salt and biomass.

Comparison of propanediol products with the traditional petroleum based products



Recently a company has developed a patented process to manufacture 1,3 propanediol, the so called bio-PDO™, from renewable resources instead of previously used traditional petrochemicals. Bio-PDO™ is one of the first commercial-scale industrial applications of metabolic engineering designed to make a 100% renewable resources based material from corn starch, and is the key element for many materials we use every day. The production of Bio-PDO™ has a much smaller impact on the environment than its petroleum-based equivalent. Design data[15] shows that the production of Bio-PDO™ consumes 40% less energy and reduces greenhouse gas emissions by 56% versus petroleum-based propanediol. It has a broad range of applications in fibres, films, thermoplastics, detergents, cosmetics products, ink and several other industrial areas.

Car engines are not the only way to reduce fuel consumption and the impact of vehicles on the environment. **Tyres** can play a crucial role: out of every five full tanks of fuel, one is consumed by tyre friction on the road[16]. To reduce the energy consumed by the tyres hitting the road, a technology was developed using corn starch as a polymer filler that reinforces the tyre's compounds and optimises their properties. Traditional chemical compounds such as silicia and carbon black (which give tyres their deep black colour) can be replaced with a renewable and environmentally-friendly additive.

Tyres made using this technology weigh less than traditional tires and have a 20% reduction to rolling resistance. Combined, these two advantages have shown a decrease in fuel consumption of up to 5% in tests. Moreover, this new technology decreases CO_2 emissions by 7,7g/km (0,2g/km in the production process of the filler and 7,5g/km as result of lower rolling resistance). Last but not least, the improved filler helps reduce tyre noise level by some 50%.

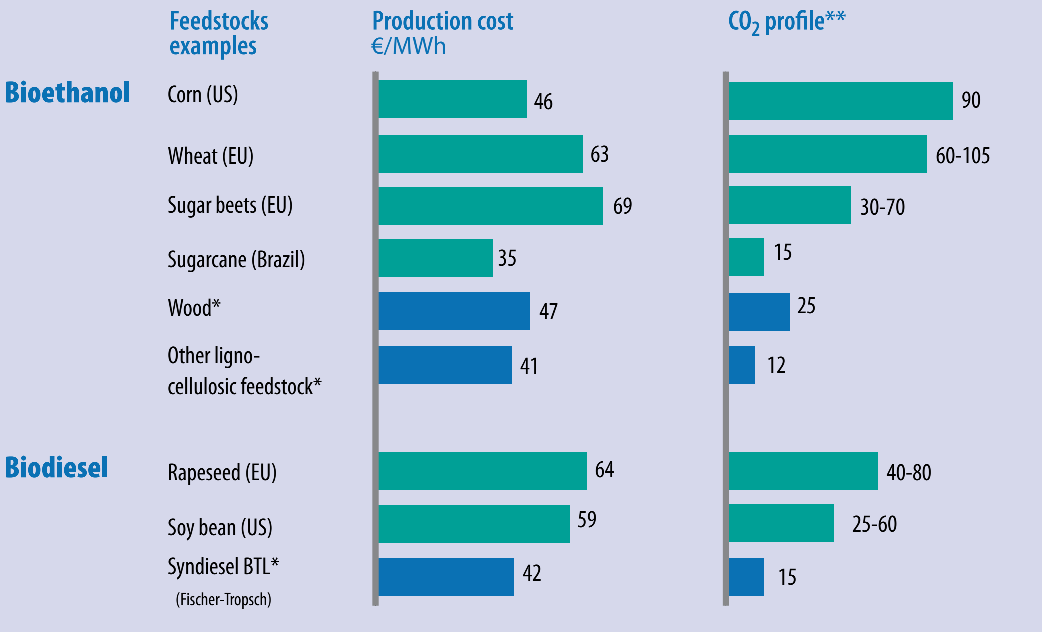
Some companies[17] recently started a collaboration to develop a bioprocess from renewable raw materials to make isoprene which is used to manufacture tyres. BioIsoprene™ is expected to deliver benefits over the conventional petroleum-based production process used today to produce high purity isoprene.

Biofuels

To stop the ever-increasing petrol consumption and GHG emissions in the transport sector, there are no short to medium term alternatives but to combine further leaps forward in automobile fuel efficiency with biofuels.

Several studies have been published on the eco-efficiency of biofuels[18] , reporting CO_2 savings with the present biofuel technologies between 20 and 80% (depending on the feedstock and conversion process) compared with using conventional petrol. And it is estimated that this can increase to 90% and higher for second generation biofuels such as cellulosic ethanol. Further innovation in the biofuel supply chain, such as high energy feedstock, less fuel intensive cultivation of crops and low carbon conversion processes could help to achieve further CO_2 savings as well as a more sustainable use of biomass. We recommend also to read EuropaBio's specific fact sheets on biofuels[19] for futher information.

Biofuels CO_2 profile saving by feedstock[20]



🟦 Second generation biofuel

* Expected cost in 2020 ** Percentage of CO_2 release for the corresponding fossil fuel (well to wheel)

Food industry

Enzymes have been used in food manufacturing for hundreds of years, mainly based on fermentation by micro-organisms. The last 10 years in particular has seen an increase in new enzyme applications in food. Before that, the dominant new enzyme innovations were aimed at the production of high fructose syrups from corn starch. Today, novel enzyme applications are also being implemented in baking, fruit and vegetable processing, brewing, wine-making, processing of vegetable oils, cheese manufacturing, and meat- and fish-processing.

There are different drivers for the use of enzyme technology in the food industry. Enzyme technology can improve the quality of the food product, for instance, by making juice products that are more cloud-stable [that stay clear and do not precipitated particles from the pulp] or by reducing the content of unsaturated fat in fat spreads. The technology can further reduce processing costs by reducing chemical and energy use and processing time.

Finally many enzymes applications in the food industry are advantageous mainly due to their impact on processing conditions in food manufacturing plants, where enzyme use may result in savings of energy and chemicals.

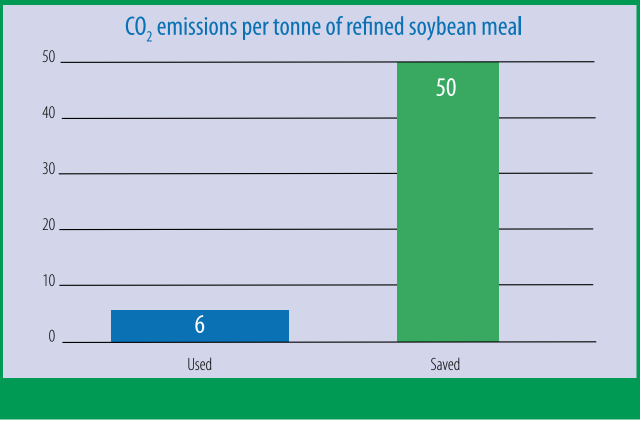
Reduced waste of bread by the use of maltogenic amylase[22]

Recently a special amylase has been commercialised that diminishes the crystallisation of starch, reducing waste of bread by allowing bread to stay fresh and moist longer. This effect has provided industrial bakeries with new opportunities for changing their production and delivery setup in order to produce at larger, centralised bakeries and make fewer deliveries to retailers. The industry can save both money and energy, while less waste bread also means more efficient use of agricultural raw materials.

There are significant environmental gains due to better utilisation of agricultural raw materials. A reduction of GHG emissions of up to 54 t per million loaves of bread sold can be obtained. The major contribution to the reduction of CO_2 emissions is also, in this case, the agricultural load. Some 65% of the reduction stems from savings in the production of wheat, including agricultural emissions, production of fertiliser and traction. Some 15% of the reduction comes from savings in energy consumption during milling and baking and 15% comes from reduced transportation.

Degumming of soybean oil using phospholipase

Degumming is the removal of phospholipids from vegetable oil. The phospholipids cause problems for the storage stability of the oil and the downstream processing and are often removed by a caustic process. An LCA[21] study has compared the enzymatic and the caustic process using data from a US manufacturer who operates both processes. The study showed a reduction of 44 t of GHG per 1000 t of refined oil for the enzymatic process. The major factor explaining the results is the increased yield of the enzymatic process causing savings in the production of vegetable oil, therefore more than 50% of the reductions in GHG emissions stem from the reduced agricultural production of vegetable oil. Other important contributors to reduced CO2 emissions are due to less NaOH production and waste treatment – together these constitute 20% of the total reduction.


CO_2 emissions per tonne of refined soybean meal

Tanning and leather industry

Enzymes have been used in the tanning industry for centuries because they are efficient in degrading protein and fat. In early times, the enzymes were derived from animal excrement and later on from the pancreases of cattle. Today, the enzymes are almost entirely produced by microbial fermentation.

Soaking enzymes reduce the required soaking time, the surfactant [a molecule that lowers surface tension, e. g. increasing its wetting properties or assisting the formulation of emulsified liquids] and soda requirements during the tanning process. Reduced soaking time leads to electricity savings in turning the drum where the hides rest. Enzymes that remove hair during the tanning process reduce the sulfide requirements for the process.

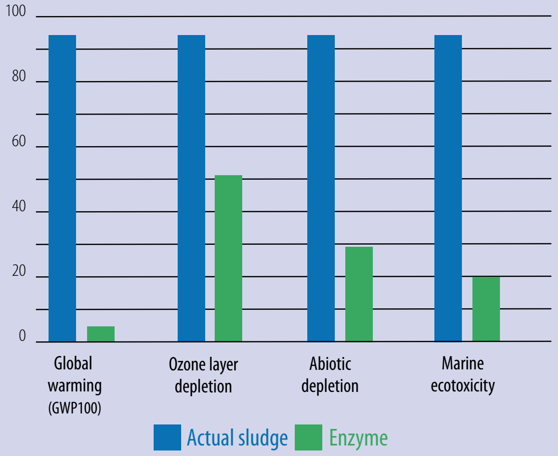
The environmental impacts of producing and delivering the enzymes to the tannery on the one hand and the savings in chemicals and electricity on the other have been evaluated via a LCA[23] study. This comparison of conventional and enzyme-assisted bovine soaking and de-hairing/liming processes indicates that the application of enzymes in the tanning industry is justified by considerable energy savings and considerable reductions in the processes' contribution to global warming. Assuming that the environmental improvements by switching from conventional to enzyme-assisted soaking and de-hairing/liming are applicable worldwide, the global saving potential is in the order of 8 million GJ of energy and 0.7 million tonnes of CO_2 per year.

Dye industry

Thanks to the production of dyes through more environmentally friendly processes, as well as through wastewater treatment, enzymes can help to reduce the potential environmental impact of dyes. Bioprocesses to produce biobased colourants have been developed and recently patented as an alternative to traditional chemical synthesis. While the creation of chemical-based dyes requires temperature up to 70-90°C in harsh conditions, the enzymatic synthesis of these colourants can be obtained at ambient temperature, under mild conditions. A life cycle analysis[24] has shown that on an industrial scale, enzymatic processes could help to reduce CO_2 emissions and toxicity towards the environment..

Enzymatic treatment of coloured wastewater was shown to cut toxicity towards human cells in half. A LCA[25] showed that, as compared to classical chemical sludge, enzymes can reduce by 10 times the impact on global warming, reduce by a factor of 2 the impact on the ozone layer, reduce by a factor of 3 the impact on abiotic [non living components in the environment) depletion and decrease by a factor of 3 the impact on marine toxicity.

Impact of enzymatic *versus* traditional wastewater treatment



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Further reading New Biotech Tools for a Cleaner Environment, BIO - http://www.bio.org/ind/pubs/cleaner2004/CleanerReport.pdf

The European Association for Bioindustries

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