What is PHA?

Natural PHA (PolyHydroxyAlkanoate)[1] is a versatile class of **biopolymers** that provides a **renewable carbon-based and biodegradable alternative** to the fossil plastics commonly used.

PHAs offer a **natural solution to our need for plastic-like materials** and should play a prominent role in our regenerative, renewable, bio-based, and circular product ecosystems.

PHAs are an effective way to use nature's toolbox to sustainably tackle and prevent some of the world's most pressing challenges.

GO!PHA
Global Organization for PHA

Solving two major global crises

PHAs can help reduce our impact on climate change and plastics pollution.

Renewable

No chemicals involved. PHAs are natural products created using a wide variety of carbon feedstocks that are natural and renewable.

100% biodegradable

No microplastics or nanoplastics. PHAs degrade harmlessly into the soil or the ocean.

Plastics free

Naturally occuring PHA-biopolymers, like PHB and a number of its copolymers like PHBV, PHBHx and P3HB4HB are not 'plastics', but are materials made and found in nature, like cellulose or starch.

Older than mankind

PHA materials are already used in nature for many purposes and for much longer than the existence of mankind. PHAs are part of the metabolism in all living organisms such as plants, animals, and humans. They've always functioned as nutritious and energy storage materials, so they are supposed to be used for that purpose.

Wide range of applications[2]

PHA materials show a larger application versatility than any other existing material platforms. PHAs are a natural solution to our need for a large variety of plastic-like materials.

[1] PHA is a large family of materials, in this context we refer to PHB and its copolymers (P3HB, P4HB, PHBV, PHBH, P3HB4HB, P3HB3HV, P3HB3HV4HV, P3HB3Hx, P3HB3HO, P3HB3HD).
[2] PHA biopolymers have been validated in 100s of different applications where fossil plastics are used, and are poised for significant growth.

Which global problems does PHA tackle?

Plastic pollution

Fossil-based plastic overfilling into our landfills and oceans has become one of the most pressing global environmental issues. Here's why:

8 million tons

The amount of plastic escaping into the oceans annually.[3]

15 years

50% of all plastics ever manufactured have been made in the last 15 years. Production is expected to double by 2050.[3]

20-500 years

The years it takes for fossil-based plastic to decompose.[4]

Microplastics and our health

When plastic enters the ocean, the wind, sunlight, and waves break down the plastic into tiny particles: microplastics and nanoplastics. These microplastics are found all over the world. They can be found in the food we eat, in the water we drink and even in the air we breathe.

Harm to wildlife

Millions of animals are killed by plastics every year, mainly through starvation or entanglement. Nearly 700 species are known to have been affected by plastics.[3]

How does PHA take on plastic pollution?

Plastic products made from PHA are **100% compostable and biodegradable**. They **break down harmlessly into the soil or the ocean** without affecting nature.

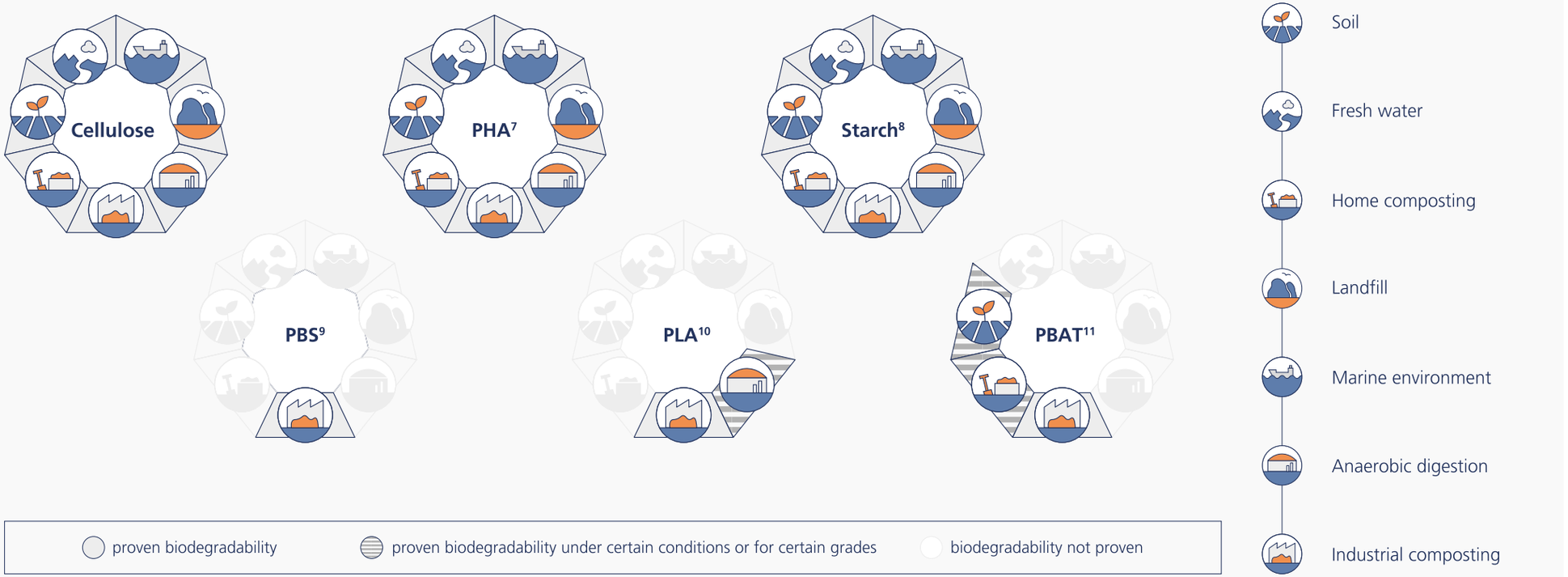
As a summary, here are the **end-of-life options** for PHA:

- It can be recycled back to the polymer, ready to be reused for new applications.
- Recycle it organically through industrial or home composting.
- PHA can be used as a renewable feedstock.
- Leaked PHA biodegrades in soil, fresh water and in marine environments.
- PHA is completely biodegradable and can become a nutrient for living organisms.

PHA can also be turned into **renewable energy** using the existing incineration procedures.[5]

[3] *Source:* Laura Parker, *The world's plastic pollution crisis explained* (National Geographic)
[4] Source: *The lifecycle of plastics* (WWF)
[5] *The least favorable option for our climate*

How does PHA compare to other materials?[6]



[6] *Adapted from 'Biodegradable Polymers in Various Environments According to Established Standards & Certifications Schemes' (nova-Institut et al.)*
[7] *PHA is biosynthesised and made via fermentation, similar to beer and mead*
[8] *Natural but chemically modified*
[9] *Partially renewable, partially fossil-based*
[10] *Chemically synthesized*
[11] *Fossil-based*

How does PHA contribute to climate change prevention?

Climate change is undoubtedly one of the biggest long-term threats to mankind. The science of climate change is very clear:

- There's a direct link between the **concentration of greenhouse gases** in our atmosphere and the average global temperature.
- CO_2 accounts for ca. **two-thirds** of **greenhouse gas emissions**.
- Human activities are the **main cause of CO_2 generation** and hence global warming.
- Since industrialization, the **acidity level** in the oceans has increased by 30%, causing less oxygen production by phytoplankton.[12]

Microplastics and CO_2

Our oceans are estimated to have captured a quarter to a half of all human-derived CO_2 from the atmosphere in the last 200 years. Marine scientists have found that the uptake and storage of CO_2 in our oceans may be negatively affected by microplastics.[13]

The study suggests salp faecal pellets[14] will remain at the sea surface for longer when they contain microplastics and while there, they may get broken down causing the CO_2 to be re-released back into the ocean and atmosphere.

This means microplastics have the potential to lower the efficiency of one of the most important natural processes occurring within our oceans – the biologically-driven transport of CO_2 to the seafloor.[13]

How does PHA take on climate change?

Use greenhouse gases and renewable carbon-rich substances as feedstock

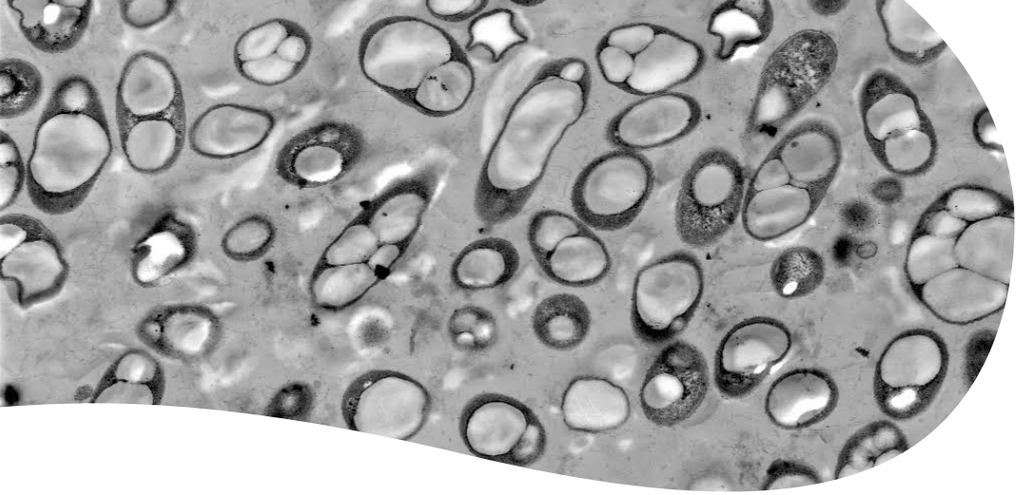
CO_2 and methane can be used as feedstocks to produce PHA, helping reduce greenhouse gases in the atmosphere.

Composted carbon-rich feedstock diverted from landfills, means CO_2 and methane are not being emitted.

Eliminating microplastics

As PHAs are 100% biodegradable, PHA materials won't turn into microplastics which lower the uptake and storage of CO_2 in our oceans.

[12] Phytoplankton is responsible for 50% of the amount of oxygen created on Earth. The other 50% comes from plants and trees.
[13] Environmental Science & Technology 2019, 53, 9, 5387-5395
[14] Discharge from barrel-shaped planktonic grazers. They are of importance to the ocean's carbon cycle as their fecal pellets are fast sinking and contribute to carrying carbon to the ocean's floor.



Renewable feedstocks that produce PHAs

Many types of bacteria produce PHAs in nature by consuming different types of **carbon-rich feedstocks**. These bacteria can be paired with different feedstocks using distinct growing conditions that result in endless material possibilities.

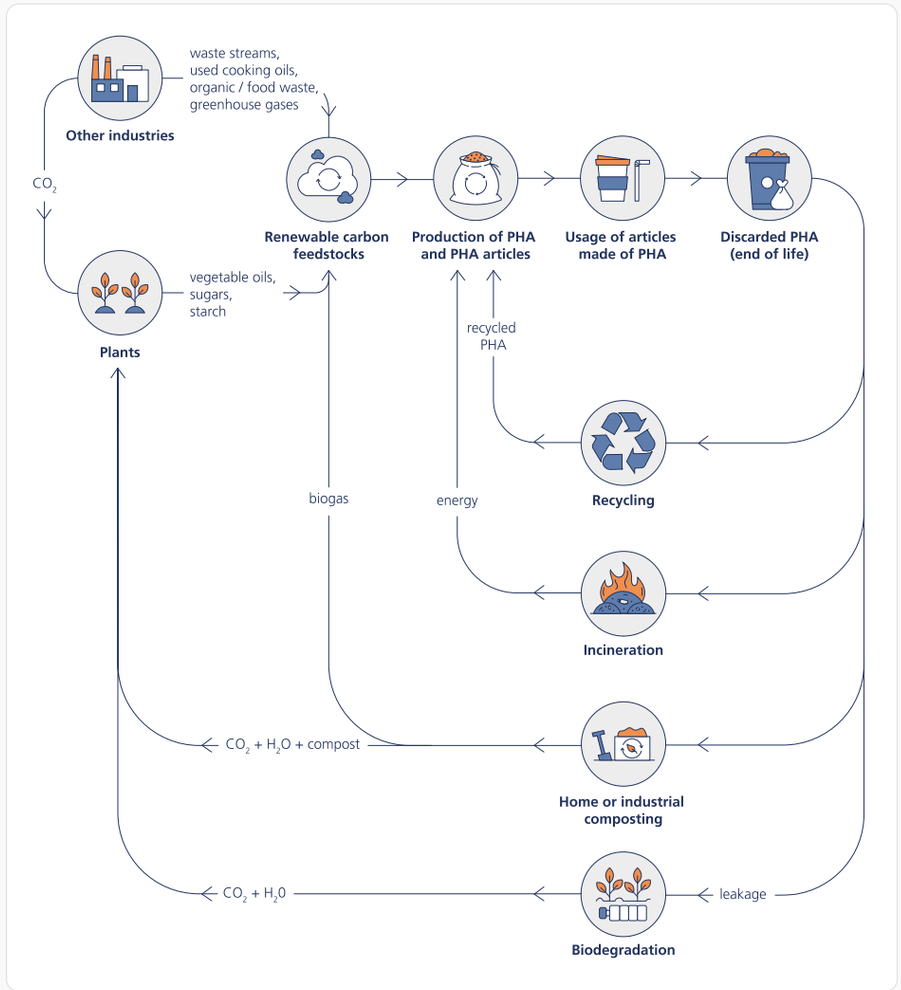
The main feedstock sources for natural PHAs are:

- **plant-based and renewable feedstocks**: corn, sugarcane, and vegetable oils.
- **waste streams**: used cooking oils, wastewater streams, organic waste, plastic waste.
- **greenhouse gases**: CO_2 and methane.

Today, almost any carbon-rich feedstock can help produce PHA biopolymers, providing a unique opportunity to reduce greenhouse gas emissions and close the loop for organic and synthetic virgin and recycled feedstocks.

Image: PHA producing microorganisms, magnification 30.000 x, pictures prepared and provided by Dr. Elisabeth Ingolić, FELMI/ZFE, TU Graz.

Here's how PHAs close the loop:



Target markets and applications

The PHA family accommodates a **wide range of market applications**, due to their **biocompatibility, biodegradability, and performance versatility**. PHA can replace about half of any fossil plastic on the market today.

Depending on type and grade, PHAs can be used for injection moulding, extrusion, thermoforming, foam, woven (textiles) & non-woven applications, fibers, 3D printing, identification agents, paper coating, and fertiliser coating, glues, adhesives, in lubrication systems, as an additive for reinforcement or plasticisation or as a building block for thermosets in paints and foams. Several non-traditional plastic applications have been developed as well, e.g. animal feed, medical care for humans and animals, denitrification, artificial turf infill, and cosmetic ingredients.

The main markets where PHAs are already accomplishing major growth initiatives are **packaging, food service applications, agriculture, and medical products.**

"We think that natural PHA materials show a larger application versatility than any other existing material platforms can mimic. The reason for this thought is that natural PHA materials are already used in nature for many purposes and for much longer than the existence of mankind."

- Jan Ravenstijn and Gui-Qiang Chen

Why is PHA important to you as a change agent or influencer?

An ever-increasing amount of public attention, investors, and legislation (e.g. the European Green Deal) is focusing on combating or reducing climate change and (plastic) pollution. Circularity and sustainability are taking center stage, globally.

Making **the switch from fossil-based plastics to 100% natural-based materials** is one solution that will have a tremendous effect on climate change.

Meet climate targets

- CO_2 and methane can be used as feedstocks to create PHAs, helping the reduction of greenhouse gases in the atmosphere.
- Articles made from natural PHAs won't turn into microplastics which lower the uptake and storage of CO_2 in our oceans.
- PHA can be produced using renewable and plant-based feedstocks.

Boost the bio-based circular economy

- Natural PHAs offer a wide range of end-of-life options including recycling or upcycling, home, industrial and marine composting, and biodegradation (closing the loop in the front-end).
- Natural PHAs are fully compatible with nature and can be absorbed by natural bacteria (closing the loop in the back-end).

Prevent plastic pollution and tackle (food) waste

- Waste streams like used cooking oils, organic/food waste, plastic waste, and wastewater are used as feedstock to create PHA.
- Products made from natural PHAs will degrade harmlessly into the soil or the ocean without harming wildlife, people or the environment.

A cost-efficient and cost-competitive solution

- Natural PHAs are already competing at reasonable levels with their fossil-based equivalents for specific applications.
- With increased production capacities and processes, cost-efficiency and cost-competitiveness will only improve.
- Investing in a natural alternative to fossil-based plastics that tackles so many pressing global issues all at once = saving money in the long run.

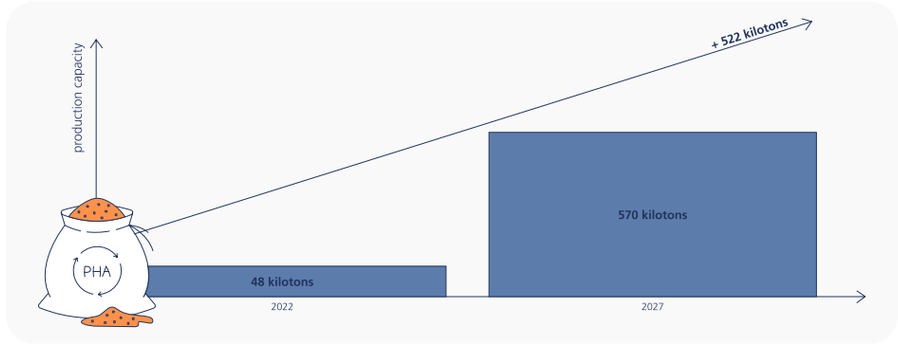
How scalable is PHA?

The demand for PHA on the market is heavily increasing. Gradually, multi-national brands and innovative startups are collaborating with producers to innovate traditional fossil-based plastics.

But can PHA handle growing market demand?

The PHA industry has taken ±40 years to develop, pilot, and install about 48 kilotons of different PHA polymer types per annum.

This capacity is expected to increase tenfold in the next five years. It is estimated to reach a **production capacity of about 570 kilotons**. This increase is the result of rising demand and the advancement of technology.[15]



The PHA industry is surpassing its growth expectations. Several PHA biopolymers have already proven their success in various market applications and are ready to scale, while others are quickly advancing in their development.

The recent expansions and the rapid increase in capacity demonstrate the scalability of the PHA production process. The PHA industry also has the advantage of having a very diverse feedstock intake. Different producers use different renewable and recycled feedstocks making future growth limitless.

[15] *Nova institute and GO!PHA Industry Landscape Report 2022*

Would you like to help us reduce and elliminate plastic pollution?

The Global Organization for PHA is a member-driven, non-profit initiative to accelerate the growth of the PHA industry.
GO!PHA is a platform for learning, creating, and sharing experiences and knowledge on PHA biopolymers and to facilitate the growth and proliferation of the PHA Industry and its downstream markets.

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