Over the past few years, bio-based plastics have been developed rapidly owing to rising petroleum prices and many environmental concerns related to plastic pollution. Increasingly, reduction of carbon dioxide emissions has become another reason for promoting bio-based plastics amid the worldwide financial tsunami.a

Generally speaking, bio-based plastics include starch-based plastics, protein (soybean protein) based plastics, and cellulose-blended plastics. They can also be blended with conventional plastics such as polyethylene (PE), polypropylene (PP), and poly(vinyl alcohol). However, such bio-based plastics are only partially biodegradable. The residual petroleum-based plastics remain as broken pieces, creating additional pollution. In addition, these plastics have intrinsic thermal and mechanical weaknesses, and they are now discouraged for applications. To produce bio-based plastics completely resembling conventional plastics, bacteria are employed to make the building blocks for plastic polymers from renewable sources, including starch, cellulose, fatty acids, and whatever bacteria can consume for growth.

Polyhydroxyalkanoates (PHA), a family of biopolyesters with diverse structures, are the only bioplastics completely synthesized by microorganisms. PHA can be synthesized by over 30% of soil-inhabiting bacteria. Many bacteria in activated sludge, in high seas, and in extreme environments are also capable of making PHA. In the last 10 years, PHA have been developed rapidly to find applications in various fields.

PHA have rich properties depending on the structures. Homopolymers, random copolymers, and block copolymers of PHA can be produced depending on the bacterial species and growth conditions. With over 150 different PHA monomers being reported, PHA with flexible thermal and mechanical properties have been developed. Such diversity has allowed the development of various applications, including environmentally friendly biodegradable plastics for packaging purposes, fibers, biodegradable and biocompatible implants, and controlled drug release carriers. PHA monomers can also be used to develop biofuels, drugs, or chiral intermediates.

Owing to these developments, microbial PHA has formed an industrial value chain ranging from industrial fermentation, materials, medicine, and biofuels to fine chemicals.

To ensure the safe distribution of goods worldwide, it is beyond dispute that there is an increasing need for polymeric compounds acting as packaging materials. The contemporary utilization of restricted fossil resources for the production of polymers provokes prevailing worldwide problems such as the greenhouse effect and global warming. This is caused by the fact that these materials are utilized only during a relatively short time span. After that, they are often incinerated, elevating the atmospheric carbon dioxide concentration that contributes to the said heating effects. By incineration of plastic waste, the energy that is chemically stored therein is recovered as thermal energy.

Heating values are rather high and, regarded simply from the energetic point of view, incineration of plastic waste is of interest. But it cannot be overlooked that the main problem arising from incineration is the same as for energy recovery from fuel oil, petrol, gasoline, natural gas and coal: carbon that was fixed over millions of years and that within this time was not part of the natural carbon cycle is converted to carbon dioxide that eventually accumulates in the atmosphere. When incineration is planned, strict emission standards have to be obeyed not only for carbon dioxide, but also for highly toxic compounds such as dioxins and HCl deriving from poly(vinyl chloride).

The environmental necessity to stop this negative development by switching to alternative strategies independent of fossil resources nowadays is generally undisputed. Already in 1992, the United Nations ‘Rio Declaration on Environment and Development’ explicitly specified the political intention and willingness of most countries to forcefully support the development of bio-based and biocompatible materials. With the tools of life cycle assessment (LCA) and cleaner production studies, much effort is contemporarily devoted to quantifying the environmental impact and feasibility of processes for production of polymeric materials.

In addition to the ecological considerations, the price of crude oil rocketed to a new all-time high of US $147 per barrel in 2008. Data for remaining amounts of fossil oil in Earth’s interior are changing quickly owing to advanced methods for tracing and discharging of mineral oils. Nevertheless, one day fossil feedstocks will finally be depleted. This causes an increasing awareness of the industrial branches involved for the exigency of fostering novel production techniques based on renewable resources and embedded into nature’s closed cycles. With this ‘white biotechnology’, sustainable production of fine chemicals, bulk chemicals, polymers and fuels is achieved by the action of living organisms or parts thereof such as enzymes.