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Reducing Plastic Leakage into the Environment in Africa

Sustainable alternative materials, innovative packaging and recycling

Report on technologies

ACKNOWLEDGMENTS

This publication has been prepared by Yui Ogawa, Tsubasa Nakajima and Hiroyuki Ueda, analysts at Mitsubishi UFJ Research and Consulting Co., Ltd., as part of the UNIDO project “Study on available sustainable alternative materials to plastics and innovative packaging and recycling technologies that meet market needs in Africa to reduce plastic leakages to the environment”.

The purpose of the UNIDO project is to provide stakeholders in Africa with an overview of the technology options available in line with local contexts and needs, allowing them to take the measures needed reduce plastic waste leaking to the environment in their countries.

The project is funded by the Government of Japan under the MARINE initiative to support the G20’s Osaka Blue Ocean Vision, common global vision unveiled in June 2019 at the G20 Osaka Summit the Japanese presidency of the G20. The vision aims to reduce additional pollution by marine plastic litter to zero by 2050 through a comprehensive life-cycle approach that includes reducing the discharge of mismanaged plastic litter by improved waste management and innovative solutions, while recognizing the important role of plastics for society.

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From the People of Japan

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Introduction

1.1. Background

The global community, particularly G20 members, have mobilized around the issue of global marine plastics. The Japanese presidency of the G20 in 2019 prioritized the challenge of global marine litter and aimed to implement concerted action. The Osaka Blue Ocean Vision to reduce additional pollution by marine plastic litter to zero by 2050 was presented at the G20 Osaka Summit held on 28–29 June 2019. The summit also included an announcement that Japan would support the efforts of developing countries, including capacity-building and infrastructure development in the area of waste management, including plastic waste.

The problem of marine plastic litter can be addressed by implementing circular economy practices. Circular economy practices require policy frameworks to create incentives for economic actors, including industry and consumers, to increase the productivity of resources used. This is achieved by maintaining the value of the product and its materials at all points of the life cycle and avoiding premature disposal of products and their materials, which include plastics. In conjunction with optimizing landfill management, circular economy practices have the potential to substantially reduce the associated marine plastic litter. This complements measures to tighten up the management of sources of marine litter and clean-up operations, where feasible, to stem and prevent plastic pollution in oceans.

To support the challenges faced by African countries in dealing with plastic waste leaking into the environment, as a leading United Nations agency promoting the circular economy and resource efficiency in industry, the United Nations Industrial Development Organization (UNIDO) has produced this study "Reducing Plastic Leakage into the Environment in Africa – Sustainable alternative materials, innovative packaging and recycling", with funding from the Government of Japan.

The project included a study, with related consultation and communication activities, to identify available sustainable alternative materials to plastics, alongside innovative packaging and recycling technologies to meet the needs of the African market and reduce plastic leakage into the environment.

1.2. Objective of the report

Focused on Japanese technologies, this report presents the results of the study on available sustainable alternative materials to plastics and innovative packaging and recycling technologies. It recommends appropriate technologies that meet the needs of the African market to reduce plastic leakage into the environment.

Chapter 2 of the report introduces different types of alternative materials, including bioplastics and biocomposite. With the special focus on single-use packaging, chapter 3 introduces the idea of innovative packaging, provides examples of technologies and practices and offers a brief explanation of the roles of packaging. Chapter 4 provides an introduction to plastic recycling. Chapter 5 gives an overview of the trends of the shift to innovative materials and packaging technologies by companies in Japan. Finally, chapter 6 provides a brief discussion of trends and the selection of technologies.

2 Alternative materials

2.1. Introduction

Plastics are used in a variety of applications as they are lightweight, durable and easily shaped. However, most plastics are made from exhaustible fossil resources. From an end-of-life perspective, incineration of these materials increases the concentration of CO_2 in the atmosphere. Moreover, when plastic products are released into the natural environment, they turn into microplastics, leading to environmental pollution.

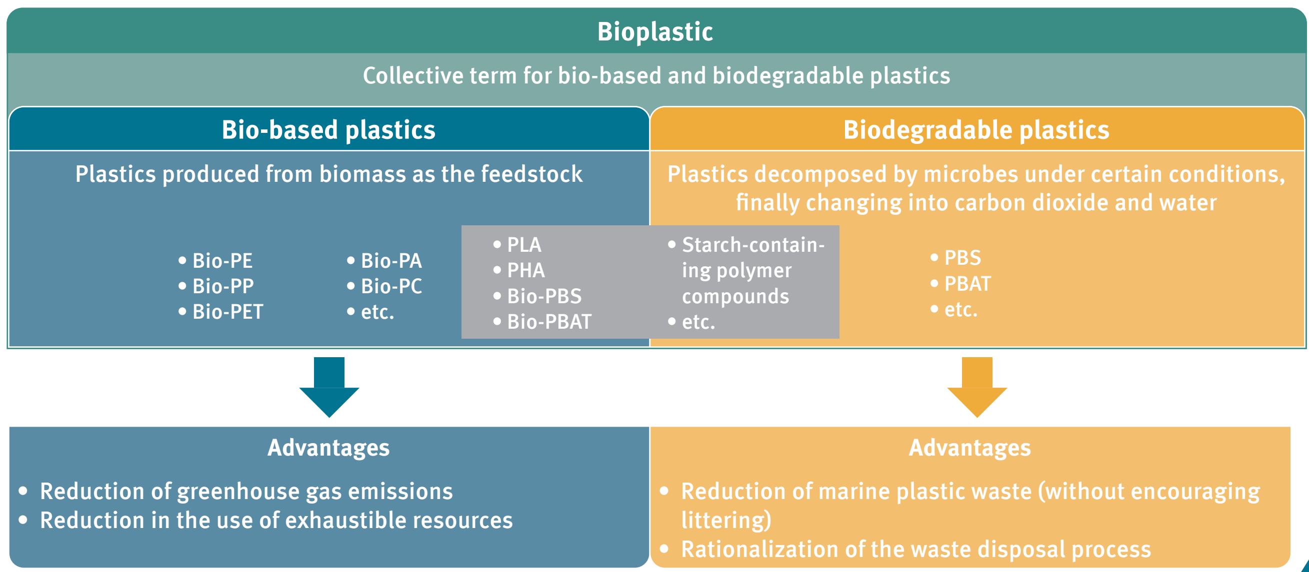
This makes the development and adoption of alternative materials to replace conventional plastics important. This chapter introduces bioplastics and other biomass-derived materials.

2.2. Bioplastics

2.2.1. Definition of bioplastics

Bioplastics is a collective term for bio-based and biodegradable plastics. Bio-based plastics are plastics produced using renewable organic resources (including plants) as the feedstock. They can contribute to reducing both greenhouse gas emissions and the use of exhaustible resources. Biodegradable plastics are plastics that can be broken down by the action of microbes, finally resulting in carbon dioxide and water. They can help reduce marine plastic waste and rationalize waste disposal processes, for example, garbage collection with biodegradable plastic bags, which can then turn into compost.

Figure 2.1. Definition and advantages of bioplastics



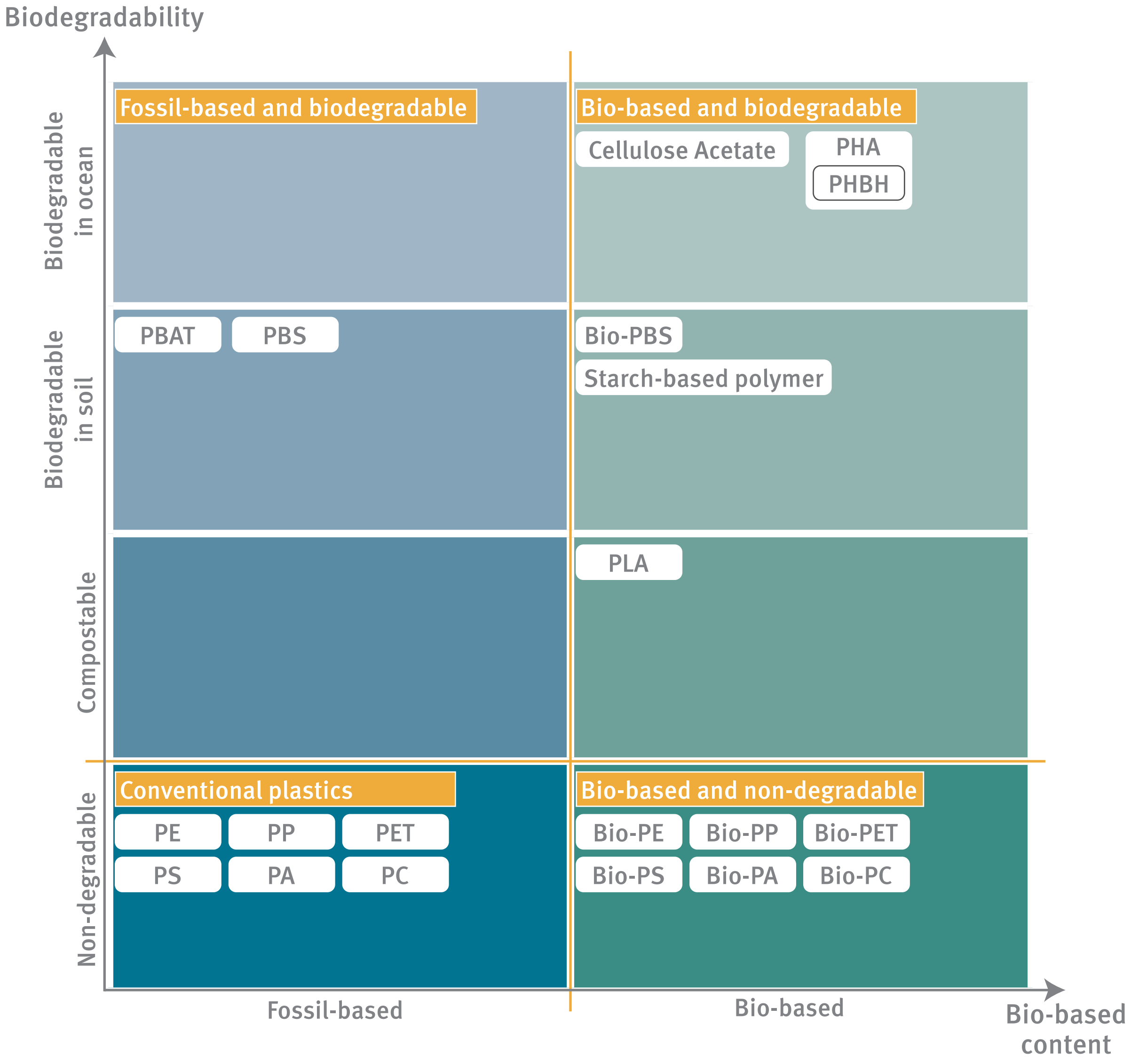
2.2.2. Types of bioplastics

Based on the distinction between bio-based and biodegradable plastics, bioplastics can be further classified into four types (figure 2.2).

There are also various grades of biodegradable plastics, depending on the strength of the biodegradability. For example, polylactic acid (PLA), a typical biodegradable plastic, degrades in composting facilities but generally not in soil or in the ocean. It is necessary to select the appropriate bioplastic for each application and its degradation environment.

Bio-based plastics can be further divided into two types: those with the same composition as fossil-based plastics and that are easily replaced, such as bio-polyethylene (bio-PE), bio-polypropylene (bio-PP) and bio-polyethylene terephthalate (bio-PET), and those that are not conventionally made from petroleum, such as polyactic acid and polyhydroxyalkanoates (PHA).

Figure 2.2. Bioplastics matrix



2.2.3. Bio-polyethylene (PE)

Polyethylene (PE) is a general-purpose resin used in various applications. Its bio-based equivalent, bio-PE, has the same composition as fossil-based PE. As bio-PE can be introduced on a "drop-in" basis, without changes to processing facilities, it is used as an alternative to fossil-based PE in a variety of applications, including shopping bags, garbage bags and daily goods.

For years, the only supplier of bio-PE was Braskem in Brazil, which produced bio-PE from bioethanol, using sugar cane molasses as feedstock. Recently, a process has also been developed to produce bio-PE using bionaphtha from used cooking oil or tall oil as the feedstock and cracking it together with fossil-based naphtha.

Table 2.1. Bio-PE datasheet

Properties	Bio-based	• **Production process 1**: Fully bio-based • **Production process 2**: Fully/partially bio-attributed (mass balance approach)
	Biodegradability	• Not biodegradable
	Recyclability	• Mechanical recycling, chemical recycling and energy recovery are possible
	Other properties	• Same as fossil-based PE
Applications		• Same as fossil-based PE (shopping bags, food packaging, automobile parts, garbage bags, other daily commodities, etc.)
Production	Feedstock/ production processes	• **Production process 1**: Produce bioethylene through dehydration condensation of bioethanol made from molasses (sugarcane draff), as the feedstock and then produce bio-PE through ethylene polymerization. • **Production process 2**: Convert plant oil from waste (e.g. used cooking oil or tall oil) into bionaphtha and blend it with fossil-based naphtha to make the produced PE partially bio-based. Generally, the bio-based fraction is allocated to a specific portion of PE using a mass balance approach.
	Main manufacturers	• **Production process 1**: Braskem (Brazil) • **Production process 2**: LyondellBasell (United States), Dow (United States), Sabic (Saudi Arabia), LG Chemical (Korea)
	Production capacity	• **Production process 1**: 20,000 tons (2020)[1] • **Production process 2**: 10,000 tons (2020)[1]
Life cycle CO_2		• **Production process 1**: -3.09 kg CO_2e/kg (feedstock production to resin production)[2] • **Production process 2**: -2.31 kg CO_2e/kg (cradle to gate)[3]

Sources:

1. Nova Institute GmbH, "Bio-based Building Blocks and Polymers - Global Capacities, Production and Trends 2020-2025" (2021).
2. Braskem, "Integrated report 2020". Available at ‹https://www.braskem.com.br/portal/Principal/arquivos/relatorio-anual/Braskem_RI2020_EN.pdf›
3. Sabic, "Sabic Certified Renewable Polyolefins" (2015). Available at ‹www.iscc-system.org/wp-content/uploads/2017/04/Kaptijn_Sabic_ISCC_Sustainability_Conference_040215.pdf›

2.2.4. Bio-polypropylene (PP)

Polypropylene (PP) is a general-purpose resin used in various applications. As its bio-based equivalent, there has been significant research and development on bio-PP in anticipation of its adoption by the market.

In recent years, two manufacturing processes of bio-PP have been developed. The first uses bionaphtha produced from used cooking oil or tall oil as the feedstock, cracking it together with fossil-based naphtha. The other uses biopropane, which is produced during the hydrogenation of vegetable oil, as a raw material, which is mixed with fossil-based propane, followed by the synthesis of bio-attributed PP. Products using bio-PP made from these processes are already on the market. In addition, a manufacturing process using sugar fermentation is being developed by Mitsui Chemicals (Japan).

Table 2.2. Bio-PP datasheet

Properties	Bio-based	• **Production process 1:** Fully/partially bio-attributed (mass balance approach) • **Production process 2:** Fully/partially bio-attributed (mass balance approach) • **Production process 3:** Fully bio-based
	Biodegradability	• Not biodegradable
	Recyclability	• Mechanical recycling, chemical recycling and energy recovery are possible
	Other properties	• Same as fossil-based PP
Applications		• Same as fossil-based PP (automobile parts, consumer electronics parts, packaging film, food containers, containers/pallets, fibre, daily commodities, etc.)
Production	Feedstock/ production processes	• **Production process 1:** Convert plant oil from waste (e.g. used cooking oil or tall oil) into bionaphtha and blend it with fossil-based naphtha to make the produced PP partially bio-based. Generally, the bio-based fraction is allocated to a specific portion of the PP by a mass balance approach. • **Production process 2:** Use biopropane produced from the production process of biodiesel and bionaphtha from plant oil, then convert it into propylene to polymerize PP. A mass balance approach is used to allocate the bio-based fractions after blending with fossil-based feedstock. • **Production process 3:** Use sugar as the feedstock to produce isopropanol, which is an intermediate of Bio-PP, by fermentation. This process is under development by Mitsui Chemicals.
	Main manufacturers	• **Production process 1:** LyondellBasell (United States), Sabic (Saudi Arabia), LG chemical (Korea), TELKO (Finland) • **Production process 2:** Borealis (Austria) • **Production process 3:** Mitsui Chemicals (Japan) *Under development
	Production capacity	• **Production process 1:** 20,000 tons (2020)[1] • **Production process 2:** 10,000 tons (2020)[1]
Life cycle CO_2		• **Production process 1:** -2.51 $kgCO_2e/kg$ (cradle to gate)[2] • **Production process 2:** -0.58 $kgCO_2e/kg$ (cradle to gate)[3]

Sources:

1. Nova Institute GmbH, "Bio-based Building Blocks and Polymers - Global Capacities, Production and Trends 2020-2025" (2021).
2. Moretti, Christian, Martin Junginger and Li Shen, "Environmental life cycle assessment of polypropylene made from used cooking oil", *Resources, Conservation & Recycling*, vol. 157 (2020), 104750.
3. Borealis, "The Bornewables™: a sustainable alternative to virgin polyolefins". Available at ‹www.borealisgroup.com/storage/Polyolefins/Circular-Economy-Solutions/The-Bornewables/The-Bornewables-a-sustainable-alternative-virgin-PO.pdf›

2.2.5. Bio-polyethylene terephthalate (PET)

Polyethylene Terephthalate (PET) is a general-purpose plastic whose uses include beverage bottles, films and fibre. As its bio-based equivalent, bio-PET, can be used on a "drop-in" basis, without changes to processing facilities. It is used as an alternative to fossil-based PET in a variety of applications.

PET is synthesized from two monomers: monoethylene glycol (MEG) and terephthalic acid. Bio-MEG is commercially produced from bioethanol by India Glycols (India). However, since bio-based terephthalic acid is not commercially produced, currently only partially bio-based PET is commercially available. In line with the weighting of MEG in PET, the maximum bio-based content of bio-PET is about 30 per cent. In the future, however, if bio-based terephthalic acid is made commercially available, fully bio-based PET will be marketed. Suntory Holdings (Japan) has been engaged in developing a fully bio-PET bottle in conjunction with Anellotech, a US-based biochemical venture company.[1]

Table 2.3. Bio-PET datasheet

Properties	Bio-based	• Partially bio-based (in line with the weighting of MEG, the maximum bio-based content of bio-PET is 30 per cent)
	Biodegradability	• Not biodegradable
	Recyclability	• Mechanical recycling, chemical recycling and energy recovery are possible
	Other properties	• Same as fossil-based PET
Applications		• Same as fossil-based PET (beverage bottles, films, fibre/clothes, etc.)
Production	Feedstock/ production processes	• **Bio-PET (polymer):** Bio-PET is produced through dehydration condensation of bio-MEG and terephthalic acid. • **Bio-MEG (monomer):** Bio-MEG is manufactured using bioethylene derived from bioethanol. • **Terephthalic acid (monomer):** Terephthalic acid is produced from petroleum. A commercial production process for bio-based terephthalic acid is currently under development.
	Main manufacturers	• **Bio-PET (polymer):** Indorama Ventures (Thailand), Lotte Chemical (Korea), Far Eastern New Century Corporation (Taiwan), Teijin (Japan), Toray Industries (Japan) • **Bio-MEG (monomer):** India Glycols (India) • **Terephthalic acid (monomer):** Suntory Holdings & Annelotech (under development)
	Production capacity	• Approx. 165,000 tons (2020)[2]
Life cycle CO_2		• 2.99 $kgCO_2e/kg$ (feedstock production to resin production), 4.63 $kgCO_2e/kg$ (feedstock production to disposal)[3]

Sources:

1. Anellotech, "100% Renewable Plastic Bottle Significantly Closer to Reality After Successful Production of Bio-based Paraxylene from Non-food Biomass Bio-based Benzene Is Next", 26 February 2019. Available at ‹www.anellotech.com/press/100-renewable-plastic-bottle-significantly-closer-reality-after-successful-production-bio›
2. Nova Institute GmbH, "Bio-based Building Blocks and Polymers - Global Capacities, Production and Trends 2020-2025" (2021).
3. Satomi Yagihashi, Ayumi Shibata, Hiroshi Oshima and Norihiro Itsubo, "LCA of polyethylene terephthalate from biomass", Seventh Meeting of the Institute of Life Cycle Assessment, Japan (2012). Available at ‹www.jstage.jst.go.jp/article/ilcaj/2011/0/2011_0_22/_pdf/-char/ja›

2.2.6. Bio-polyamide (PA)

Polyamide (PA), also known as nylon, is a family of amide-linked polymers with excellent heat resistance. They are composed of one or two monomers. If one or both of the monomers are derived from biomass, the PA is classed as bio-PA. The bio-based content varies depending on the type of resin and ranges from 40 to 100 per cent.

Bio-PAs use biomass feedstock primarily to achieve their mechanical properties. Secondarily, they also have the features of bio-based plastics, such as low greenhouse gas emissions. Since the compositions of bio-PAs are different from those of fossil-based PAs, their physical properties and other functionalities need to be verified before replacing existing PAs.

Table 2.4. Bio-PA datasheet

Variety		• There are various types of bio-PAs, depending on the combination of monomers. The name of an individual bio-PA is derived from the name of its monomers or the number of carbons in them.
Properties	Bio-based	• Partially/fully bio-based
	Biodegradability	• Not biodegradable
	Recyclability	• Mechanical recycling, chemical recycling and energy recovery are possible
	Other properties	• Heat resistance, etc.
Applications		• Automobile parts, electric/electronic parts, etc.
Production	Feedstock/ production processes	• Bio-based feedstocks, such as sebacic acid produced from castor oil, are used. • **PA11:** Plant-derived undecanlactam is used as a raw material. • **PA610**: Polymerizes fossil-based hexamethylenediamine and plant-derived sebacic acid. • **PA1010:** Polymerizes plant-derived decanediamine and sebacic acid. • **PA1012**: Polymerizes plant-derived decanediamine and dodecanedioic acid. • **PA10T**: Polymerizes plant-derived decanediamine and fossil-based terephthalic acid. • **PA11T**: Polymerizes plant-derived undecanediamine and fossil-based terephthalic acid.
	Main manufacturers	• Arkema (France): PA11, PA610, PA1010 • Evonik (Germany): PA610, PA1010, PA1012 • BASF (Germany): PA610 • DuPont (United States): PA610, PA1010 • EMS-Grivory (Switzerland): PA610, PA1010 • Toray Industries (Japan): PA610 • UNITIKA (Japan): PA11, PA10T • Toyobo (Japan): PA11T • Mitsubishi Gas Chemical Company (Japan): PAMX10
	Production capacity	• Approx. 245,000 tons (2020)[1]
Life cycle CO_2		• **PA610**: 4.6 kg CO_2e/kg[2] • **PA1010**: 4.0 kg CO_2e/kg[2] • **PA1012**: 5.2 kg CO_2e/kg[2]

Sources:

1. Nova Institute GmbH, "Bio-based Building Blocks and Polymers - Global Capacities, Production and Trends 2020-2025" (2021).
2. Evonik, "VESTAMID® Terra: General information", no date. Available at ‹www.vestamid.com/en/products-services/VESTAMID-terra/general-information› (accessed 6 September 2021).

2.2.7. Bio-polycarbonate (PC)

Polycarbonate (PC) is a plastic with excellent impact resistance, durability and transparency. PC is produced from bisphenol A, which is derived from petroleum, as one of the monomers.

So far, Japanese companies (Mitsubishi Chemical Corporation and Teijin) have separately developed and marketed bio-PCs that do not use bisphenol A but use isosorbide made from starch instead.

Recently, similar to the case of bio-PE and bio-PP, a new production process using bionaphtha made from vegetable oils has also been developed. This is a bio-based version of the conventional PC made from petroleum.

Table 2.5. Bio-PC datasheet

Properties	Bio-based	• **Bio-PC (isosorbide based)**: Partially bio-based • **Bio-PC (bisphenol A based)**: Fully/partially bio-attributed (mass balance approach)
	Biodegradability	• Not biodegradable
	Recyclability	• Mechanical recycling, chemical recycling and energy recovery are possible
	Other properties	• **Bio-PC (isosorbide based)**: superior to fossil-based PC in some properties • **Bio-PC (bisphenol A based)**: same as fossil-based PC
Applications		• Automobile interior/exterior equipment parts, sound insulation walls, cellular phone housings, display deflecting plates, sunglasses, cosmetics containers, LED lighting, automobile door handle film, etc.
Production	Feedstock/ production processes	• **Bio-PC (isosorbide based)**: Copolymerization of isosorbide produced from starch as the feedstock with other components. • **Bio-PC (bisphenol A based)**: Conversion of vegetable oil such as used cooking oil into bionaphtha and blend it with fossil-based naphtha to make partially bio-based PC. Generally, the bio-based fraction is allocated to a specific portion of PC using a mass balance approach.
	Main manufacturers	• **Bio-PC (isosorbide based)**: Mitsubishi Chemical Corporation (Japan), Teijin (Japan) • **Bio-PC (bisphenol A based)**: Sabic (Saudi Arabia), LG chemical (Korea), Covestro (Germany), Trinseo (United States)
	Production capacity	• **Bio-PC (isosorbide based)**: Approx. 24,000 tons (2020)[1]
Life cycle CO_2		• N/A

Sources:

1. Nova Institute GmbH, "Bio-based Building Blocks and Polymers - Global Capacities, Production and Trends 2020-2025" (2021).

2.2.8. Polylactic acid (PLA)

Polylactic acid (PLA) is a fully bio-based and biodegradable plastic, which is widely used all over the world. It is widely used in applications such as packaging, cutlery and fibre.

Although PLA is a well-known biodegradable plastic, it requires industrial composting facilities to biodegrade and generally does not break down in soil or in the ocean.

Table 2.6. PLA datasheet

Properties	Bio-based	• Fully bio-based
	Biodegradability	• Biodegradable (industrial composting)
	Recyclability	• Mechanical recycling is possible if collected separately • Chemical recycling is under development • Energy recovery is possible
	Other properties	• Low heat resistance (improved PLA resin exists)
Applications		• Transparent food/non-food packaging, cutlery, fibre, agricultural film, 3D printing filaments, etc.
Production	Feedstock/ production processes	• Polymerization of lactic acid produced by saccharifying and fermenting starch crop or sugar crop
	Main manufacturers	• NatureWorks (United States), Total Corbion PLA (Netherlands), Zhejiang Hisun Biomaterials (China), COFCO (China), Guangzhou Bioplus Materials Technology (China), SUPLA Material Technology (China)
	Production capacity	• Approx. 395,000 tons (2020)[1]
Life cycle CO_2		• **NatureWorks**: 0.62 kgCO_2e/kg (from feedstock production to polymer production)[2] • **Total Corbion PLA**: 0.50 kgCO_2e/kg (from feedstock production to polymer production)[3]

Sources:

1. Nova Institute GmbH, “Bio-based Building Blocks and Polymers - Global Capacities, Production and Trends 2020-2025” (2021).
2. NatureWorks, “Eco-Profile”, 2021. Available at ‹www.natureworksllc.com/What-is-Ingeo/Why-it-Matters/Eco-Profile›
3. A. Morão and F. de Bie, “Life Cycle Impact Assessment of Polylactic Acid (PLA) Produced from Sugarcane in Thailand”, *Journal of Polymers and the Environment*, vol. 27, (2019), pp. 2523–2539.

2.2.9. Polyhydroxyalkanoate (PHA)

Polyhydroxyalkanoate (PHA) is a fully bio-based resin produced through microbial fermentation process. There is a wide range of PHA, depending on the type of monomers and their combination. Many companies are developing various types of PHA, some of which are already available on the market.

One of the characteristics of PHA is its excellent biodegradability. Some PHA resins, including PHBH produced by Kaneka Corporation (Japan), have been confirmed to degrade in the ocean and have obtained certification for marine biodegradability (“OK biodegradable MARINE” from TÜV Austria).

Table 2.7. PHA datasheet

Variety		• There is a wide range of PHA, depending on the type of monomers and their combination
Properties	Bio-based	• Fully bio-based
	Biodegradability	• Biodegradable (industrial composting, home composting, soil, ocean) • Biodegradability varies by resin product
	Recyclability	• Mechanical recycling is possible if collected separately • Energy recovery is possible
	Other properties	
Applications		• Plastic bags, bottles, trays, cutlery, etc.
Production	Feedstock/ production processes	• PHA polymers are directly produced through the fermentation process by specific microorganisms using sugar or vegetable oils as feedstock
	Main manufacturers	• Danimer Scientific (United States), Newlight Technologies (United States), Kaneka Corporation (Japan), RWDC Industries (Singapore), Tianan Biologic Material (China), CJ CheilJedang Corporation (Korea)
	Production capacity	• Approx. 31,000 tons (2020)[1]
Life cycle CO_2		• -2.3 to 6.9 kg CO_2e/kg[2]

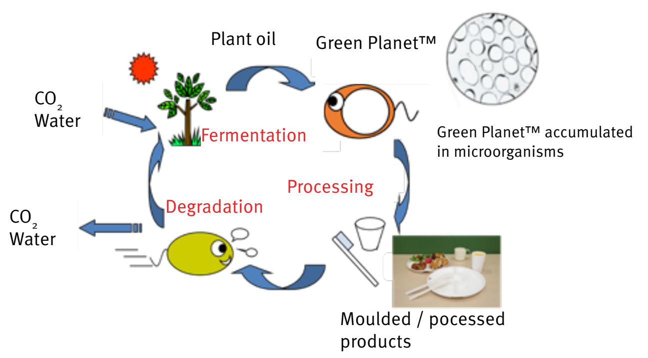
Sources:

1. Nova Institute GmbH, “Bio-based Building Blocks and Polymers - Global Capacities, Production and Trends 2020-2025” (2021).
2. Jorge Cristóbal, Cristina T. Matos, Jean-Philippe Aurambout, Simone Manfredi and Boyan Kavalov, “Environmental sustainability assessment of bioeconomy value chains”, *Biomass and Bioenergy*, vol. 89, (2016), pp. 159–171.

Example: KANEKA Biodegradable Polymer Green Planet™ (PHBH)

Overview

KANEKA Biodegradable Polymer Green Planet™ (PHBH) is a PHA polymer produced from plant oils. It is 100 per cent bio-based and offers excellent biodegradability. It is produced by Kaneka's unique microbial fermentation process and can be used in a wide variety of biodegradable and durable applications. Recent research shows that Green Planet™ also has excellent biodegradable properties in marine environments, helping to reduce marine plastic pollution.



Manufacturer

- Kaneka Corporation (Japan)
- Current production capacity: 5,000 tons per year
- Plans to expand production capacity to 100,000-200,000 tons per year by 2030

Main features and advantages

- Excellent biodegradability for composting and anaerobic digestion
- Biodegradability in seawater, helping address marine microplastics
- Suitable for a variety of applications as an alternative for PE, PP, ABS
- 100 per cent bio-based biopolymer, produced from plant oils, which is in line with the principles of the circular economy

Applications

- A wide range of applications, such as food packaging, containers, cutlery and agricultural/civil engineering materials
- The most suitable applications are products that are difficult to separate in the waste collection stream, such as waste collection bags

Certificates

- Bio-based carbon content and biodegradability of Green Planet™ are certified by organizations in Europe, the United States and Japan.

Certificates	Biomass	Biodegradation			
Europe	OK biobased TÜV AUSTRIA ★★★★ S0318	OK compost TÜV AUSTRIA INDUSTRIAL S0318	HOME OK compost TÜV AUSTRIA HOME S0318	SOIL OK bio-degradable TÜV AUSTRIA SOIL S0318	MARINE OK bio-degradable TÜV AUSTRIA MARINE S0318
USA		BPI COMPOSTABLE IN INDUSTRIAL FACILITIES			
Japan	BP バイオマスプラ	生分解性 バイオマスプラ			

Ongoing projects

- **Introduction of PHBH biodegradable shopping bags in Kenya.** Kaneka Corporation has been working to promote the widespread use of shopping bags made from PHBH in the Republic of Kenya, where fossil-based plastic bags have been banned since August 2017. In particular, Kaneka has been supporting the introduction of the certification and labelling system for biodegradability and is providing technical training to local manufacturers to produce biodegradable shopping bags. This project is being implemented under the auspices of the Japan International Cooperation Agency.

  ⇢ Kaneka press release: ‹www.kaneka.co.jp/en/service/news/nr20181019/›

- **Life cycle demonstration project for PHA polymers.** In this project, used cooking oil was used as a raw material for PHBH. The obtained PHBH was converted into bags, and the bags were tested for organic waste collection in Kyoto City. Eventually, the collected organic waste with the PHBH bags were treated by an anaerobic digestion system. The project aims to establish domestic PHA production and a waste treatment system in which anaerobic digestible PHA bags are used. The project is implemented under the auspices of the Japanese Ministry of Environment.

  ⇢ Japanese Ministry of Environment press release: ‹www.env.go.jp/press/107210.html›

Sources

1. UNIDO website: ‹www.unido.or.jp/en/technology_db/5277/›
2. Presentation of Kaneka on the Ministry of Environment website: ‹www.env.go.jp/council/03recycle/y0312-02/y031202-6r.pdf›

2.2.10. Bio-polybutylene adipate terephthalate (PBAT)

Polybutylene adipate terephthalate (PBAT) is an aliphatic/aromatic copolyester with high biodegradability. It is soft but strong, has excellent heat resistance stability and spreadability, and is highly suitable for blending with other biodegradable plastics. PBAT, which is mainly produced from petroleum, is often used as a blend material with other biodegradable resins because of its cost-effectiveness. As a single material, it is used in products such as agricultural mulching film.

In addition to fossil-based PBAT, partially bio-based PBAT is also produced, using a bio-based 1,4-butanediol monomer. In the future, when terephthalic acid and adipic acid can be made from biomass, the bio-based content of PBAT will be further increased.

Table 2.8. (Bio-)PBAT datasheet

Properties	Bio-based	• Fossil-based, partially bio-based
	Biodegradability	• Biodegradable (industrial composting, home composting, soil)
	Recyclability	• Mechanical recycling is possible if collected separately • Energy recovery is possible
	Other properties	• Soft but strong physical properties • Excellent in heat resistance stability and spreadability during moulding • Suitable for blending with other biodegradable plastics
Applications		• Blending material with other biodegradable plastics, agricultural mulching film, etc.
Production	Feedstock/ production processes	• PBAT is produced by copolymerizing 1,4-butanediol, adipic acid and terephthalic acid • Currently, all monomers are primarily made from fossil resources although some PBAT manufacturers use bio-based 1,4-butanediol to produce partially bio-based PBAT
	Main manufacturers	• **PBAT (fossil-based):** BASF (Germany), Novamont (Italy), Kingfa Sci. & Tech. (China), Xinjiang BlueRidge Tunhe Chemical Industry Joint Stock (China) • **Bio-PBAT (partially bio-based):** Novamont (Italy)
	Production capacity	• Approx. 286,000 tons (2020)[1]
Life cycle CO_2		• N/A

Sources:

1. Nova Institute GmbH, "Bio-based Building Blocks and Polymers - Global Capacities, Production and Trends 2020-2025" (2021).

2.2.11. (Bio-)polybutylene succinate (PBS)

Polybutylene succinate (PBS) is a biodegradable plastic produced by copolymerizing 1,4-butanediol and succinic acid. It offers excellent biodegradability and heat resistance, and is highly compatible with other materials.

In addition to fossil-based PBS, partially bio-based PBS is also produced, using bio-based succinic acid. When bio-based 1,4-butanediol is used, PBS becomes fully bio-based.

Table 2.9. (Bio-)PBS datasheet

Properties	Bio-based	• Fossil-based, partially bio-based
	Biodegradability	• Biodegradable (industrial composting, home composting, soil)
	Recyclability	• Mechanical recycling is possible if collected separately • Energy recovery is possible
	Other properties	• Higher biodegradability and heat resistance than general biodegradable resins, including PLA and PBAT[1] • High compatibility with fibre and other materials[1]
Applications		• Materials for agricultural use (mulching film, sheets for forestry use, etc.), eating utensils (cutlery, paper cup, straw), compostable bags, non-woven fabric, etc.
Production	Feedstock/ production processes	• PBS is produced by copolymerizing 1,4-butanediol and succinic acid • All monomers are made from fossil resources, while PTT MCC Biochem use bio-based succinic acid to produce partially bio-based PBS
	Main manufacturers	• **PBS (fossil-based):** China New Materials Holdings (China), Anqing He Xing Chemical (China), Zhejiang Hangzhou Xinfu Pharmaceutical (China) • **Bio-PBS (partially bio-based):** PTT MCC Biochem (Thailand) (Joint venture of Mitsubishi Chemical Corporation (Japan) and PTT Global Chemical (Thailand)
	Production capacity	• PBS (fossil-based): Approx. 86,000 tons (2020)[2] • Bio-PBS (partially bio-based): Approx. 20,000 tons (2020)[2]
Life cycle CO_2		• N/A

Sources:

1. Mitsubishi Chemical Holdings, "Newsletter". Available at ‹www.m-chemical.co.jp/topics/2019/__icsFiles/afieldfile/2019/12/16/NL_BioPBS_HP.pdf› (accessed 6 September 2021).
2. Nova Institute GmbH, "Bio-based Building Blocks and Polymers - Global Capacities, Production and Trends 2020-2025" (2021).

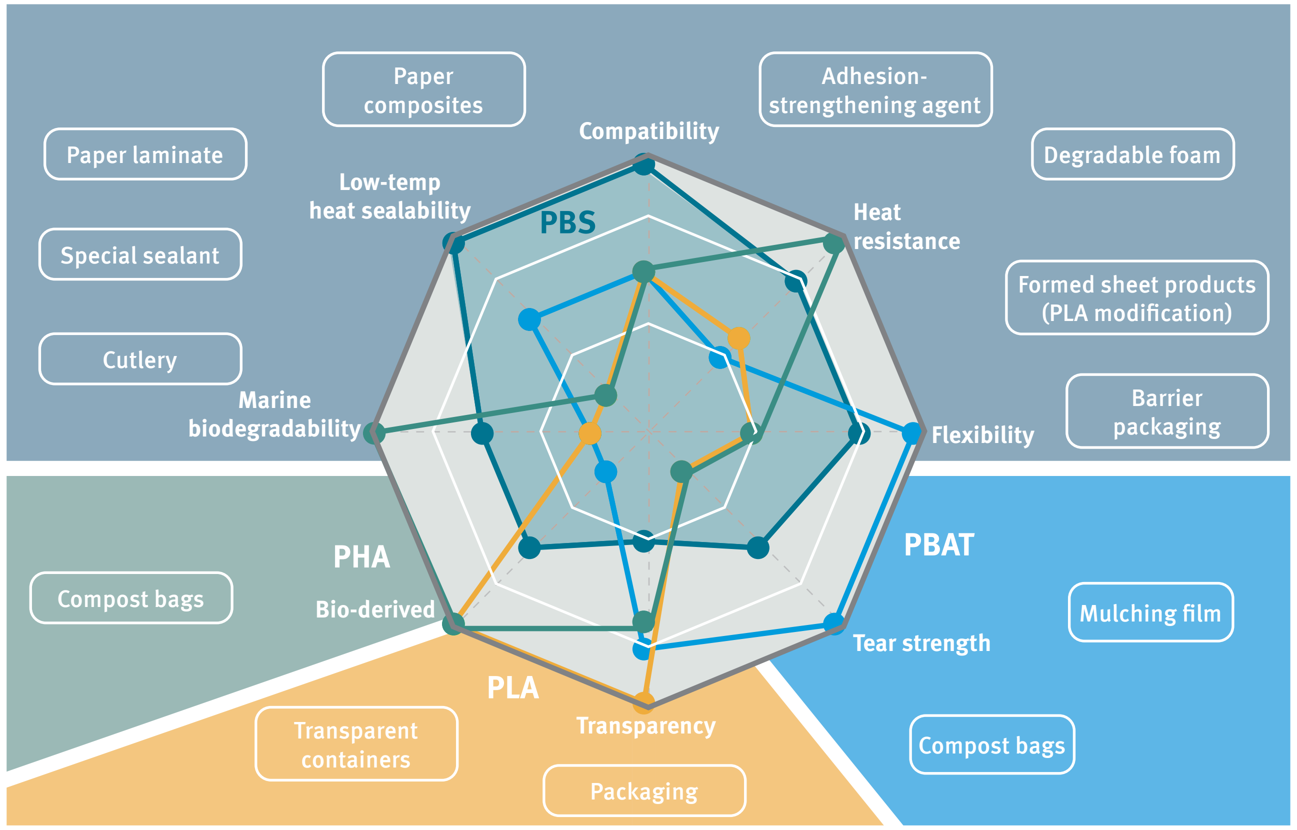
Example: BioPBS™

Manufacturer

- Since 2017, BioPBS™ has been produced by PTT MCC Biochem Company Limited (Thailand), a joint venture between the Mitsubishi Chemical Corporation (Japan) and PTT Global Chemical Public Company Limited (Thailand)
- Production capability: 20,000 tons

Features of BioPBS™

- BioPBS™ is made with succinic acid derived from plant materials, a renewable resource. At this point, the other monomer 1,4-butanediol is manufactured from fossil resources, resulting in bio-based content of 50 per cent. In the future, 100% BioPBS is planned to be produced and trials for mass production have already been conducted.
- BioPBS™ has excellent performance in aspects such as biodegradability at ambient temperatures, low-temperature heat-sealing, compatibility, heat resistance and flexibility. Properties that BioPBS™ does not have by itself can be achieved when it is used in composites with other resins and materials.



Sources: Provided by Mitsubishi chemical corporation.

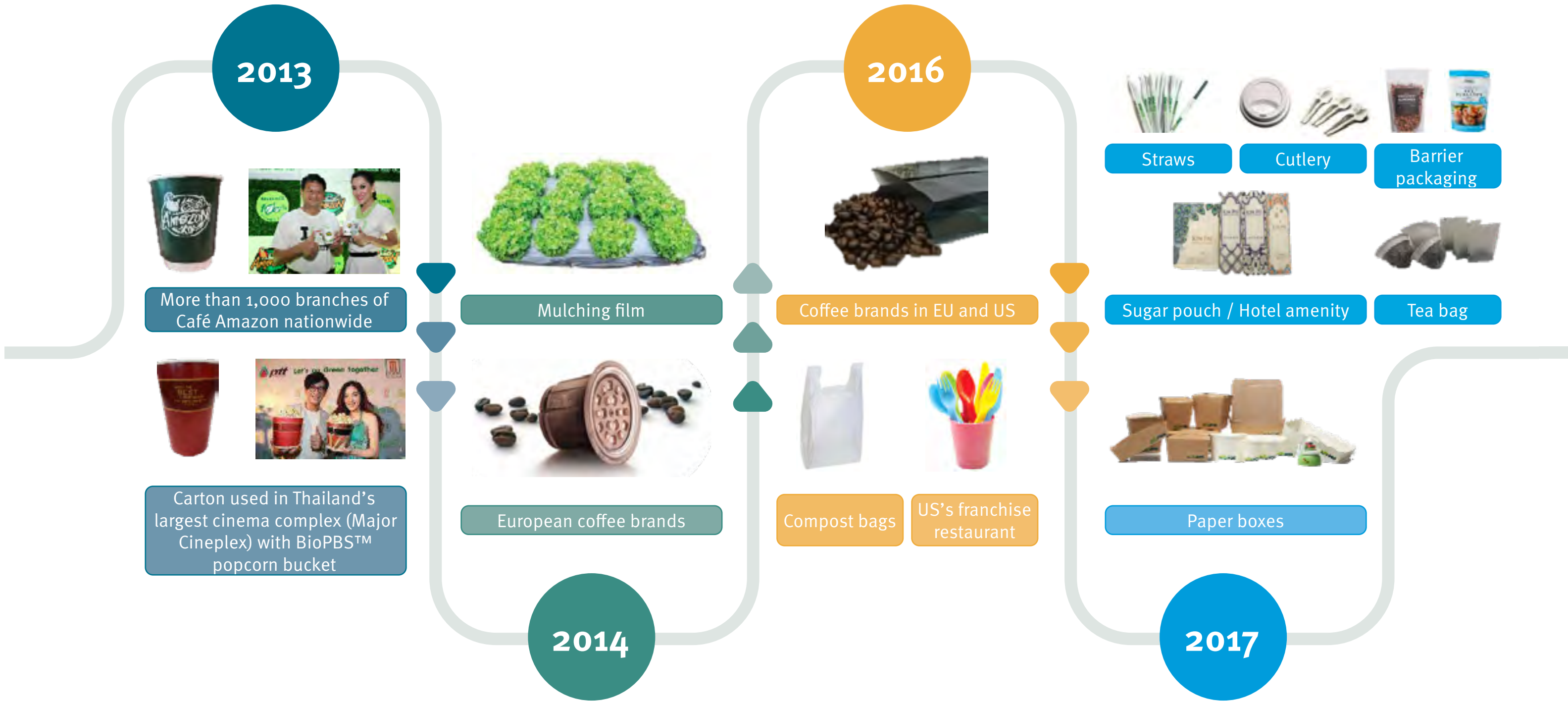
Ongoing projects

Development and demonstration of the practical use of BioPBS™ films for agricultural and other uses. This project aims to establish a new agricultural system that uses biodegradable and bio-based plastics for agricultural mulching films, which entail a significant environmental, labour and economic cost for collection and disposal after use. Its goal is to establish a method to control film degradation with polymer engineering and biochemical approaches and promote the use of agricultural mulching films that do not require disposal processing for as many crops and areas as possible. This project is backed by the Japanese Ministry of Environment.

⟶ Mitsubishi Chemical Company press release: ‹www.m-chemical.co.jp/news/2019/1207422_7467.html›

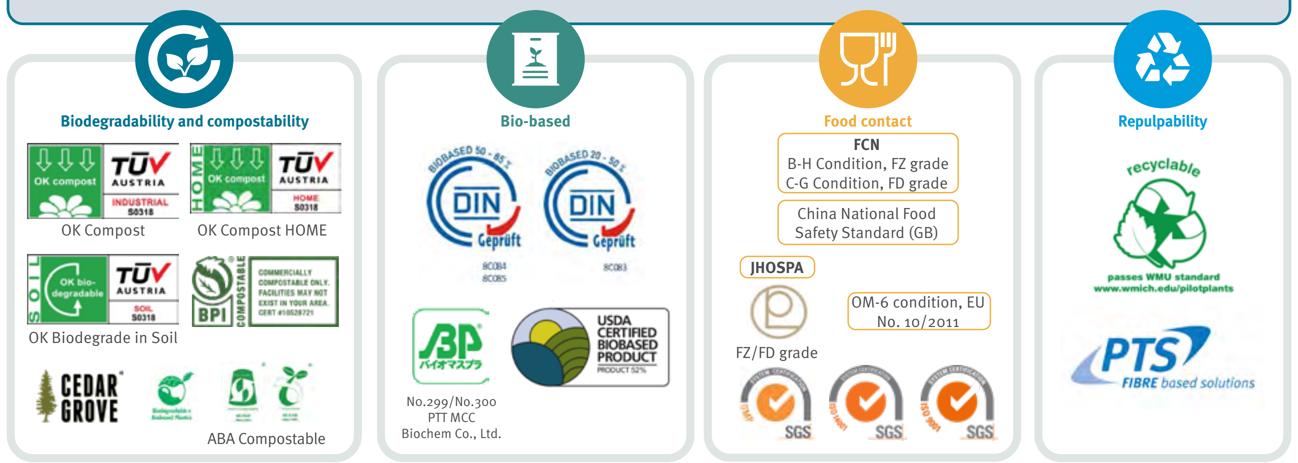
Applications

- Various products using BioPBS™ are being developed, including films for agricultural use, garbage bags for composting, shopping bags, fruits and vegetable bags, paper lamination, fibers for nonwoven fabrics, cutlery, straws and packaging material.
- Coffee capsules and tea bags that leave chaff, or multi layer food packages, which are not suitable for recycling.



Certifications

BioPBS™ has obtained certification from organizations in Europe, the United States and Japan for bio-based content and biodegradability:



Sources

1. Mitsubishi Chemical Holdings Newsletter: ‹www.m-chemical.co.jp/topics/2019/__icsFiles/afieldfile/2019/12/16/NL_BioPBS_HP.pdf›
2. Mitsubishi Chemical Holdings website, ‹www.m-chemical.co.jp/csr/activities/case1.html›
3. Mitsubishi Chemical Holdings website, ‹www.m-chemical.co.jp/products/departments/mcc/sustainable/product/1200364_7166.html›

2.2.12. Starch-containing polymer compounds

Starch-containing polymer compounds are resins of single or multiple types of biodegradable polymers blended with plasticized starch. It is also possible to use only bio-based polymers for fully bio-based polymer compounds. Starch-containing polymer compounds are becoming increasingly popular for applications that require biodegradability.

Table 2.10. Starch-containing polymer compounds datasheet

Properties	**Bio-based**	• Partially/fully bio-based
	Biodegradability	• Biodegradable (industrial composting, home composting, soil) • Biodegradability varies by resin product
	Recyclability	• Energy recovery is possible
	Other properties	
Applications		• Shopping bags, fruit and vegetable bags, agricultural mulching film, garbage bags, etc.
Production	**Feedstock/ production processes**	• Starch-containing polymer compounds are produced by plasticizing the starch from corn or other crops and blending it with other biodegradable plastics
	Main manufacturers	• Novamont (Italy), BIOTEC (Germany), BioLogiQ (United States), Shanghai Disoxidation Macromolecule Materials (China), Rodenburg Biopolymers (Netherlands)
	Production capacity	• Approx. 395,000 tons (2020)[1]
Life cycle CO_2		• N/A

Sources:

1. Nova Institute GmbH, “Bio-based Building Blocks and Polymers - Global Capacities, Production and Trends 2020-2025” (2021).

2.3. Other alternatives to bioplastics

2.3.1. Biocomposites

Biocomposites are produced by blending plastics with materials derived from biomass as fillers. They generally use fossil-based polyolefins (PE or PP) as base materials, although bioplastics may also be used. Commonly used materials for fillers are starch, agricultural residues, wood powder, paper powder, clam shells and eggshells. The proportion of biomass-derived materials can be over 50 per cent. In general, mixing hydrophobic plastics with hydrophilic biomass-derived materials is not easy and requires expertise in mixing using an extruder.

Biocomposites are effective in reducing both greenhouse gas emissions and the use of exhaustible resources. However, due to their reduced recyclability, care should be taken in selecting applications. In addition, it should be noted that when non-degradable plastics are used, the resulting biocomposite will also not biodegrade.

Figure 2.3. Overview of biocomposites

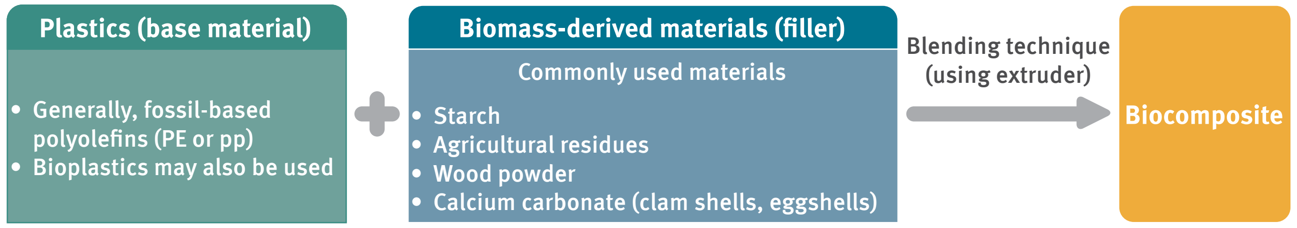


Table 2.11. List of biocomposites developed by Japanese companies

Company	Product name	Material	Applications	Description
Agricultural residue based				
Amica Terra	Modo-cell	Plant-based resin + rice straw, bamboo, starch, etc.	Cups, cutlery, straw, etc.	
GS Alliance	Nano-Sakura	Biodegradable resin + nano cellulose, biomass waste (plants, wood, tree, bamboo, waste wood, waste paper, etc.)	Cutlery, etc. (other applications like bottles, straws and bags are also under development)	• 100% natural biomass-derived biodegradable resin material is used
Texchem Group	TEXa	Plastic + agricultural waste (≥50%)	Home appliances, everyday goods, furniture, tableware and utensils, etc.	• Headquartered in Malaysia • Use of agricultural waste such as chaff palm waste (up to 51%) • Recyclable
Starch based				
Biomass Res-in Holdings	RiceResin, Wood-Resin, etc.	Polyolefin + plant-based materials (inedible rice, crushed rice, wood flour, bamboo, food waste)	Bags, cutlery, food containers, daily goods, etc.	• Rice resin can be made to have a 70% rice content
Biopoly Joetsu	SRP70, Ricelon55	Polyolefin + old rice	Garbage bags, cutlery, trays, etc.	
Kobayashi	ReseamST	Polyolefin + corn starch	Bags, bottles, everyday goods, etc.	• Industrial corn (dent corn) starch is used • Corn starch content is 30–60%
Wood based				
i-Compology	i-WPC	Polyolefin + wood flour	Trays, bottles, plant pots, etc.	• Injection moulding is possible • Wood flour content can be adjusted (51wt% and 31wt% are standard products)
	Biofade	PHA + wood flour	Sheets, film, injection moulded products (cutlery, etc.)	• Injection moulding is possible
Panasonic	Moulding materi-al containing high concentration cellulose fibre	Plastic + cellulose fibre	Chassis of home appliances, construction materials, automobile parts, everyday goods, etc.	• Contains more than 55% cellulose fibre • Design can make the most of the natural feel of the material through original moulding technology
Toclas Corpo-ration	Woodnanoplus	Plastic (PP, etc.) + wood flour (including cellu-lose nanofiber)	Automobile parts, machine parts, etc.	• Cellulose nanofiber improves impact resistance by a factor of 1.5
Wood Plastic Technology	Wood plastic	Plastic + woody material	Pallets for logistics, etc.	• Use of wood fibre generated from lumber mills
Paper and pulp based				
Camino	Paplus	PLA + paper	Tableware, everyday goods, automobile interiors, construction materials, etc.	• Biodegradable in composting facilities and in soil
Eco Research Institute	Mapka	Polyolefin + paper	Tableware, cutlery, daily goods, etc.	• Paper content: 51%
Calcium carbonate based				
EPM		Plastic (PP, PS, etc.) + eggshells (10%)	Food containers, etc.	
Myoko		PP + scallop shells (›51%)	Cutlery, etc.	
NEQAS	NEQAS BIO	Polyolefin + eggshells, rice, wood flour, clam shells, ash, etc.	Shopping bags, trays, etc.	• NEQAS OCEAN, a cellulose acetate-based product that biodegrades in the ocean, is also on the markett
Samurai Trading	Plashell	Plastic such as PP (40%) + eggshells (60%)	Container, novelty goods, tableware, cutlery, etc.	
TBM	Limex	Polyolefin + limestone	Container and packaging, etc.	• Working with companies to develop various applications • Annual production capacity of 23,000 tons
	Biodegradable Limex	PBAT + limestone		• Under development • Composite material of limestone and cellulose acetate is also under develop-ment (with Daicel)
WM	ETE resin	Plastic + eggshells	Tableware, cutlery, etc.	• High antibacterial power

Example: Biocomposite made from rice

Manufacturer

- Biopoly Joetsu Co. (Japan)

Sources: Biopoly Joetsu website: ‹www.biopoly.jp›.

Feedstock and production process

- Base plastic: PE or PP
- Biomass: old rice (not suitable for eating)

(There are also grades that use wood flour, flour mill residues and scallop shells)

Properties

- Rice can be blended with polyolefin up to 70 per cent. Depending on the application, it can be diluted with PE or PP to achieve the required physical properties.
- Reduces the use of fossil-based plastics, depending on the amount of rice blended.
- Supports local agriculture.

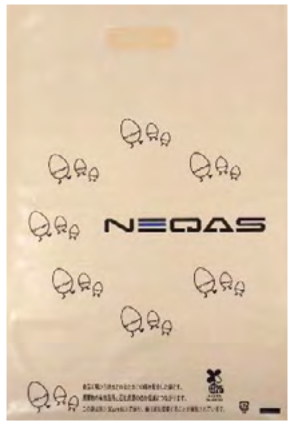
Applications

Garbage bags (approx. 20 per cent rice content)

Example: Biocomposite made from waste

Manufacturer

- NEQAS (Japan)
- Biocomposite materials are sold under the name NEQAS BIO
- Its parent company Sanwa Shokai manufactures and sells extruding machines (SANTEC-BIO), which can efficiently mix biomass resources and plastics



Sources: NEQAS website: ‹https://neqas.co.jp/neqas-bio/›.

Feedstock and production process

- Eggshell (70 per cent) + PP/PE (30 per cent).
- The standard eggshell content is 70 per cent. It can be diluted with PE or PP to achieve the required physical properties and molded into various products (in the case of shopping bags, the ratio of eggshell is 30–36 per cent).
- Other biomass derived materials, such as rice, wood flour, clam shells and ash, can also be used.
- The company is also developing NEQAS OCEAN, using cellulose acetate as a plastic material and offering marine biodegradability

Properties

- Recycling and adding value to materials that used to be discarded
- Helps reduce fossil-based plastic, depending on the amount of biomass blended
- Potential for stable supply and low cost

Applications

Shopping bags, trays, daily goods, etc.

2.3.2. Other alternative materials

Novel alternative materials based on paper and cellulose, or agar and seaweed are also being developed. Some examples are listed below in Table 2.12 and Table 2.13.

Table 2.12. Novel paper and cellulose materials developed by Japanese companies

Company	Product name	Material	Applications	Description
Futamura Chemical	NatureFlex	Wood pulp	Packaging	• Biodegradable cellulose film • Suitable for printing and heat sealing
Nippon Paper Industries	SHIELDPLUS	Paper	Packaging	• New material made by applying a special coating to paper • Barrier properties against moisture, air and odours
Oji Holdings Corporation	SILBIO BARRIER	Paper	Packaging	• Barrier to both water vapour and oxygen
	PaPiPress	Paper	Containers, cup lids	• Water-resistant and can be used as a lid for paper cups • Smoother and better appearance than conventional pulp moulds
Rengo	REBIOS	Cellophane/paper + biodegradable material	Packaging for food, everyday goods, clothing, sanitary goods, etc.	
Rengo	Biscopearl	Wood pulp	Carrier for fragrances, fungicides and deodorant	• 0.3–4 mm cellulose particles that can be used as an alternative to plastic beads • Porous, with high water and oil absorption

Table 2.13. Agar and seaweed materials

Company	Product name	Material	Applications	Description
Evoware (Indonesia)		Seaweed-based material	Packaging, cups	• Edible biopackaging made from seaweed • Shelf life of two years • Edible and biodegradable grades available
Skipping Rocks Lab (UK)	Ooho	Seaweed-based material	Beverage containers	• Edible beverage containers made from seaweed • Edible, with multiple flavours available
LOLIWARE (United States)	LOLISTRAW	Seaweed-based material	Straw	• Can retain its shape in liquid for up to 24 hours • Shelf life of up to two years

2.4. Needs of users and companies

When using alternative materials, it is important to identify the environmental, functional and economic impacts over the life cycle and to balance them with the needs of users.

2.4.1. Environmental aspects

As noted above, there are various types of alternative materials, and the environmental benefits vary. Bio-based materials have the effect of reducing greenhouse gas emissions and the use of depletable resources, while biodegradable materials reduce plastic waste in the natural environment and rationalize the waste disposal process.

It is important to think through the stages of the product life cycle (feedstock production, product manufacturing, use, disposal and recycling) to ensure the desired environmental effects are achieved. For example, it is not appropriate to use biodegradable plastics or biocomposites if they will be recycled together with other plastic products. Nor should non-degradable bio-based plastics be used in situations where biodegradability is required. In addition, there are also cases when switching to alternative materials increases the weight of the product, which in turn increases the environmental burden.

2.4.2. Functional aspects

In terms of function, there are various requirements for each application and sufficient consideration must be given in advance when substituting materials. Factors include temperature resistance (heat and cold), water resistance, mouldability, transparency, barrier properties, formability and recyclability.

It is important to fully verify these properties in advance using sample products. For example, the following points should be considered: whether the existing production line can be used and whether there will be any problems filling and storing the contents when the product is used for containers and packaging.

2.4.3. Economic aspects

In many cases, alternative materials are more expensive than traditional plastics. In addition to the price of the material itself, it is important to consider the cost implications over the full life cycle. For example, higher costs can result from increased moulding times and shorter shelf lives. On the other hand, when biodegradable plastics are used for agricultural mulch films, they are decomposed by being ploughed into the soil, which saves the time and effort required to collect them after use. Bio-based plastics like bio-PE, bio-PP and bio-PET, whose composition is the same as plastics originally produced from petroleum, can be mixed with conventional plastics in any desired ratio, helping control the impact of increased costs.

Another important aspect is the availability of the material. As our awareness of problems caused by plastics has increased in recent years, the supply and demand dynamics for certain alternative materials has tightened. It is necessary to confirm whether the required amount can be stably procured.

2.5. Alternative materials currently under development

2.5.1. Polyethylene furanoate (PEF)

Polyethylene furanoate (PEF) is a bio-based plastic that can be made fully bio-based. It is expected to be used for carbonated beverage containers and multilayer films because its properties are similar to PET, with even better gas barrier properties. A number of manufacturers are currently developing commercial processes for one of its monomers, furandicarboxylic acid (table 2.14)

2.5.2. Casein-based plastic

Casein-based plastic is a bioplastic made from the casein protein present in milk. It is developed and manufactured by Lactips (France), using surplus milk. The features of the resin produced include being bio-based, biodegradability, water solubility, gas barrier properties and edibility (table 2.15)

Table 2.14. PEF datasheet

Properties	Bio-based	• Fully bio-based
	Biodegradability	• Not biodegradable
	Recyclability	• Mechanical recycling and energy recovery are possible
	Other properties	• Physical properties similar to those of general-purpose plastics like PET and PE • Superior gas barrier, transparency and heat resistance (10 times higher barrier properties for oxygen, four times higher for carbon dioxide and two times higher for moisture compared to PET)[1]
Applications		• Beverage bottles, other bottles, pouch packaging materials, etc.
Production	Feedstock/ production processes	• Dehydrative condensation of bio-based furandicarboxylic acid (FDCA) with monoethylene glycol (MEG)
	Main manufacturers	• **Polymer (PEF)**: Avantium (Netherlands), Toyobo (Japan) • **Monomer (FDCA)**: Avantium (Netherlands), Origin Materials (United States), Novamont (Italy), Stora Enso (Finland), Corbion (Netherlands)

Sources:

1. BioPla Journal Special Feature, "Emergence of 100 per cent bio-based materials with functionality beyond PET", *BioPla Journal*, No. 65 (2017).

Table 2.15. Casein-based plastics data sheet

Properties	Bio-based	• Fully bio-based
	Biodegradability	• Biodegradable (industrial composting, home composting, soil, ocean)
	Recyclability	• Energy recovery is possible
	Other properties	• Similar to PVA (polyvinyl alcohol) • Biodegradability, water solubility, gas barrier properties and edibility
Applications		• Food packaging, detergent packaging, etc.
Production	Feedstock/ production processes	• Manufactured from casein, which is one of the proteins in milk
	Main manufacturers	• Lactips (France)

Sources:

1. Lactips, "Polymère naturel et biodégradable en milieu aquatique" (no date). Available at ‹www.lactips.com/en/technology› (accessed 7 September 2021).

2.6. Research and development at universities and other institutions

A large amount of research and development is being conducted on alternative materials like bioplastics, including the development of new materials, the improvement of the physical properties of existing ones, the improvement of manufacturing processes and the construction of resource circulation systems using bioplastics. Table 2.16 contains examples of research and development projects in Japan.

Table 2.16. Japanese research and development projects

Representative institution	Principal researcher	Material	Brief description	Source
Development of novel materials				
University of Tokyo	Prof. Kohzo Ito	Marine degradable multi-lock biopolymers	**Research and development of marine-degradable multi-lock biopolymers from inedible biomass** • To overcome the trade-off between biodegradability and polymer durability/toughness, this project introduces a multi-lock mechanism for polymer degradation. • By requiring multiple simultaneous stimuli such as light, heat, oxygen, water, enzymes, microorganisms and catalysts as triggers for degradation, the system maintains toughness and prevents degradation during use while allowing for fast on-demand degradation when accidentally diffused into the environment. • Target products include plastics, tyres, textiles, fishing nets and fishing gear.	[1]
Gunma University	Prof. Kenichi Kasuya	Marine degradable plastics with biodegradation trigger switch function	**Research and development of marine-degradable plastics with biodegradation trigger switch function** • The project aims to create at least three new marine-biodegradable plastic materials with a biodegradation performance of 90 per cent in six months in seawater at 30˚C, after the switching function is triggered. • Demonstrate the biodegradability of new marine-biodegradable plastics with switching functions that meet the above conditions in real marine environments, including the deep sea. • Create new marine-biodegradable base materials using biomass or CO_2 as the main raw materials.	[1]
Japanese Advanced Institute of Science and Technology (JAIST)	Prof. Tatsuo Kaneko	Photo-switchable marine degradable	**Development of photoswitchable marine-degradable edible plastics** • Development target is a plastic that is sufficiently durable during use but has photoswitchable degradability under strong sunlight in the marine environment. • Three types of photoswitches will be constructed: ‣ ON-type photoswitch: after dumping, strong sunlight and water reach the inside of the plastic and biodegradation begins (ON). This project will also establish the conditions for the plastic to become edible, so that it will break down in the digestive tract if accidentally ingested by marine organisms or mixed in with human food. ‣ OFF-type photoswitch: inhibits biodegradation in the presence of fluorescent light or sunlight exposure and begins biodegradation in dark environments such as seawater, the seabed and compost. ‣ ON/OFF-type photoswitch: an ideal system with both the above light switches.	[1]
Japanese Advanced Institute of Science and Technology (JAIST)	Prof. Tatsuo Kaneko	Polyimide	**Development of a bioplastic with the world's highest heat resistance of over 390°C** • The project team has developed the world's most heat-resistant bioplastic using photochemical methods on cinnamon-type molecules obtained from genetically modified microorganisms. • This polyimide delivered heat resistance up to a temperature of 390–425°C, exceeding the previously reported maximum heat resistance of 305°C for aromatic biopolyesters. • The new resin is expected to be used as a substitute material for glass in flexible displays and automotive parts.	[2]
Osaka University	Prof. Hiroshi Uyama	Composite material of starch and cellulose	**Development of a high-strength, highly water-resistant marine-biodegradable plastic from starch and cellulose** • By combining starch and cellulose using original technology, the project team developed a high-strength plastic sheet that biodegrades in the ocean. • The water resistance of starch was greatly improved and the resulting sheet composite material exhibited excellent water resistance and high strength. It was also confirmed to be highly biodegradable in seawater. • Joint development with Nihon Shokuhin Kako Co., Ltd.	[3]
Improvement of existing materials				
Osaka University	N/A	PLA + Eucommia elastomer	**Development and application of an impact-resistant resin fully made of biomass plastic** • ocusing on the elastomer produced in Tochu (*Eucommia* elastomer, EuTPI), a small amount of EuTPI is blended with polylactic acid to achieve impact resistance comparable to acrylonitrile butadiene styrene (ABS) resin.	[4]
Osaka University	N/A	PLA + PHA	**Production of a PLA-blend film by functional modification using photo-activated chlorine dioxide** • The project aims to blend polylactic acid (PLA) with other resins such as polyhydroxyalkanoic acid (PHA), using a new resin modification technology based on photo-activated chlorine dioxide.	[4]
Kyoto University	Prof. Yano Hiroyuki	PE + cellulose nanofiber	**Evaluation of the implementation of acetylated cellulose nanofiber-reinforced bio-PE produced by the Kyoto process** • This project aims to substitute bioplastics for automotive resin materials, and to demonstrate the effects of reducing CO_2 emissions in automotive air conditioners by strengthening the biopolyethylene resin through the use of high-strength cellulose nanofibers.	[4]
Improvement of production process				
Hokkaido University	Prof. Kiyotaka Nakajima, Prof. Atsushi Fukuoka	PEF	**Development of technology for mass synthesis of intermediate material for PEF** • The research team developed a new technology for the efficient synthesis of furandicarboxylic acid (FDCA), an intermediate material for the high-performance biopolyester polyethylene furanoate (PEF) in a highly productive and environmentally friendly process.	[5]
Development of resource circulation systems using bioplastics				
Advanced Science, Technology and Management Research Institute of Kyoto (ASTEM)	N/A	PHA	**Life cycle demonstration project for PHA polymers** • This project aims to develop the bioplastics production process using domestic biomass and to establish a waste treatment system that takes advantage of the properties of the bioplastic. • The project aims to demonstrate PHBH production from waste cooking oil and the use of PHBH for garbage bags and biogas conversion, as well as clarifying the effects of life cycle environmental improvement. • This is a joint project with ASTEM, Kaneka Corporation and Hitachi Zosen Corporation.	[4]

Sources:

1. NEDO, Moonshot Research and Development Programme: ‹www.nedo.go.jp/content/100922202.pdf›
2. JAIST press release: ‹www.jst.go.jp/pr/announce/20140214-3/index.html›
3. Osaka University press release: ‹www.eng.osaka-u.ac.jp/wp-content/uploads/2020/03/1583468108_1.pdf›
4. Ministry of Environment, Demonstration project for establishing a resource circulation system for plastics to support a decarbonized Society: ‹www.env.go.jp/press/107210.html›
5. Hokkaido University press release: ‹www.hokudai.ac.jp/news/2019/04/post-520.html›

3

Innovative packaging technologies

3.1. Introduction

Plastic packaging is widely used throughout the world. While it plays an important role in protecting its contents, issues such as marine plastic litter and the use of virgin plastics mean it is important to shift to using more sustainable packaging. With a special focus on Japanese technologies, this chapter provides examples of innovative packaging technologies and practices that help reduce the environmental impact of plastic packaging.

3.2. Roles and functions of packaging

Packaging plays many roles in our daily lives. Its main function is the protection of contents from damage caused by external factors like breakage or oxidization. It also provides convenience: different sizes of packaging can suit different uses (for example, single-dose packaging) and packaging influences ease of transport and handling. It also plays a role in communicating information to consumers, such as product names, ingredients and the manufacturer's address. These roles and functions are summarized below.

1. Protection of contents
   - Preservation of the quality of contents and extending the lifespan of products
   - For food or drink packaging, longer expiry dates help reduce food waste
   - Protection from external factors, for example:
     - Physical factors: impact from falls, vibration and compression
     - Chemical factors: oxidization, deterioration from light, rotting and changes caused by active chemical substances
     - Biological factors: putrefying bacteria, insects and rats
     - Human factors: falsification and misuse

2. Convenience for handling and usability for consumers
   - Logistics: transport and handling of materials (ease, efficiency and easy to distinguish) and storage (easy to stock and move around)
   - Sales: display (easy to arrange side by side, to distinguish and to move around) and unit size (easy to sell)
   - Consumption: open, reseal, portable and readiness for consumption (for example, microwavable)
   - Universal design: usability for all kinds of people regardless of their age, size, ability or disability

3. Information communication
   - Product appeal: design, brand logo and colour, product features, etc.
   - Labelling: product name, content description, use-by date/quality assurance period, quantity, user instructions, ingredients, manufacturer and distributor, etc.

While these roles and functions are important and necessary, consideration should be also given to reducing the environmental impact of plastic packaging. The next section provides an overview of such technologies and practices.

3.3. Examples of innovative technologies and practices

This section introduces a number of innovative packaging technologies and practices that help reduce the environmental impact of plastic packaging while maintaining the functions required for the correct performance of packaging. Particular attention is given to single-use plastic packaging.

When introducing specific technologies and practices, the following environmental benefits are considered:

- Reduce: reduction of virgin plastic used for packaging
- Reuse: reuse of packaging
- Recycle: recycle (recyclability) of packaging
- Renewable: the use of renewable materials such as paper or bio-based plastic for packaging
- Replace: the use of environmentally sustainable materials other than renewable ones.

The list of examples introduced in this section are summarized below in table 3.1. More detailed explanations follow after the list.

Table 3.1. Examples of innovative technologies and practices

	Product/technology/ initiative	Applications			Environmental benefits					Description
		Food	Beverage	Non-food	Reduce	Reuse	Recycle	Renewable	Replace	
1	Barrier PP Monomaterial Packaging	✓	✓	✓	✓		✓			PP-based monomaterial packaging material with high recyclability. Maintains a range of functions for applications such as food and daily necessities.
2	GL BARRIER (transparent barrier film)	✓	✓	✓	✓					Line of transparent barrier films with the world's highest level of barrier performance. Uses Toppan Printing's original transparent vapour-deposition and coating technologies.
3	Monomaterial barrier packaging (GL-BP, GL-LE)	✓	✓	✓	✓		✓			GL-BP and GL-LE are transparent barrier films based on polypropylene (PP) and polyethylene (PE), respectively. Developed as new additions to the line-up of GL Films (transparent vapour-deposition barrier film).
4	SILBIO BARRIER multi-barrier paper	✓		✓	✓		✓	✓		Paper material with high barrier properties. Can be used as an alternative to single-use plastic barrier films used for food packaging and industrial material packaging.
5	SHIELDPLUS (eco-friendly barrier paper)	✓		✓	✓		✓	✓		Environmentally friendly paper-based material with a barrier coating layer to prevent permeation of oxygen and water vapour. Applications include primary packaging for food (to preserve freshness), cosmetics, spices and other products.
6	LAMINA (heat-seal paper for packaging)	✓		✓	✓		✓	✓		Packaging material with heat-seal performance, based on paper as an eco-friendly, renewable material. Applications include secondary packaging materials (food, cosmetics, pharmaceuticals, etc.) that do not require barrier performance, as well as household goods and logistics materials.
7	SILBIO EZ SEAL heat-seal paper			✓	✓		✓	✓		Paper material with heat-seal performance. Can be used as an alternative to single-use plastics used for indirect food packaging and industrial material packaging. Does not have barrier performance.
8	Cellulose composites			✓	✓			✓		Resin pellet made by compounding biodegradable resin with pulp, which is composed of wooden fibre (cellulose), product is suitable for injection moulding and offering enhanced physical properties such as degree of elasticity, strength and heat resistance by compounding with pulp.
9	Transparent container using biaxially oriented PET technology	✓			✓					Technology to improve the heat resistance and strength of PET by stretching the material in two directions: vertical and horizontal. FP Corporation has been using this technology since 2021 to market biaxially oriented PET (BoPET) transparent containers with lids for food applications.
10	Tray-to-tray and bottle-to-tray recycling	✓			✓		✓			Bottle-to-tray: since 2011, FP Corporation has been collecting used PET bottles, and turning them into raw materials to produce recycled transparent containers (Eco-APET).
11	Paper-sealed tray	✓			✓			✓		Highly heat-resistant paper tray for food products. Since it is made using a heat-resistant paper material, it can be used in microwave ovens, standard ovens and steam convection ovens. Helps improve operational efficiency of in-store kitchens in supermarkets.
12	Light-weighting PET bottle design		✓		✓					Kirin Holdings has carried out significant research and development on saving materials in beverage packaging through its original designs, where consumer acceptance and functionality are compatible with the previous heavy bottles. PET bottles are among the most intensive technical fields for light-weighting. For example, the company has developed the lightest two-litre water bottles in Japan.
13	Paper-pressed lid for cold beverages (Tokan PA-Lid)		✓		✓		✓	✓		Paper-pressed beverage lid formed from a single sheet of paperboard, which can be used as a substitute for plastic lids for cold beverages. When combined with a paper cup and paper straw, beverage containers made entirely from paper can be produced.
14	SPOPS (paper container for personal-care products, etc.)			✓	✓	✓		✓		In Japan, refill pouches are widely used as containers for shampoos and other liquid personal-care products and household goods. SPOPS is a paper container that is easier to use and more eco-friendly than refill pouches. Intended for use with personal-care products and household goods, it also can also be used for hand sanitizers.
15	Environmentally friendly can production system		✓		✓		✓		✓	Aluminium Toyo Ultimate Can (aTULC) is a two-piece aluminium can, developed by the Toyo Seikan Group to reduce ecological impact and protect the global environment. Combining this technology with the company's "Compact system" allows beverage producers to produce cans in-house.
16	Cardboard packaging to replace plastics			✓	✓		✓	✓		In response to environmental issues and storage space concerns, cases of switching from plastic cushioning materials or trays to those made of cardboard is increasing. Examples of such cases are provided through the adoption of Rengo's cardboard manufacturing technologies.

No. 1	Company:	Dai Nippon Printing Co. Ltd					
	Product:	Barrier PP mono-material packaging					
✓ Food	✓ Beverage	✓ Non-food	✓ Reduce	Reuse	✓ Recycle	Renewable	Replace

Overview of technology

What is barrier PP mono-material packaging?

Barrier PP mono-material packaging is a PP-based mono-material packaging material with high recyclability that maintains a variety of functions for applications such as food and daily necessities. In response to environmental issues such as marine plastic pollution, recycling is being accelerated around the world to develop a circular economy. Mono-material packaging contributes to this goal.

Why is it innovative?

Many flexible packaging solutions for food and daily necessities are made from different materials that have different properties to provide different functions, such as preserving the contents and ensuring the strength of the packaging. However, flexible packaging made from multiple materials is difficult to recycle, since it is hard to separate the single material base layers. Mono-material packaging makes it much easier to recycle and improve the quality of the recycled material.

One of the main challenges for mono-material packaging is that the protection of contents is often diminished. By applying high gas barrier properties against oxygen and water vapour to a PP-based film using its unique conversion technology, Dai Nippon Printing's barrier PP mono-material packaging achieved high levels of oxygen and water-vapor barrier properties without using aluminum foil, vacuum metalized-PET film or PET-based transparent vapour-deposition film.

Environmental impact reduction

As this packaging material is made from more than 90 per cent PP, it is possible to meet the Circular Economy for Flexible Packaging (CEFLEX) guidelines, published by a European consortium promoting recycling in the flexible packaging industry.

High-gloss and high-barrier PP mono-material packaging

Key functions

High-gloss and high-barrier PP mono-material packaging is an environmentally friendly packaging with a structure of layers based on a single PP material to improve recyclability. The company's unique conversion technology provides a high barrier against oxygen and water vapour, and is also light-proof, allowing it to replace packaging using different materials such as aluminium foil or vacuum metalized PET film.

Available in three-layer and two-layer versions, the three-layer version offers excellent impact resistance and sealing properties, while the two-layer version reduces the amount of plastic used, further reducing the environmental impact.

Structure example

Conventional	→ 3-ply structure	→ 2-ply structure
PET or nylon	OPP	OPP
VM-PET	Special VM-PP	Special VM-PP
CPP	Special CPP	

Applications

High-gloss and high-barrier PP mono-material packaging is compatible with liquids, which allows its application for a variety of purposes, including daily necessities such as shampoo and conditioners, foods, powdered drinks and viscous materials.

Environmental impact reduction

High-gloss and high-barrier PP mono-material packaging has been certified for recyclability by Interseroh, a German recycling certification company, and has obtained the Made for Recycling mark.

MADE FOR RECYCLING interseroh

Conditions and facilities for introduction

Could be produced using existing filling machines. However, trials are needed to confirm performance.

Barrier PP mono-material packaging suitable for heat sterilization

Key functions

A transparent mono-material packaging that is suitable for pasteurization (using hot water up to 100°C) and retort sterilization (via pressured heat sterilization in excess of 100°C) after filling. Currently available mono-material packaging materials present challenges in terms of their barrier properties after heat sterilization. By applying Dai Nippon Printing's transparent vapour-deposition innovative barrier film technology, it is possible to maintain barrier properties following heat sterilization and keep a long shelf life.

Conventional	→ Mono-material
Transparent barrier PET	OPP
Nylon	Transparent barrier PP
CPP or PP peelable film	CPP or PP peelable film

Structure example

Applications and product line-up

There are two products: pouch-type and lid-type packaging for plastic containers. They can be used for a wide range of applications, including cooked soup, ready-to-eat meals, cooked seasoned rice and pet food. The new packaging can also be used for the lidding of plastic containers that require heat sterilization, such as fruits and jellies.

Example applications

Since September 2020, this solution has been adopted by Unilever for stand-up pouches for Lipton tea in Japan.

To preserve the taste and flavour of the tea, Unilever's Lipton series previously used a multi-material flexible packaging, with an aluminium foil barrier layer. However, the aluminium foil layer was difficult to separate and presented a major challenge for recycling. It also generated a large amount of CO_2 during production and disposal, making it a major issue from an environmental perspective.

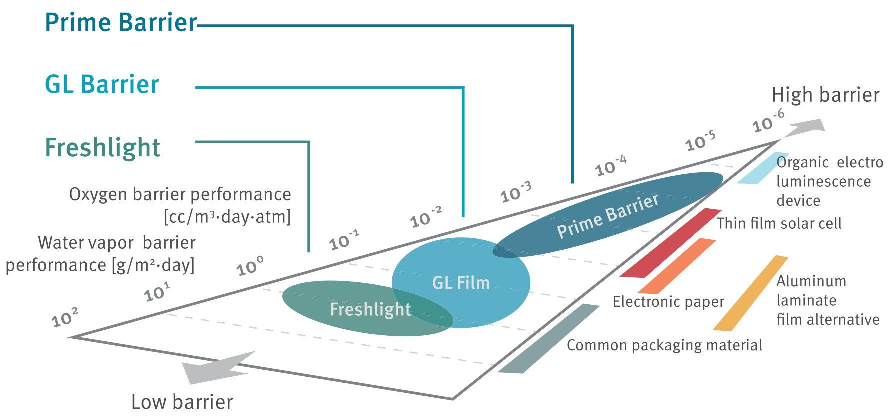
Dai Nippon Printing's mono-material packaging was chosen for its ability to maintain high barrier properties while being recyclable. Compared to the aluminium foil packaging, it reduces the air pressure to open the pouch before filling, thus reducing the amount of electricity needed for airflow. The weight of the pouch is also reduced compared to the aluminium foil structure, leading to a reduction in the amount of waste. Positive feedback has been received on the tangible environmental benefits of this product for Unilever to help deliver a circular economy. Compared to the aluminium foil structure, the new product is expected to reduce CO_2 emissions by 21.7 tons per 1 million bags used (Dai Nippon Printing estimate).

No. 2	Company:	Toppan Printing Co., Ltd.					
	Product:	GL BARRIER (transparent barrier film)					
✓ Food	✓ Beverage	✓ Non-food	✓ Reduce	Reuse	Recycle	Renewable	Replace

Overview of technology

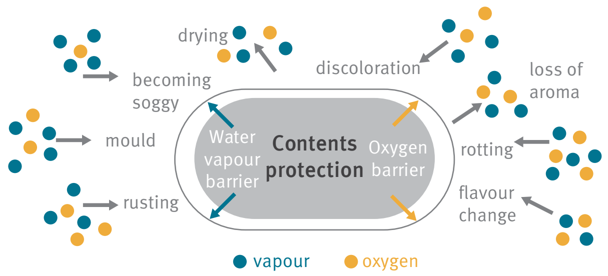
What is GL BARRIER?

GL BARRIER is a line of transparent barrier films offering the world's highest level of barrier performance and using Toppan Printing's original transparent vapour-deposition and coating technologies. Used in more than 45 countries and regions, it is suitable for various types of packaging applications, including food, medical and pharmaceutical goods, and electronics.



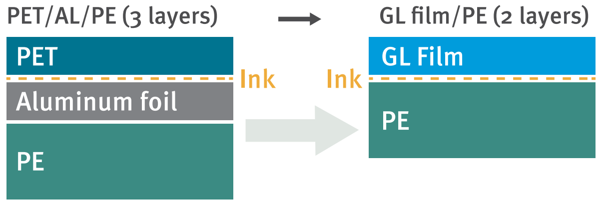
Oxygen and water vapour are major causes of deterioration of the contents of packaging. GL BARRIER provides a high level of barrier performance against these substances (equivalent to aluminium foil). Substituting aluminium foil enables transparent and metal-free packaging, which is suitable for microwavable food. It also allows the use of metal detectors to inspect impurities in the manufacturing process.

Images of barrier performance



Reducing packaging thickness

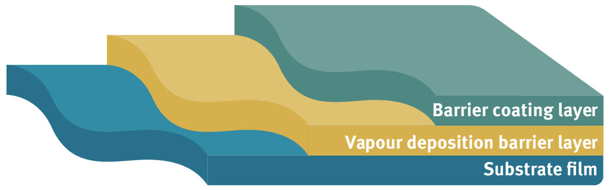
Gl film can simplify the structure of packaging.



Key functions

GL BARRIER is based on the lamination of a barrier coating layer and inorganic vapour-deposition layer (alumina or silica) on top of the base film (PET, PP, PE or nylon). Its multilayered structure, which combines a proprietary coating layer with high-grade vapour deposition, is well suited to subsequent processing such as printing and lamination and has shown stable barrier performance.

- High barrier performance
  - Protects contents from deterioration (moisture absorption, drying and rotting)
- High transparency and non-conductivity
  - Enables the use of metal detectors and electronic tags
  - Suitable for preparation in microwave ovens, since it is aluminium-free
  - Enables safety: transparency makes contents visible
- A wide range of options
  - Different grades available for different applications



Conditions and facilities for introduction

Since it is sold overseas as an original film, lamination and bag-making by the converters are required at the local installation site.

Environmental impact reduction

1. Enables a wide range of approaches to help prevent food loss:
   - Barrier performance helps to maintain freshness and extend best-by dates
   - Easier to use all contents from retort food packaging and tubes
   - Also suitable for single-portion packaging
2. CO_2 emissions reduction and plastic reduction:
   - Reduces CO_2 emissions in the manufacturing process since the printing and barrier layer are combined into one
   - Substituting aluminium foil reduces CO2 emissions during film production
   - Substituting aluminium foil reduces current packaging materials
3. Improved recyclability and waste treatment:
   - Monomaterial barrier package with barrier performance increases recyclability
   - Generates almost no residue and no hazardous gases during incineration

Example applications

GL Barrier is used in various products, including flexible packaging for food and snacks, retort pouches, chilled and frozen food packaging, packaging for electronics, medical and pharmaceutical goods, toiletries and composite liquid containers.

Flexible packaging / retortable packaging

Electronics packaging

Packaging for medical and pharma goods

Toiletries

Composite paper containers for liquids (EP-PAK, Cartocan, etc.)

Chilled or frozen food packaging

No. 3	Company:	Toppan Printing Co., Ltd.					
	Product:	Monomaterial barrier packaging (GL-BP, GL-LE)					
✓ Food	✓ Beverage	✓ Non-food	✓ Reduce	Reuse	✓ Recycle	Renewable	Replace

Overview of technology

What are GL-BP and GL-LE?

GL-BP and GL-LE are transparent barrier films based on polypropylene (PP) and polyethylene (PE), respectively. They were developed as new additions to the line-up of GL Films (transparent vapour-deposition barrier film), which has the highest market share in the world. The two products allow the company to provide a full line-up of monomaterial PET, PP and PE barrier packaging.

Advantages of high-performance monomaterial packaging

The issue of plastic waste is attracting increasing attention and demand is growing for eco-friendly packaging materials. Many global enterprises are setting recycling targets for the high-quality resource circulation of plastic packaging. One of these initiatives involves facilitating the horizontal recycling of materials through monomaterial packaging. Horizontal recycling is when products are recycled into ones similar to their original use.

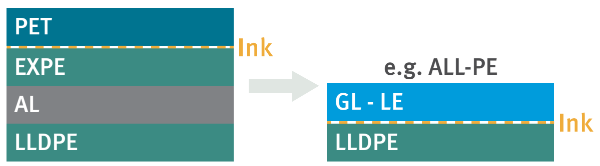
At present, most plastic packaging comprises multiple materials. The difficulty in separating these into individual materials during the recycling process is a barrier to horizontal recycling. Monomaterial packaging with barrier performance fixes this.

Multi-material structure

The general package configuration combines multiple materials to give barrier performance

Monomaterial structure

GL Films make it possible to achieve barrier performance, even with monomaterial structure



Key functions GL-BP

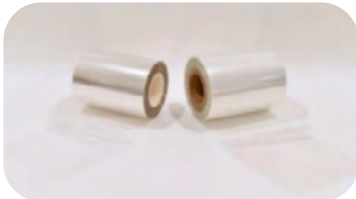
Enables boiling-water sterilization and hot filling, both of which have been hard to achieve with conventional PP materials

- Base material: biaxially oriented polypropylene film
- Main applications: food products with liquid content, such as baby food and fruit compote (envisaged uses include spout pouches and laminated tubes)
- Strengths
  - Outstanding heat and water resistance make it suitable for boiling-water sterilization and hot filling
  - Allows the filling of liquids: the strengthened heat-seal performance helps to prevent leakage

Key functions of GL-LE

The world's first PE-based transparent vapour-deposition barrier film, developed using Toppan Printing's advanced processing technology to add barrier properties to PE material (historically a challenge for vapour deposition).

- Base material: polyethylene (PE)
- Main applications: dried items such as pet food, beef jerky and granola bars
- Strengths: PE-based monomaterial barrier packaging, with recycling routes already established in the United States



GL-BP, GL-LE

Environmental impact reduction

Traditionally, monomaterial packaging without barrier performance could not be used for applications requiring this functionality. By developing a monomaterial packaging that also provides barrier performance, Toppan Printing will contribute to recycling initiatives. This is expected to help reduce the consumption of virgin plastics.

Conditions and facilities for introduction

Sold overseas in the form of its original film. Subsequent processing must be conducted locally.

Example applications

Sample shipments and sales (mainly for overseas markets) began in October 2019 for GL-LE as a single-layer film and in the first half of 2020 for GL-BP as a multilayer lamination film. A significant number of enquiries have been received for both products, mostly from overseas.

No. 4	Company:	Oji Holdings Corporation					
	Product:	SILBIO BARRIER multi-barrier paper					
✓ Food	Beverage	✓ Non-food	✓ Reduce	Reuse	✓ Recycle	✓ Renewable	Replace

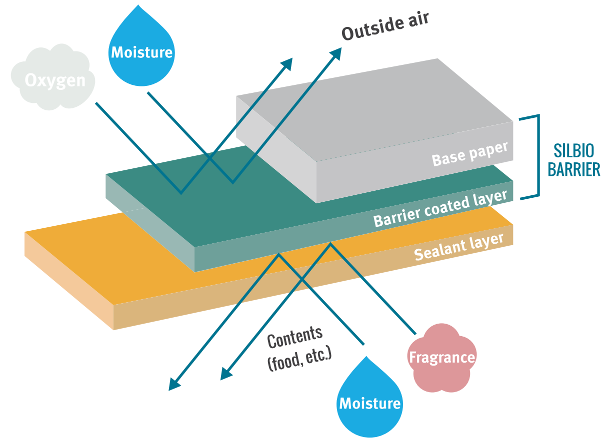
Overview of technology

What is SILBIO BARRIER?

SILBIO BARRIER is a paper material with high barrier properties. It can be used as an alternative to single-use plastic barrier films used for food packaging and industrial material packaging.

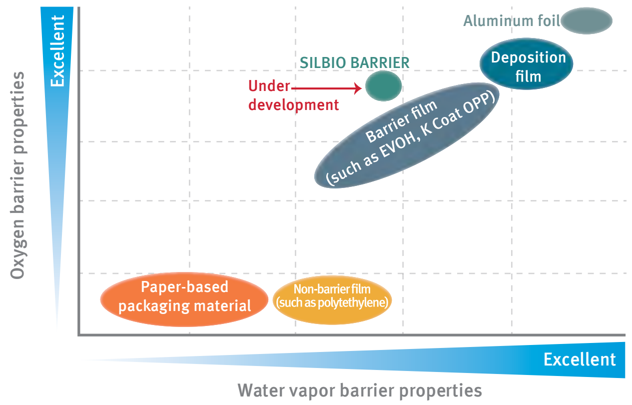
Structure of SILBIO BARRIER

The barrier coating layer reduces the permeation of oxygen, moisture and fragrance from outside air. It also prevents contents from diffusing moisture and fragrance.



Key functions

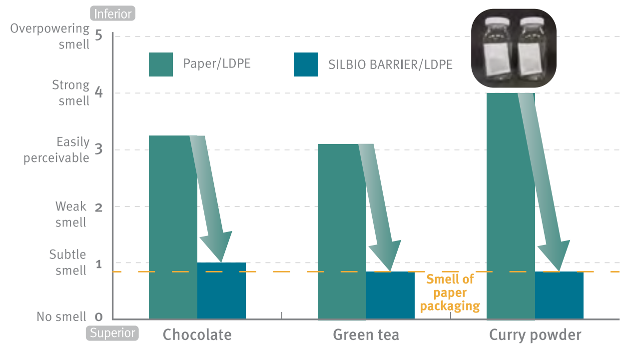
Same barrier property as conventional barrier film.



- **Aroma retention.** Gas barrier performance prevents the leakage of smells.

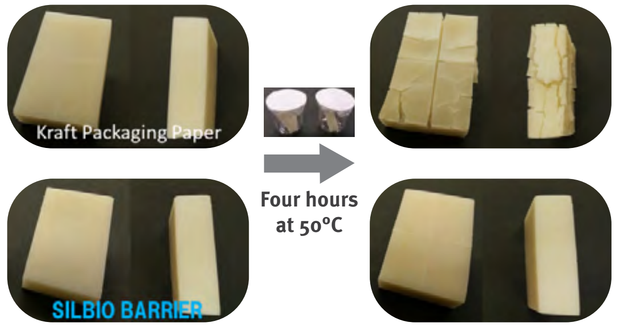
Prevention experiment for smell leakage of contents

Sensory evaluation of subjects selected by odour judgement technician



- **Moisture barrier.** Water-vapour barrier performance prevents evaporation of moisture of contents.

Prevention experiment for drying of cut rice cake



Environmental impact reduction

Replacing plastic packaging with paper helps reduce the use of depletable resources and CO_2 emissions.

Conditions and facilities for introduction

Normally delivered as a barrier paper, without sealant layer and in the form of a roll.

Example applications

Adopted as:

- primary and secondary packaging of food, seasonings, etc.
- primary and secondary packaging of daily necessities
- packaging of industrial materials and for transportation



No. 5	Company:	Nippon Paper Industries Co., Ltd.
	Product:	SHIELDPLUS (eco-friendly barrier paper)

✓Food	Beverage	✓Non-food	✓Reduce	Reuse	✓Recycle	✓Renewable	Replace

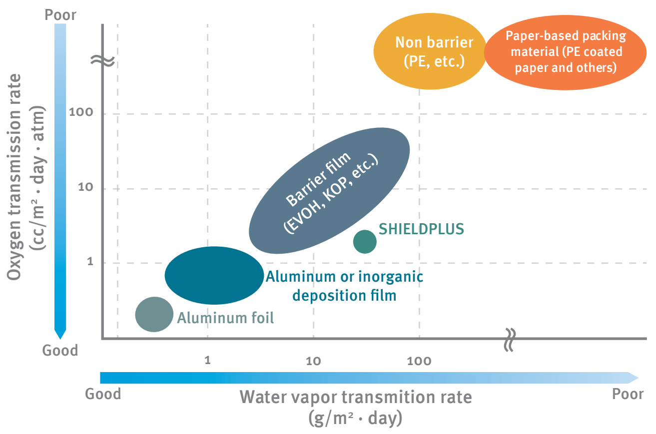
Overview of technology

What is SHIELDPLUS?
SHIELDPLUS is an environmentally friendly paper-based material, with a barrier coating layer to prevent permeation of oxygen and water vapour. Its applications include primary packaging for food (to preserve freshness), cosmetics, spices and other products. It can be supplied from two production sites: Asia (Japan) and Europe (Finland).

Why is it innovative?
Traditionally, it has been difficult to use paper for food packaging, since gases like oxygen permeate the gaps between paper fibres. Nippon Paper Industries has developed a barrier layer to cover the gaps based on the water-based coating technologies it has developed for the surface treatment of printing paper.

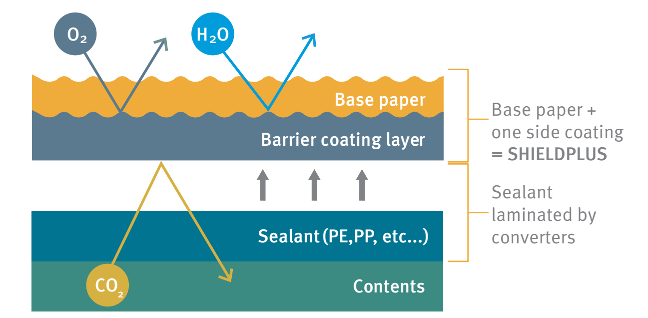
Key functions
Oxygen and water-vapour barrier: The oxygen permeation of nearly 1 cc/m²-day-atm is equivalent to widely used multilayer plastic barrier films. The solution can also achieve a suitable level of water-vapour barrier using sealant layers used in flexible packaging (for example, PE and PP). The heat-seal layer is purposely not laminated to allow users to choose sealant layers in line with the intended usage and desired quality.

Positioning of barrier materials



Flavour barrier: Depending on the contents, barrier performance can achieve the same level as general-purpose multilayer plastic films. Performance is particularly high for products such as chocolate, powdered detergents and vanilla extract.

Layer structure



Environmentally friendly: A highly eco-friendly material that offers renewability, carbon neutrality, recyclability and outstanding biodegradability.

Environmental impact reduction
CO_2 emissions and plastic usage: Product life cycle assessment shows that replacement by SHIELDPLUS achieved a 34 per cent reduction in CO_2 compared to plastic food packaging with similar barrier performance. Compared to a similar composition, the reduction in the use of plastic is approximately 50 per cent.*

Biodegradability: SHIELDPLUS offers similar biodegradability to cellulose. Using biodegradable resin as the heat-seal layer allows for biodegradable packaging. A high-biomass and high-biodegradable packaging material has been developed in a joint initiative using the barrier performance of SHIELDPLUS and the heat-seal performance of BioPBSTM, a biodegradable resin from the Mitsubishi Chemical Corporation.

Conditions and facilities for introduction
Lamination: Lamination on SHIELDPLUS is required to maintain barrier performance. Extrusion lamination is recommended.

Printing: Since the printing surface of paper materials is exposed on the outside of packaging, varnishing may be required, depending on the transport and storage conditions.

Bag-making and wrapping: Easier with machinery for paper materials. Machinery solely for plastics may require adjustment or modification.

*Composition of materials assessed: OPP 20µm/EVOH 12µm/LLDPE 25µm. SHIELDPLUS product composition: SHIELDPLUS 66g/m² / PE 30 µm

Example applications

Chocolate packaging: Conche
(additive-free chocolate shop in the Shizuoka prefecture: ‹www.conche.net›)

- **Reason for adoption**: Company was looking to switch primary packaging, which is essential for product quality, to a material with a low environmental impact and as carbon-neutral as possible.
- **Benefits**: Highly eco-friendly packaging that meets product quality requirements. Also reduced costs by revising other specifications (such as printing and labels) in conjunction with the paper packaging adoption.

Bath salt packaging: Tenshi no Bath Powder
(MAX Co., Ltd.: ‹www.soapmax.co.jp›)

- **Reason for adoption**: Desire to shift to paper packaging, aiming for "earth friendly" packaging and skin-friendly bath salts.
- **Benefits**: Use of plastic has been halved by switching from normal three-layer packaging to two layers. Embodies the product concept of an "earth and skin-friendly bath salt" while ensuring scent barrier performance.

No. 6	Company:	Nippon Paper Industries Co., Ltd.
	Product:	LAMINA (heat-seal paper for packaging)

✓Food	Beverage	✓Non-food	✓Reduce	Reuse	✓Recycle	✓Renewable	Replace

Overview of technology

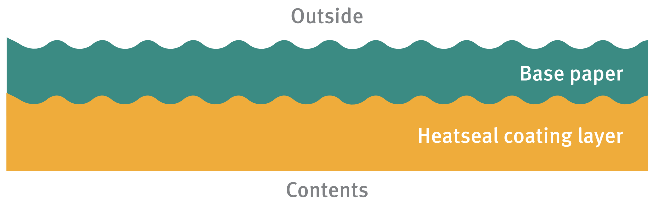
What is LAMINA?
LAMINA is a packaging material with heat-seal performance that is based on paper, an eco-friendly, renewable material. By adding a heat-seal coating layer on the paper, using paper-making and coating technologies, it eliminates the need for a plastic laminate layer. It can be used in a wide range of applications for secondary packaging material including for food, cosmetics and pharmaceuticals that do not require barrier performance, household goods and logistics materials.

Why is it innovative?
Generally, plastic films and laminated paper used for flexible packaging are laminated with plastic films such as PE and PP (sealant layers).

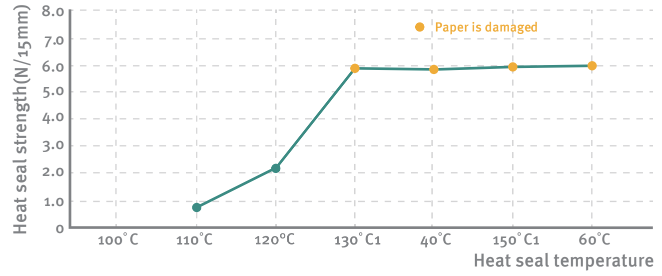
LAMINA uses paper coating technology to create a heat-sealed coating layer with proven sealing performance when heated. This makes it possible to produce bags using Lamina alone, reducing the use of plastic and increasing biomass ratio.

Key functions

Heat-seal performance: As the illustration shows, LAMINA has a two-layer structure, where the paper base material is coated with a heat-seal layer. It has a sealing temperature of approximately 110–130°C. At 130°C or higher, performance is approximately 6 N/15 mm and the paper-based material itself is torn instead of the heat-sealed part. It does not have gas barrier performance. A biodegradable type and a low-temperature sealing type are currently under development.



Streamlined manufacturing process and reduced lead time: Flexible packaging materials made from plastics are often laminated with films such as polyethylene, to provide heat-sealability. This requires lamination and ageing processes prior to shipping. In contrast, since LAMINA has a heat-sealed layer itself, it is possible to omit this process and shorten lead time. A further benefit is the use of digital printing methods, since there is no need for plate-making.



- Sample: LAMINA unbleached kraft (60g/m²)
- Heat-seal condition: 2 kgf/cm² × 0.5 second (adhesion between coated surfaces)
- Test method: JIS Z1707 (test speed: 200 mm/min)

Reference: comparison of manufacturing processes

- Plastic packaging materials: Printing ⟶ Lamination ⟶ Ageing ⟶ Slitting ⟶ Shipping
- LAMINA: Printing ⟶ Slitting ⟶ Shipping

Environmental impact reduction
Plastic use: Switching to LAMINA has the potential to reduce plastics by approximately 80 per cent compared to a typical sample food plastic packaging material.

Reference: Composition of assessed packaging materials

- Compared material: OPP 20 µm / CPP 30 µm (outer bag used for snacks)
- LAMINA: 60 g/m² (paper base material: brown unbleached kraft paper)
- Pulp recycling: LAMINA does not have plastic lamination and makes it easier to process in pulp recycling due to fewer impurities.

Conditions and facilities for introduction
Printing: Since the printing surface of paper materials is exposed on the outside of packaging, depending on the transport and storage conditions, measures such as protecting the printed surface using varnish may be necessary.

Bag-making and wrapping: Easier with machinery for paper materials. Machinery solely for plastics may require adjustment or modification.

Example applications

Secondary packaging for pocket toilet paper
(Tokyoshiko Co., Ltd.: ‹www.tokyoshikou.co.jp›)

- **Reason for adoption**: Desire to use eco-friendly packaging for a convenient portable product suited to a wide range of uses (including outdoors).
- **Benefits**:
  - Reduced use of plastics compared to plastic film packaging.
  - Eco-friendly paper materials used for the outer packaging, as well as the toilet paper rolls and enclosed individual packs.

Reference: ‹www.tokyoshikou.co.jp/item.html›

No. 7	Company:	Oji Holdings Corporation					
	Product:	SILBIO EZ SEAL Heat-Seal Paper					
Food	Beverage	✓ Non-food	✓ Reduce	Reuse	✓ Recycle	✓ Renewable	Replace

Overview of technology

What is SILBIO EZ SEAL?

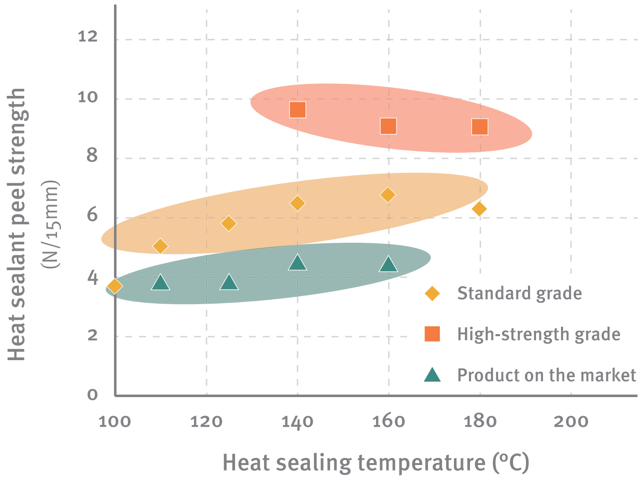
SILBIO EZ SEAL is a paper material with heat-seal performance. It can be used as an alternative to single-use plastics for indirect food packaging and industrial material packaging. The material does not have barrier performance.

Why is it innovative?

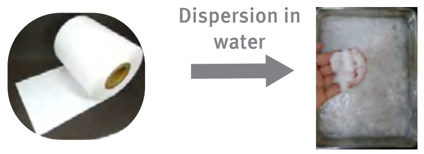
- Conventional plastic packaging does not biodegrade in the natural environment, causing waste issues.
- Replacing single-use plastics with paper packaging can reduce plastic pollution.
- Recyclable.

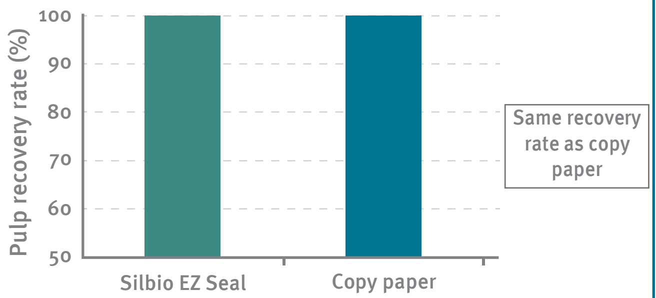
Key functions

- Heat sealable: can replace plastic packaging.



- Recyclable: recyclable like normal copy paper.





Environmental impact reduction

Replacing plastic packaging with paper helps reduce the use of depletable resources and CO_2 emissions. The material is also recyclable.

Conditions and facilities for introduction

The product will be delivered in the form of a roll.

Example applications

Can be used for indirect food packaging and industrial material packaging that does not require barrier properties.

No. 8	Company:	Oji Holdings Corporation					
	Product:	Cellulose composites					
Food	Beverage	✓ Non-food	✓ Reduce	Reuse	Recycle	✓ Renewable	Replace

Overview of technology

What are cellulose composites?

Cellulose composites are a resin pellet made by compounding biodegradable resin with pulp, which is composed of wooden fibre (cellulose). The product is suitable for injection moulding.

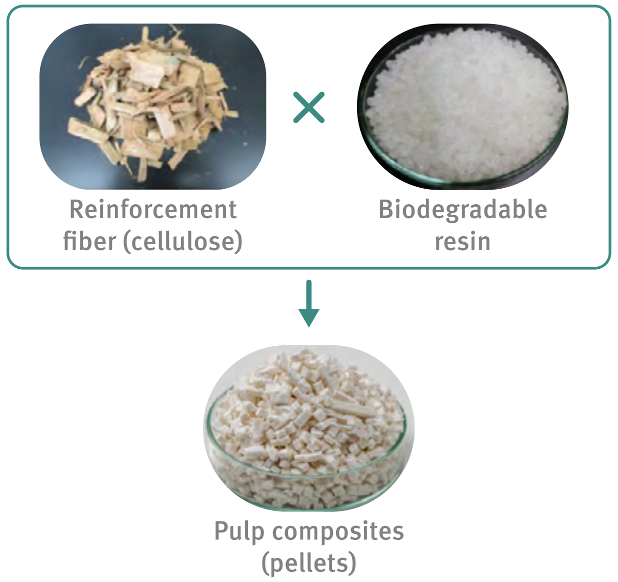
Its physical properties, such as the degree of elasticity, strength and heat resistance, are enhanced by compounding with pulp.

Why is it innovative?

Their low strength sometimes limits the applications of biodegradable resins. Increasing the strength of biodegradable resin through compounding with pulp has the potential to expand its range of applications. The pulp ratio is normally 30 per cent.

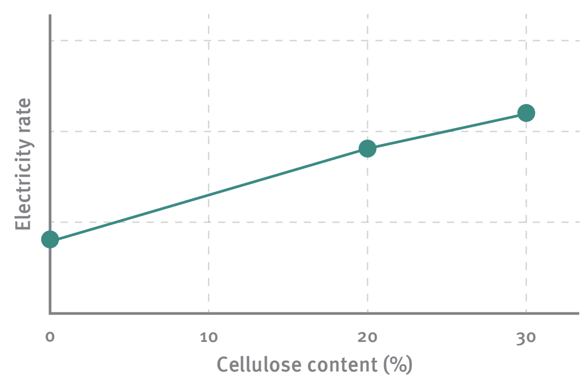
Key functions

Degree of elasticity, strength and heat-distortion temperature are improved by compounding with pulp.



Cellulose content and elasticity rate

*Example of a biodegradable plastic



In addition, since the degree of heat shrinkage is reduced when cellulose composite is used for injection moulding, it is possible to reduce the takt time of products. Injection moulding using cellulose composite is also unlikely to damage the tooling.

Environmental impact reduction

By compounding with pulp, it is possible to increase biomass ratio and reduce the use of fossil-based materials. Pulp is a sustainable material that absorbs CO_2 in the air.

Economic implications

Improvements to strength allow the thickness of the layer to be reduced.

Conditions and facilities for introduction

The product is delivered as pellets.

Example applications

Since the product is under development, expected application examples are shown.

No. 9	Company:	FP Corporation
	Product:	Transparent container using biaxially oriented PET technology

✓ Food	Beverage	Non-food	✓ Reduce	Reuse	Recycle	Renewable	Replace

Overview of technology

What is biaxially oriented PET technology?
Biaxially oriented PET is a technology that improves the heat resistance and strength of PET by stretching the material in two directions: vertical and horizontal. FP Corporation has been using this technology since 2021 for the production of biaxially oriented PET (OPET) transparent containers with lids for food applications.

Why is it innovative?
Prior to the development of OPET, the main materials used for transparent containers with lids (used mainly for meal boxes and side dishes) were biaxially oriented polystyrene (OPS) and amorphous PET (APET). While OPS delivered outstanding strength and heat resistance, it had a lower level of oil resistance. On the other hand, APET provided outstanding transparency and oil resistance but had limited heat resistance and could not be used in microwaves.

Seeking to improve the heat resistance of PET products with outstanding transparency to make foods look more attractive, at the same time as providing oil resistance, FP Corporation has seized the initiative for the development of OPET technology. In November 2012, the company launched the world's first OPET food containers. It has also been able to make use of recycled PET in food-grade products for its Eco-APET and Eco-OPET product lines.

Features of OPET products
OPET increases both the heat resistance and the strength of containers.

1. **Heat resistance**: increased to 80°C from 60°C for conventional APET products, enabling microwave use like OPS.
2. **Oil and chemical resistance**: even if sauce or dressing adheres to the lid, there is no risk of making a hole in the containers after heating in a microwave.
3. **Resistant to breakages**: improved performance compared to OPS, reducing the risk of cutting fingers or splinters when opening the lid.

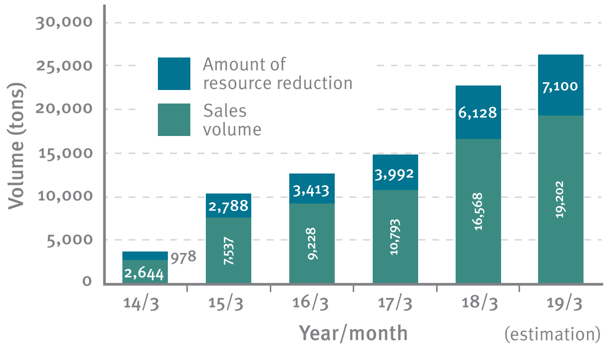
OPET products
No holes are made when heated in a microwave, even though some deformation occurs. There is also no damage from embrittlement from medium-chain triglycerides (MCTs) or similar ingredients.

Conventional OPS products
Despite having similar heat resistance to OPET products, the lack of oil resistance means heating in microwaves could result in holes. There is also the possibility of breakage due to embrittlement from MCTs or similar ingredients.

The image on the right shows a comparison of OPS and OPET for mayonnaise (a typical source of oil) and MCT oil.

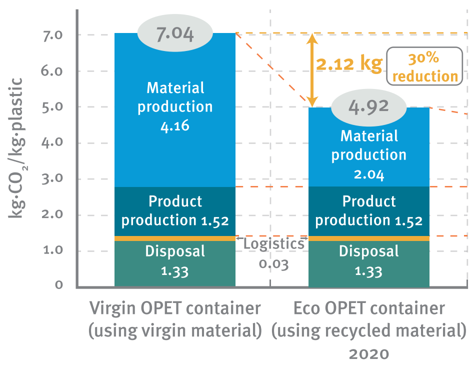
	OPS material	O-PET material
Microwave test with mayonnaise 		
Heat resistance	80 °C	80 °C
Oil resistance	×	○
Cold resistance	○	○
Cost	○	○
Crack test with MCT oil (room temp.)		

Environmental impact reduction
Switching from APET to OPET improves material strength and enables thinning of the products, allowing a reduction of approx. 27% in PET resin. The solution has meant a reduction of approx. 16,320 tons of PET resin between 2015 and 2018. (OPET sales volume and resource reduction.)



Use of OPET made from recycled materials (Eco-OPET) reduces CO_2 emissions by 30 per cent.

CO_2 emissions reduction of Eco OPET



Ratio of collected material usage 38%

Example applications

The product has been adopted by supermarkets and other users in Japan.

No. 10	Company:	FP Corporation
	Initiative:	Tray-to-tray and bottle-to-tray recycling

✓ Food	Beverage	Non-food	✓ Reduce	Reuse	✓ Recycle	Renewable	Replace

Overview of technology

Tray-to-tray recycling
Since 1990, FP Corporation has been collecting post-consumer foamed polystyrene trays at supermarkets and other locations and turning them into raw materials to recycle them into food trays.

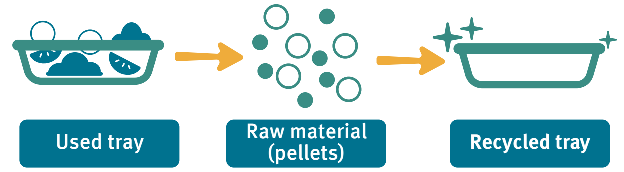
The FP Corporation recycling system involves four types of key actors: consumers; supermarkets and other retailers; packaging wholesale dealers; and FP Corporation. The system has become firmly established in Japan as one in which everyone is involved. Collection boxes for foamed polystyrene trays are installed at about 9,800 facilities nationwide (as of December 2020). The initiative helps to prevent the discharge of plastic waste into the ocean by recycling used trays instead of throwing them away after a single use.

Bottle-to-tray recycling
Since 2011, we have been collecting post-consumer PET bottles, and in our recycling plant turning them into raw materials and recycling to transparent containers (Eco APET).

FP Corporation recycles around 47,000 tons of PET bottles per year, helping to reduce plastic wastes through diversification of recycling routes to enable efficient recycling of used PET bottles instead of making them into waste.

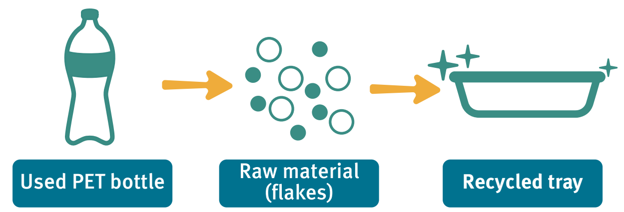
Eco-APET

Tray to tray™



Pellets: raw material for plastic products similar in shape to rice grains.

Bottle to tray™



Flakes: raw material flakes created by crushing, washing, and drying PET bottles.

Details of the recycling system

After being washed and dried, used trays are deposited in collection boxes at supermarkets and other locations. Delivery trucks take them back to FP Corporation via wholesale dealers, where they are recycled. The participation of the four types of actors helps ensure smooth recycling of a large volume of used trays and PET bottles, keeping waste to a minimum.

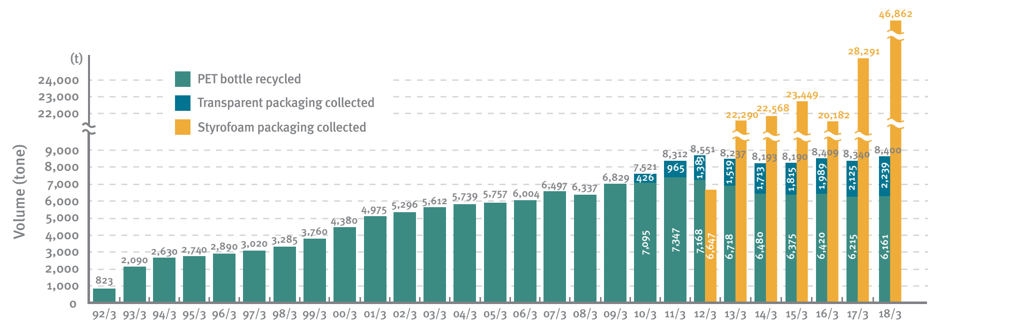
Family home	Consumers	Wash and dry	We ask consumers to separate foamed polystyrene trays from other items, and wash and dry used trays.
Sales	Supermarkets, etc.	Collect	Used trays brought in by consumers are collected in collection boxes placed at stores. This helps strengthen the connection between consumers and supermarkets.
Distribution	Packaging wholesale dealers	Pick up	We ask packaging wolesale dealers to utilize trucks from deliveries to supermarkets, etc. to pick up used trays and temporarily store them on their site.
Manufacturing	FPCO	Receive and recycle	Trucks used to deliver food containers are used to collect used trays on their return. This collection method is possible because FP Corporation carries out its own deliveries.

Raw material

Achievements

Foamed polystyrene and transparent containers collected: 8,400 tons/year (FY2018)

PET bottles recycled: approx. 47,000 tons/year (FY2018)



No. 11	Company:	Tokan Kogyo Co., Ltd.					
	Product:	Paper-sealed tray					
✓ Food	Beverage	Non-food	✓ Reduce	Reuse	Recycle	✓ Renewable	Replace

Overview of technology

What is a paper-sealed tray?

The product is a highly heat-resistant paper tray for food products. Since it is made from a heat-resistant paper, it can be used in microwave ovens, standard ovens and steam convection ovens, and improves operational efficiency of in-store kitchens in supermarkets. It has handles, and the tray can be held after heating without burning fingers, allowing comfortable use for dishes that require heating.

Since it also maintains strength in frozen conditions, it can be used for a wide range of foods that require freezing and defrosting, in addition to grilling and food served at room-temperature. It can also be used with a lid.

It was primarily developed for dishes prepared in supermarket kitchens and for frozen food products produced by food-product manufacturers.

Why is it innovative?

Conventional formed paper grip trays had issues such as dimensional precision and deformation over time. However, Tokan Kogyo has developed a container that maintains its form, even when heated, increasing strength by adding an appropriate stepped pattern around the perimeter of the container.

Key functions

- Size: length 185.7 mm, width 124.0 mm, height 38.2 mm
- Full capacity: 400 ml
- Capacity: approximately 250–280 g

Suitable for steam convection ovens, convection ovens and microwave ovens

* The surface and back of the tray are laminated in clear plastic.

Environmental impact reduction

The tray generates 43 per cent less CO_2 emissions than a resin tray made from polypropylene with filler (PPF) of an equivalent size. It also reduces resin by 80 per cent compared to a PPF resin tray of equivalent size.

Economic implications

While the tray is currently less economical than traditional plastic trays, efforts will be made to reduce costs in the future through productivity improvements and other means.

Conditions and facilities for introduction

Standard press moulding machine and mould are required.

Example applications

Since the end of March 2021, this paper tray has been adopted for two frozen food products by a major food products company in Japan. The client adopted the tray in order to shift to eco-friendly containers.

Sample product use 1

Sample product use 2

Example of adoption in a frozen-foods section

No. 12	Company:	Kirin Holdings Company, Limited					
	Technology:	PET bottle design for light-weighting					
Food	✓ Beverage	Non-food	✓ Reduce	Reuse	Recycle	Renewable	Replace

Overview of technology

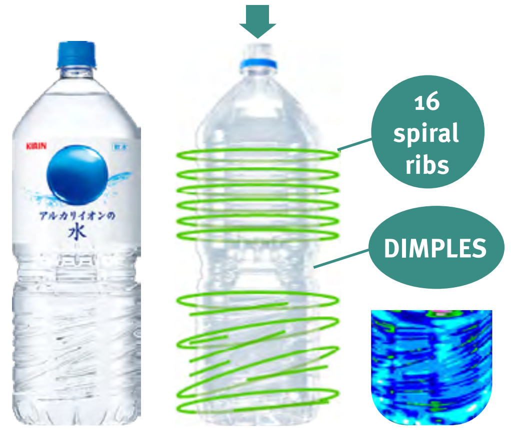
Product and technology applications

Kirin Holdings has carried out significant research and development on saving materials in beverage packaging through its original designs, where consumer acceptance and functionality are compatible with the previous heavy bottles. PET bottles are among the most intensive technical fields for light-weighting. For example, the company has developed the lightest two-litre water bottles in Japan.

The light-weighting of the design of PET bottles begins with 3D CAD and computer simulation techniques to select bottle shapes and weights for further evaluation. 3D printers are then used to make plastic moulds for prototyping, before making metal moulds for final evaluation samples. The example of the two-litre bottle is discussed below.

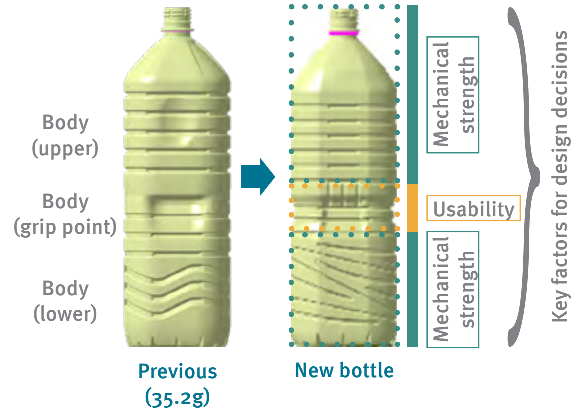
Technology developed

Light-weighting design of two-litre bottle: bottle weight reduced from 35.0 g to 28.3 g, through an effective arrangement of ribs and dimples. There was a slight negative impact on mechanical strength. The design includes a set of grip points for users in the centre of the bottle body for easy holding and other handling.

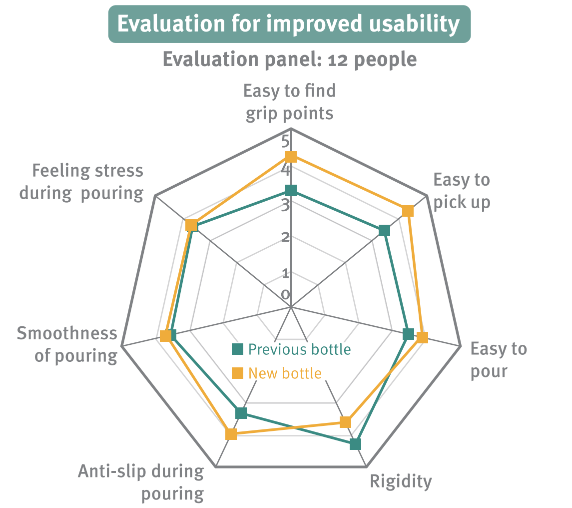


Functionality

Decision on the final design: Several candidate designs were compared to the existing bottle to optimize performance in terms of different properties, such as usability and mechanical strength. Comparing the new design and the previous design it is possible to see, for example, the more favourable width of the grip points, and the number of ribs on the upper and lower parts of the bottle.



The graph below shows the sensory evaluation of the samples of the final design.



Environmental impact reduction

- PET resin reduction: 6,700 tons/year (from 35.0 g to 28.3 g per bottle (19 per cent reduction)
- CO_2 emissions reduction: 3,850 tons/year

Economic implications

Annual savings in resin procurement of 200 million yen.

Conditions and facilities for introduction

Similar PET bottles can be achieved with 3D CAD software and hardware such as a 3D printer and blow-moulding machine.

Product example

The design is commercially distributed in Japan for Kirin's alkaline ionized water (refer to the above figure), with an annual production of about 1 billion bottles.

No. 13	Company:	Tokan Kogyo Co., Ltd.					
	Product:	Paper-pressed lid for cold beverages (Tokan PA-Lid)					
Food	✓ Beverage	Non-food	✓ Reduce	Reuse	✓ Recycle	✓ Renewable	Replace

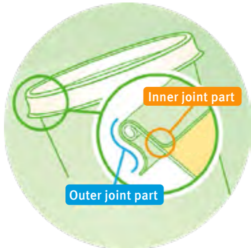
Overview of technology


What's Tokan PA-Lid?

The Tokan PA-Lid is a paper-pressed beverage lid formed from a single sheet of paperboard, which can be used as a substitute for plastic lids for cold beverages. When combined with a paper cup and paper straw, beverage containers made entirely from paper can be produced. Another feature is that highly reproducible print designs are possible as it is made from a paper material.

Why is it innovative?

Conventionally, plastic had greater advantages in areas such as productivity, cost and dimensional precision. However, the Tokan PA-Lid provides a paper alternative by improving the adherence of the inner joint part to the inside of the cup and using an undercut form for the outer joint part to improve the lid's grip.



Key functions

- Application: Lid for cold beverage cup
- Size: 89 mm diameter
- Joint part diameter: 89.0 mm
- Unit weight: 3.5 g (3.5 kg/case)
- Quantity per case: 1,000 units

* The surface and the back of the lid are laminated with transparent plastic film.

Environmental impact reduction

The Tokan PA-Lid reduces CO_2 emissions by approximately 25 per cent, compared to a lid of the same diameter made from APET. It also reduces resin use by approximately 84 per cent compared to a conventional resin lid (comparison of lids of the same diameter by weight). It can also be recycled through the same recycling schemes used for paper cups.

Economic implications

While the Tokan PA-Lid is currently less economical than a traditional plastic lid, efforts will be made to reduce costs in the future through productivity improvements and other means.

Conditions and facilities for introduction

Standard press moulding machine and mould are required.

Future development plans

The company aims to provide fully paper-based solutions for beverage containers by developing paper lids that can be used with hot beverages, such as coffee, tea and soup, through further improvement of grip performance. In addition to beverages, it is also planning to increase adoption in food applications, such as snacks, cup soups and yogurts, for which plastic slip-on lids are currently used.

Example applications

The Tokan PA-Lid was used at the Shinagawa Eco Festival in 2018.

Product used at the Shinagawa Eco Festival

Sample of commercial use

Attracting nearly 30,000 attendees every year, the Shinagawa Eco Festival is one of the largest events in Tokyo's Shinagawa ward. It aims to provide a pleasant opportunity to people to broaden their interests and learn about the environment, while inspiring people to take action.

The event is planned and operated by the Environmental Activity Promotion Committee and the Event Executive Committee, which mainly comprise businesses, private-sector groups and schools in the ward. At the event, the combination of eco-friendly Tokan PA-Lid, paper cup and straw were used for serving beverages in the event booth. This provided an opportunity for customers to use and experience fully paper-based beverage cups.

No. 14	Company:	Nippon Paper Industries Co., Ltd.					
	Product:	SPOPS (paper container for personal-care products, etc.)					
Food	Beverage	✓ Non-food	✓ Reduce	✓ Reuse	Recycle	✓ Renewable	Replace

Overview of technology

What is SPOPS?

In Japan, refill pouches are widely used as containers for shampoo and other liquid personal-care products and household goods. SPOPS is a paper container that is even easier to use and more eco-friendly than refill pouches. Intended for use with personal-care products and household goods, it can also be used for hand sanitizers, which have seen increased demand recently due to COVID-19.

Why is it innovative?

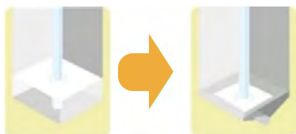
According to the survey, almost all consumers expressed dissatisfaction with using refill products, with many noting that they are time consuming, easy to spill and hard to open. Moreover, even though refill pouches enable a considerable reduction in plastic waste compared to disposable containers, given recent concerns about plastic waste, there is still room for further measures. SPOPS balances usability and eco-friendly performance.

Key functions

A paper cartridge is filled with the content and then set in a special dispenser. The paper carton is replaced each time the content runs out. This makes it possible to refill in less than 30 seconds (compared to two minutes or longer for conventional refills).

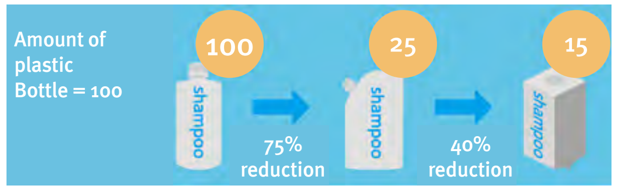
Paper carton	Special dispenser	How to use
		 1. Remove the bottom part 2. Replace the paper pack 3. Return the body

Turning the paper carton upside down also allows all content to be sucked up from the container, reducing residual waste.



Environmental impact reduction

SPOPS paper cartons are approximately 70 per cent paper and forestry-certified materials can be used. While refill pouches enable reductions of about 70–80 per cent in plastic use compared to single-use bottles, SPOPS enable further plastic consumption reductions of about 25–40 per cent compared to refill pouches.



Since these cartons reduce head space compared to pouches when packed in cardboard boxes, they can also reduce case sizes, improve loading efficiency during transport and conserve storage space.

Conditions and facilities for introduction

Filling: Special equipment is required to fill SPOPS paper cartons. Export of equipment is currently under consideration, since this requires forming partnerships for local maintenance services. It is currently possible to export products filled in Japan and two Japanese cosmetics manufacturers have adopted the filling equipment.

Packaging materials: For now, the packaging materials will be exported from Japan. Overseas production, including Europe, is being considered for the future.

Example applications

1. **Marunuma Original Body Soap (Nippon Paper Development Co., Ltd.)**: The solution was adopted for this product, which is based on naturally derived ingredients, since it fits well with the product's eco-friendly concept.

2. **Hajimari Easy+ (Sanyo Bussan Co., Ltd.)**: Adopted for shampoo, conditioner and body soap amenities for hotel bathrooms. At the time of adoption, the solution's eco-friendly performance and ease of use were decisive factors, since the hotel industry was focusing on its environmental performance and also facing labour shortages.


No. 15	Company:	Toyo Seikan Group Holdings, Ltd.					
	Technology:	Environmentally friendly can production system					
Food	✓ Beverage	Non-food	✓ Reduce	Reuse	✓ Recycle	Renewable	✓ Replace

Overview of technology

What is the aTULC can production system?

The aluminium Toyo Ultimate Can (aTULC) is a two-piece aluminium can, developed by the Toyo Seikan Group to reduce ecological impact and protect the global environment. Combining this technology with the company's "Compact system" allows beverage producers to produce cans in-house.

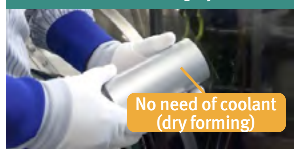
aTULC is:

- Developed to save the environment.
- A hybrid container (can + film), which enables dry forming.

Conventional can making system

- A large amount of industrial waste
- A large amount of water
- Large scale equipment (e.g. wastewater treatment)
- requires skilled operators

aTULC can making system



- No industrial waste
- No water in production
- Fewer machines
- Easy operation

Why is it innovative?

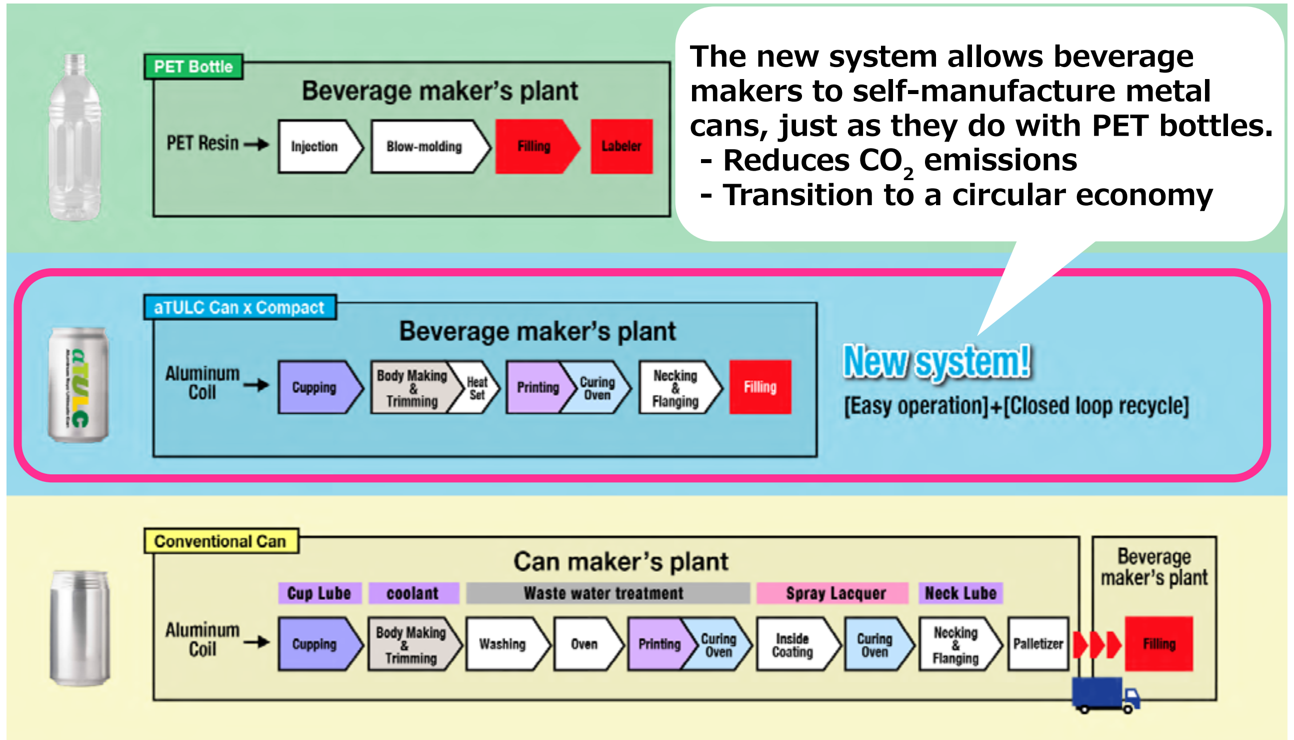
Metal can recycling systems are already well established in many countries. This means the shift to use more cans is one of the ways to accelerate the transition to a circular economy. The demand for in-house can production by beverage producers has risen in recent years, since it can help to reduce can procurement costs, secure the quantities of cans needed and reduce CO_2 emissions from the transport of empty cans.

Conventional can production systems are not suitable for in-house can production, mainly because they are designed for mass production, with an annual capacity of 500–700 million cans. However, Toyo Seikan's newly developed can production system, the Compact & Integrated TULC System (CIT), is based on the combination of aTULC production and the Compact System, which can produce 200–300 million cans/year, making in-house can production possible.

Details of technology

aTULC is made from aluminium sheet laminated with film on both sides of the substrate. This helps reduce the environmental impact of this system by eliminating sludge and water consumption in the production process. It also means fewer machines and is easier to operate than conventional aluminium can production systems.

New business model with aTULC Compact Line

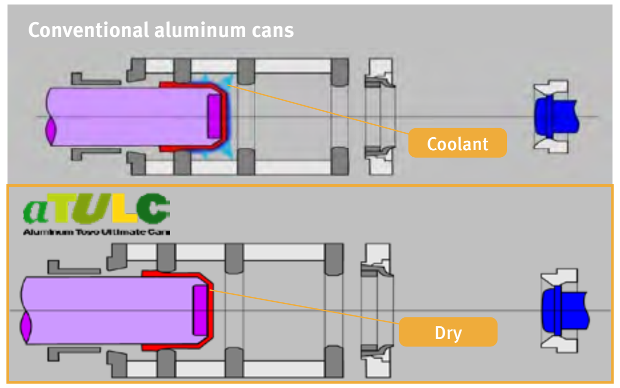


Key features

Production process

The film lamination on both surfaces permits a dry process.

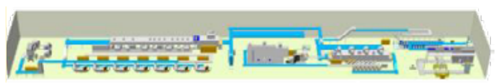
Bodymaker (redraw process)



The compact line is only possible using aTULC, not with conventional cans. The benefits of the CIT system include can production with fewer machines and operators, less space and a smaller initial outlay. It also reduces environmental impact and allows production of the exact number of cans required.

Conventional can making line

500–700 million cans/year | Speed: 2,000 cans per minute



3,200 m²

- Including wastewater treatment

aTULC can making line

500–700 million cans/year | Speed: 2,000 cans per minute

2,000 m² (63%)

- No wastewater treatment

aTULC × Compact

200–300 million cans/year | Speed: 900 cans per minute

Just developed!

900 m² (28%)

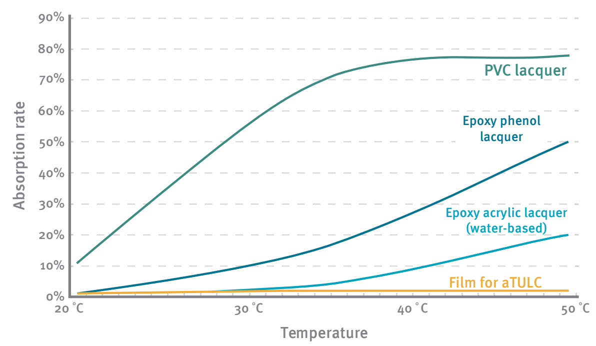
- Newly developed compact system
- It is only possible with aTULC

Produced cans

The film on the internal surface of aTULC cans has lower flavour absorption rates than the standard lacquer coating, preserving the flavour of the contents.

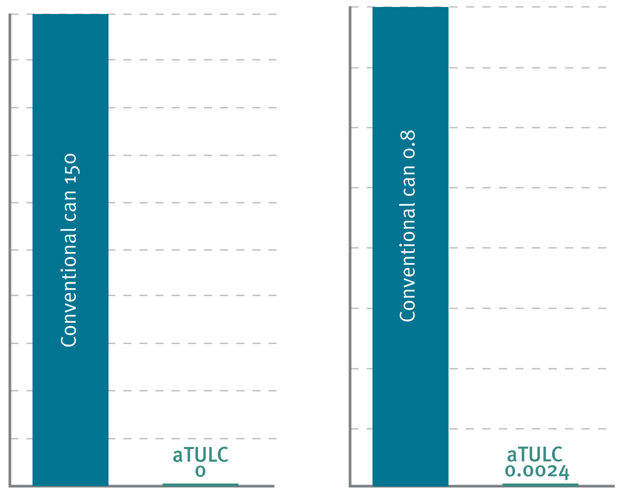
Less flavour absorption

Flavour absorption (limonene) by coating type



Environmental impact reduction

aTULC vs. conventional can



aTULC production system

- No water used for production
- No sludge from production

For 1.5 million cans, an aTULC production line saves 225,000 litres of water and 1.2 tons of solid waste

Economic implication

Should be discussed on a case-by-case basis.

Conditions and facilities for introduction

Equipment for utilities such as electricity and gas should be discussed on a case-by-case basis.

Example applications

aTULC has been used by several brands both inside and outside Japan. Plants for aTULC cans have been set up in Iran, Taiwan and Thailand (steel TULC). The CIT system has recently been developed and launched, with plans to expand the market in the future.

No. 16	Company:	Rengo Co., Ltd.					
	Product:	Cardboard packaging to replace plastics					
✓ Food	Beverage	✓ Non-food	✓ Reduce	Reuse	✓ Recycle	✓ Renewable	Replace

Overview of technology

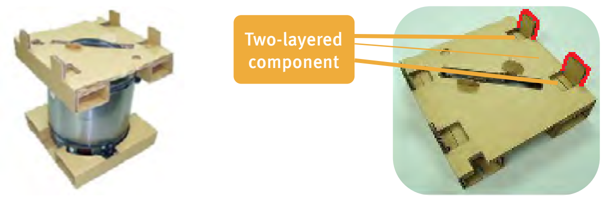
In response to environmental issues and concerns regarding storage space, more and more companies are switching from plastic cushioning materials or trays to cardboard. Rengo's cardboard manufacturing technologies have a number of applications.

- **From styrene foam to cardboard cushioning materials**

While styrene foam offers many advantages, including outstanding cushioning performance and its lightweight properties, it also has a number of disadvantages: it is made from petroleum, hard to dispose of, rarely recycled and requires moulds for each product, leading to higher costs, particularly for smaller batches.

Cardboard cushioning materials have numerous advantages: they are made from natural paper; their recycling rate is more than 90 per cent in Japan; complex forms can be made using die-cutting; and they are lightweight and provide outstanding cushioning performance. Rengo develops forms of packaging suited to various products, from cushioning for home electronics and precision instruments that are highly vulnerable to impacts, through to large-scale packaging of multiple units of heavy components.

The company has developed solutions to replace the styrene foam normally used in the upper and lower packaging of rice cookers with cardboard cushioning materials. The design of the structure is based on two layers of cardboard pads for a cylindrical product that is hard to maintain in the correct position. It provides a high level of stability and cushioning performance. Moreover, there was no cost in terms of efficiency, since it consists of two pieces (the same as styrene foam).



- **From moulded plastic trays to cardboard trays**

Advantages of plastic moulded trays include high productivity and being able to easily change the form, since mould costs are low. However, the use of plastics means they have a high environmental impact and creates issues for waste segregation and recyclability.

In this case, Rengo has designed a delivery box for cosmetics samples, combining the outer part and inner partition. Its features include being a suitable size for posting in a mailbox (no thicker than 35 mm), a shape that does not require gluing and protection of the contents from falling out or damage, even when dropped continuously on all sides from a height of 70 cm. Since the package can be delivered to the user in the form of a blank sheet, it also saves storage space and its design can be modified easily in response to minor changes in the contents of the sample.

Previous plastic tray

Blank sheet

Adopted package form

Environmental impact reduction

For standard home electronics, switching from styrene foam to cardboard cushioning materials reduces CO_2 emissions to approximately one-third of the previous level per unit.

Economic implications

While costs vary greatly with lot size, in most cases, the use of paper containers is more cost efficient than the use of moulded plastic products for small batches, with major variations. Costs are influenced by a wide range of factors, including not only individual product prices but also the labour involved in product design, producing moulds for testing and mass production, package testing and delivery times.

Conditions and facilities for introduction

In addition to cardboard production equipment, other facilities required include CAD/CAM (package-design software and high-speed cutters), qualified package-design engineers, drop-testing equipment and an accelerometer to measure impact.

Example applications

Use of cardboard cushioning materials is increasing among both home electronics producers and for cushioning and packaging for heavy items. There have not yet been many cases of switching from plastic trays but there have been positive reviews and sales are expected to increase in the future.

4

Innovative recycling technologies

4.1. Introduction

Plastic is an excellent material and has contributed greatly to improving people's lives and convenience. However, marine plastic waste has become a global environmental issue in recent years, making it increasingly important for countries to ensure plastic is used carefully and recycled to address resource and waste restrictions, marine plastic waste and global warming.

There have been two major changes in plastic recycling in recent years: one is the response to the circular economy and the other is the push to reduce greenhouse gas emissions to net zero by 2050.

In terms of the circular economy, measures include reducing the amount of new plastic input as much as possible, collecting as much used plastic as possible, and maximizing the recycling of used plastic as much as possible. To achieve net zero greenhouse gas emissions from used plastic, the incineration of used plastics must be minimized, since they are composed of fossil carbon. Alternative use of used plastic for energy could contribute to reduce the use of virgin fossil fuels in power generation, heat supply or manufacturing industries. However, we also have to be aware that fossil carbon dioxide would be produced from them.

This requires technologies and policy measures to support the recycling of plastics. This chapter reviews plastic recycling technologies, examples of plastic recycling initiatives in the value chain and products made from recycled plastics to understand how to make recycling more efficient.

Although the classification of plastic recycling technologies is determined by ISO standards ISO15270, ISO18601, etc., this chapter focuses on introducing a wide range of technologies and case studies, and describes them based on the current status of plastic recycling in each country.

4.2. Overview of innovative recycling technologies

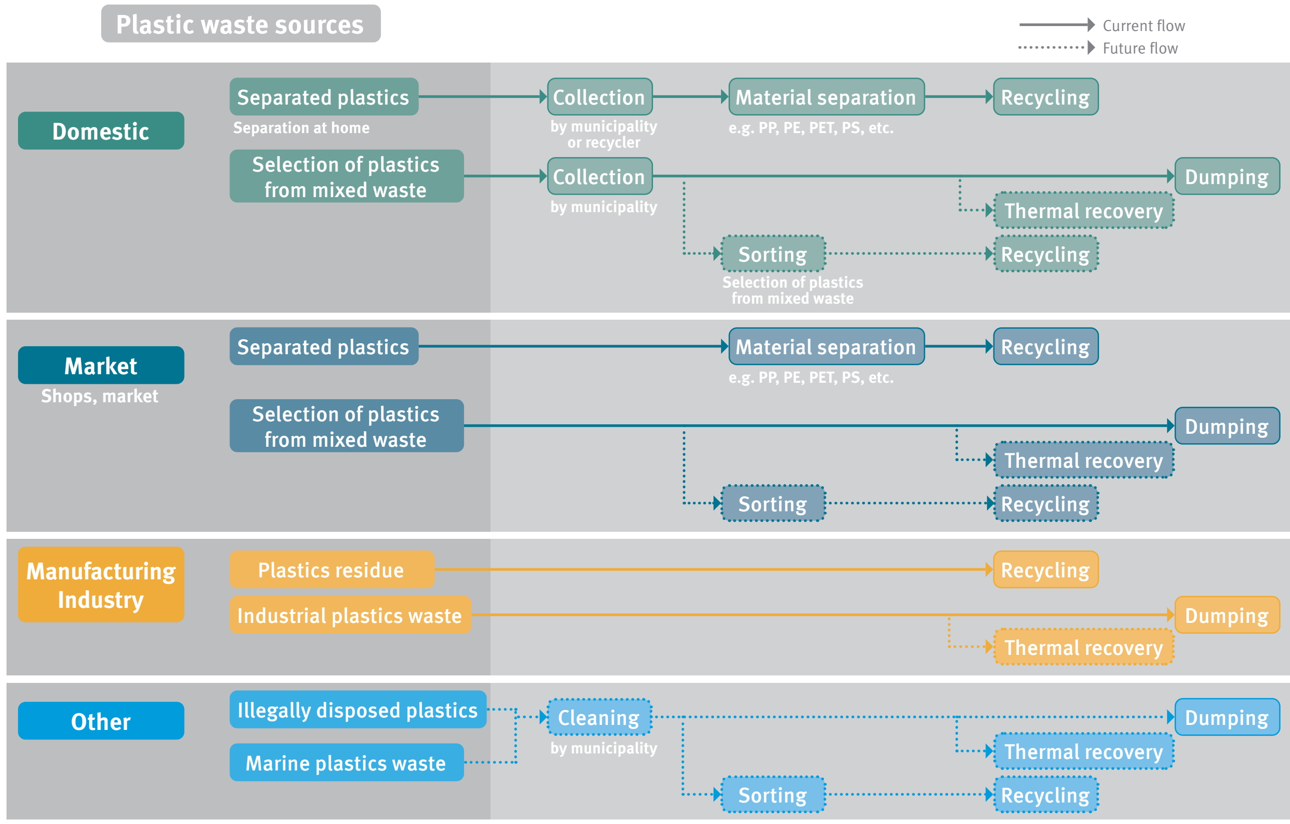
4.2.1. Basic principle of the 3Rs for plastics

The principles of the 3Rs are:

- Reduce – rationalizing the use of avoidable plastics
- Reuse – promoting their reuse
- Recycle – the cyclical use of used plastics

Figure 4.1 shows a typical treatment flow of used plastics for different sources. Although the uptake and treatment vary depending on the policies of individual countries, promoting the recycling of plastics requires policy measures at each stage – (1) collection, (2) sorting and (3) recycling – as well as technologies to support them.

Figure 4.1. Typical treatment flow of used plastics by source



4.2.2. Overview of plastic recycling technology

The best way to promote the sustainable and cyclical use of used plastics is to return them to plastic again. However, this requires the development of advanced recycling technologies and advanced systems for collection and separation. It is also necessary to consider the environmental impact and cost over the life cycle. This means it is also necessary to consider the use of recovered used plastics for applications different from their original use. For dirty or degraded plastics that are hard to recycle economically, alternative use as energy remains an option for the time being.

Plastic recycling technologies can be classified as mechanical, chemical, biological and thermal, with each technology having a different feasible output. Table 4.1 provides examples of the main technologies.

Table 4.1. Outline of plastic recycling technology

Technology	Description
Mechanical recycling	Should be prioritized for used plastic. However, since the quality of recycled material is basically down-graded, mixed use of virgin material would be necessary.
Chemical recycling	Upcycling can be achieved by recovering raw materials to their original performance and then circulating them as new plastics.
Biological recycling	Biodegradation of biodegradable plastic, such as plastic garbage bags in biogas or composting facilities. In many cases, organic waste is co-treated together.
Thermal recovery	Incineration of plastic waste with energy recovery or production of waste-derived fuel.

4.2.3. Mechanical recycling

Mechanical recycling takes used plastics as raw materials in their plastic form and applies processes that crush, clean, flake, granulate (pelletize), melt and remold them. However, as plastics degrade during these processes, it is necessary to mix them with new plastic or limit their amount of use.

Advanced technologies have recently emerged that can produce non-deteriorated recycled resins. This eliminates the need to mix new plastics.

Mechanical recycling is suited to plastics of uniform material and low contamination, meaning that used plastic from industry would be suitable. Compared to used plastics in general, waste, industrial waste plastics are characterized by the type of resin being clearly identified at the stage of discharge, with less contamination and foreign matter, discharged in large quantities.

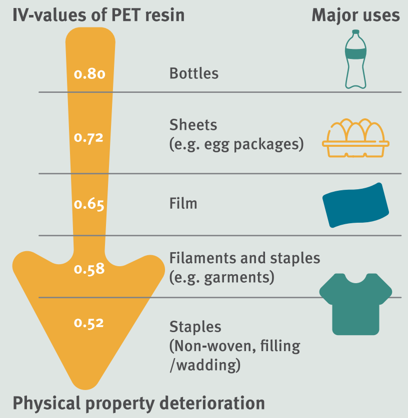
The following are examples of typical products made by mechanically recycled plastics, such as railway signs, pallets, imitation wood (for fence etc.), manhole, garden construction materials (parking blocks, step ramps, water cock boxes, boundary marking piles, etc.), plant pots, clothes hangers, stationery, bathing goods.

Figure 4.2. Examples of typical products using mechanical recycling

Source: Plastic Waste Management Institute, "An Introduction to Plastic Recycling in Japan" (2019). Available at ‹http://www.pwmi.or.jp/ei/plastic_recycling_2019.pdf›

Conventional technology cannot be used for beverage PET bottles due issues such as hygiene and odours. However, the Japanese company Kyoei Industry has developed MR-PET technology, with the recycled PET resin from used PET bottles being of an equivalent quality to virgin materials. Beverage PET bottles made from recycled PET resin are now being manufactured. The company's PET bottle-to-bottle technology is detailed in Table 4.2.

Table 4.2. Examples of advanced mechanical recycling (Kyoei Industry)

Company	Kyoei Industry Co. Ltd.
Name of technology	MR-PET technology (recycled PET resin to virgin quality PET resin technology)
Outline of technology	• This technology removes surface stains and most of the impurities that permeate the resin under a vacuum and high-temperature environment. The process also prevents physical deterioration and recovers intrinsic viscosity (IV). • The recondensation and polymerization reaction prevent physical deterioration caused by heat applied during the recycling processes and allow recovery of the IV value, which used to be a major challenge.  Intrinsic viscosity (IV) recovery
Main features and advantages	• MR-PET technology enables 100 per cent PET-bottle-to-PET-bottle recycling. • MR-PET is produced in facilities certified by the FDA (U.S. Food and Drug Administration) and EFSA (European Food Safety Authority). • MR-PET bottles can deliver a reduction of 63 per cent of CO_2 emissions in its lifecycle compared to virgin PET bottles.
Source	‹www.kyoei-rg.co.jp/english/mrpet/index.html›

4.2.4. Chemical recycling

Chemical recycling is suitable for recycling dirty PET, polystyrene, or mixed plastics that are hard to apply mechanical recycling. It can be used to recycle used plastics back to raw materials or monomers for use as virgin quality plastics again, as well as the recycling of plastics for the production of other chemicals or materials and the recycling of plastics to be used as energy. It can be broadly classified into following technologies: depolymerization/monomerization, pyrolysis (raw material for plastics/energy use), gasification (raw material for other chemicals/energy use), use in coking ovens and use in blast furnaces. Especially, depolymerization/monomerization, pyrolysis (raw material for plastics) and gasification (raw material for other chemicals) can be classified to the "Circler chemical recycling" since these technologies promote circler use of used plastics. Other technologies are categorized to "one-way chemical recycling" in contrast (table 4.3). We need to be aware that one-way chemical recycling contributes to reduce consumption of fossil fuels/raw materials, nevertheless carbon in used plastics are to be oxidized to CO_2 and released to atmosphere.

Table 4.3. Classification of chemical recycling

Classification of technologies		Features of technologies
Circular chemical recycling	Depolymerization and monomerization	Technology for producing PET resin from recycled monomer which was derived from used PET bottles with its depolymerization.
	Pyrolysis: raw material for plastic	Technology to produce plastics (polyethylene, polypropylene, polystyrene, etc.) from pyrolysis oil made by used plastics with pyrolysis under oxygen-free conditions.
	Gasification: chemical use	Technology to produce synthesis gases (carbon monoxide and hydrogen) by pyrolysis of used plastics and to use them as raw materials for chemicals (ammonia and methanol, etc.).
One-way chemical recycling	Use in blast furnace	Technology for utilizing used plastics as a reducing agent and heat source for iron production in blast furnaces.
	Use in coking oven	Technology to produce hydrocarbon oil, coke and coke oven gas by pyrolysis of coking coal with used plastics under oxygen-free conditions in a coke oven.
	Pyrolysis: energy use	Technology to produce pyrolysis oil for energy use by catalytic pyrolysis of used plastics.
	Gasification: energy use	Technology to produce combustible synthesis gases (carbon monoxide and hydrogen) by pyrolysis of municipal solid waste (mixture of used plastics and organic waste such as garbage, paper, etc.) and to use them for energy.

Table 4.4. Depolymerization and monomerization (PET Refine Technology)

Company	PET REFINE TECHNOLOGY CO., LTD (a member of JEPLAN Group)
Name of technology	BRING Technology™ (recycle of used PET bottles using chemical recycling technology and production of PET resin)
Outline of technology	• Used PET bottles can be recycled repeatedly as a resource, contributing to the reduction of petroleum use and CO_2 emissions. • BRING Technology™ is a unique chemical recycling technology which can produce PET bottles from any kind of used PET bottles, by depolymerize and deriving monomer called BHET (bis-2-hydroxyethyl terephthalate) and then purify them to meet producing high quality standards for bottle grade. 
Major Features and Advantages	• CO_2 emissions for PET resin re-production by BRING Technology™ can be reduced by 47% compared with conventional PET resin production and treatment of used PET bottle (PET resin production from crude oil and incineration of used PET bottle without energy recovery). • JEPLAN is promoting licensing business of BRING Technology™.
Source	‹https://www.prt.jp/en.html›

Figure 4.3. Chemical recycling process for used PET bottles by BRING Technology™

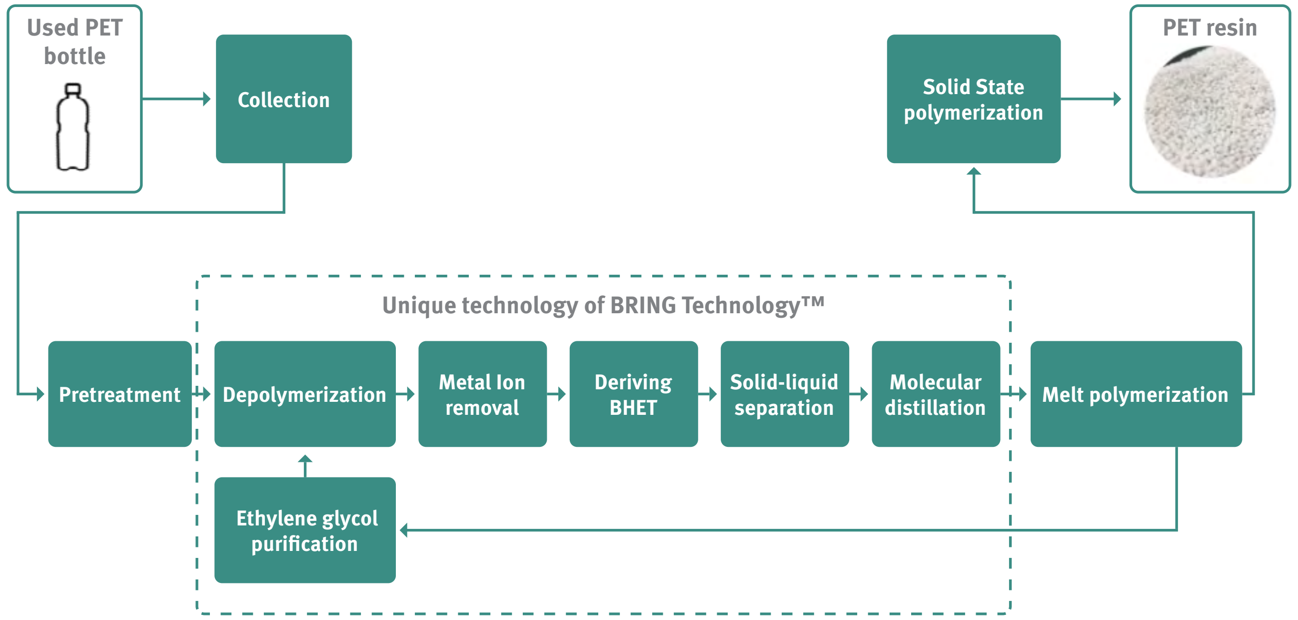


Table 4.5. Blast furnace recycling of waste plastics by JFE Steel Corporation / JFE Plastic Resource Corporation

Company	JFE Steel Corporation / JFE Plastic Resource Corporation
Name of technology	Use of waste plastics in a blast furnace
Outline of technology	• Plastic is composed of hydrogen and carbon. After being fed into the blast furnace, hydrogen gas and carbon react as a reducing agent and remove oxygen from iron ore (iron oxide). • Coke has a carbon content of 90 per cent. When it is used in blast furnaces, it is emitted as carbon monoxide or carbon dioxide. However, when plastic is used as a substitute, the hydrogen in the plastic can also be used as a reducing agent, thus reducing the amount of carbon dioxide emitted (a reduction of around 30 per cent is possible). • In addition, using plastic in a blast furnace contributes to reducing the incineration of plastic and results in CO_2 reduction from its incineration. (See figure 4.4)
Main features and advantages	• Blast furnaces can accept large quantities of waste plastic, meaning a large amount of waste plastic can be used in a cyclical manner. • This technology can be used as long as a blast furnaces are available and can be introduced in various parts of the world and in developing countries. • Since an existing blast furnace is used, there is no need to build a new plant, which is advantageous in terms of cost.
Source	‹www.jfe-plr.co.jp/en/business/›

Figure 4.4. Blast furnace recycling of waste plastics by JFE Steel Corporation / JFE Plastic Resource Corporation

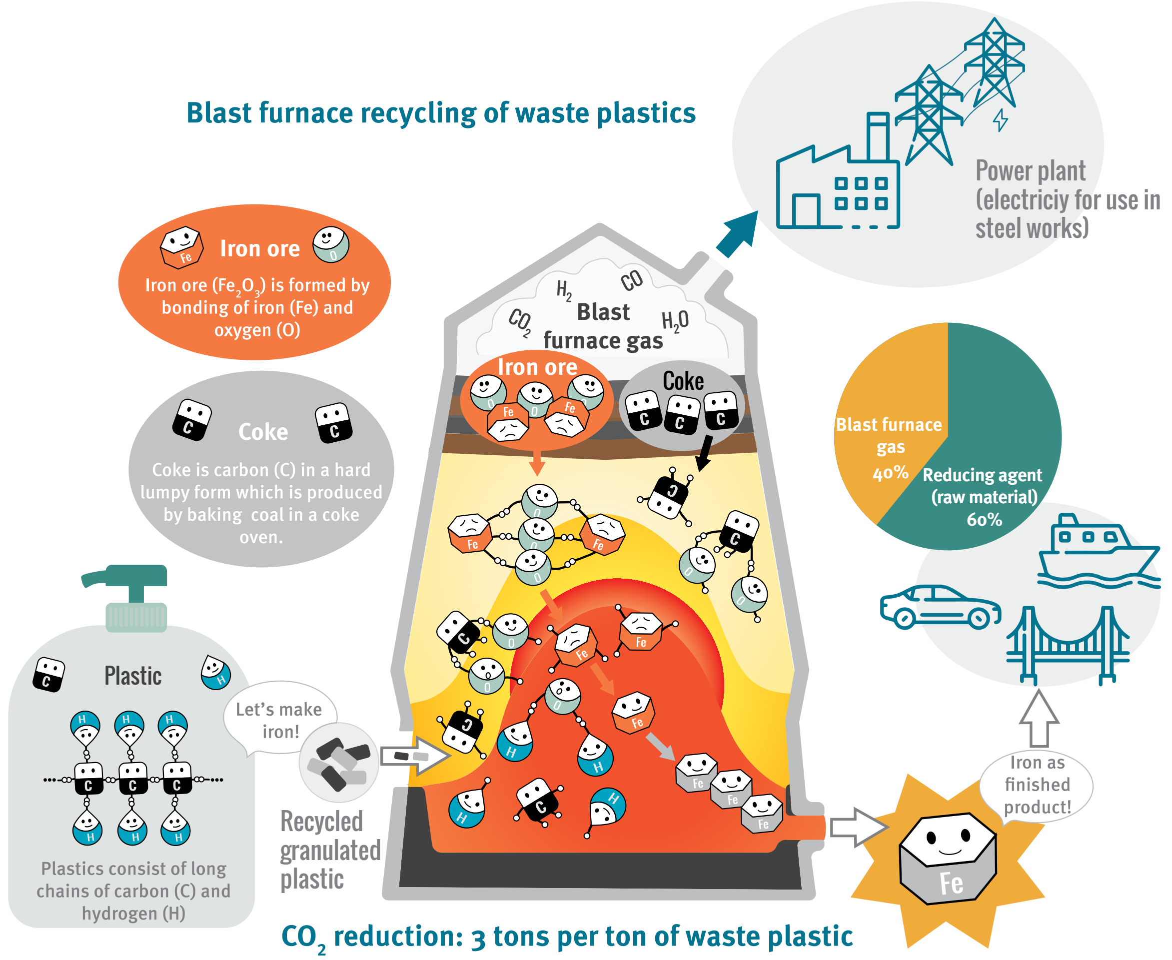


Table 4.6. Oiling: energy use (Shinko Tecnos Co., Ltd.)

Company	Shinko Tecnos Co., Ltd.
Name of technology	Plastic to oil machine
Outline of technology	• This plastic to oil machine is used to make liquid fuel, combustible gas and carbonized products – all from waste plastics and products originating from crude oil. • These recycled energy resources are ideal for use in industries where energy is in high demand, as well as for power generation in developing countries. • In addition to waste plastics, the system can also treat e-waste, waste tyre, waste toner and medical waste. 
Main features and advantages	• Ease of operation: The concept behind the machine is extremely simple. This makes it easy for machine operators and plant workers to understand. The machine is also durable, preventing it from being broken by operators. Maintenance does not require a high level of technical expertise. • Cost and energy savings: The ease of operation of the machine means it does not use up limited resources. Its efficient operation significantly reduces the running cost by lowering energy consumption. • High-quality production: The high-quality production of heavy oil and light oil means products can be used for power generation. The machine can also produce low-tar oil, which decreases the possibility of burner nozzle clogging, often caused by high-tar oil.
Source	‹www.unido.or.jp/en/technology_db/1613/› ‹www.shinko-mfg.com›

4.2.5. Biological recycling

Biodegradable plastics are decomposed into water and carbon dioxide by the reaction of microorganisms. Biological recycling utilizes this special function of biodegradable plastics to promote effective recycling of organic waste, using techniques such as biogasification and composting. Garbage bags made from biodegradable plastics allow organic waste to be effectively collected and sent directly to biological treatment facilities, with no need to open the bags and remove waste. More information on biodegradable plastics can be found in the chapter 2 "Alternative materials" of this report.

Since biodegradability of biodegradable plastic is different with materials, appropriate materials need to be selected based on targeted application. For example, some materials would be decomposed only in industrial compostable condition, which is controlled under higher temperature condition, but hard to be decomposed in home compostable condition or anaerobic condition, which means condition for biogasification process.

4.2.6. Thermal recovery

Two types of thermal recovery are possible. The first uses heat from waste incineration for power generation or heat supply. The second involves the production of fuel from waste. Power generation from waste works best when incinerating waste continuously on a certain scale (more than 100 tons/day) to ensure highly efficient power generation. For the production of fuel from waste, the use of coal can be effectively replaced by RPF (Refuse Paper and Plastic Fuel), produced from a mixture of waste paper and waste plastic, with controlled calorific value.

Considering the common target for net zero greenhouse gas emissions by 2050, it is necessary to reduce waste-derived fossil CO_2 emissions to zero in the future. To achieve this shared goal, waste generation must be minimized through 2R activities (reduce and reuse), as well as through the collection, separation, and recycling of used plastic. We have to be aware that thermal recovery is a technology for the transition period towards since it produces CO_2.

4.3. Cases of successful recycling in value chains

Efficient waste recycling requires waste generators and recyclers cooperate, rather than just the former. FP Corporation, the leading plastic food container supplier in Japan has established circular recycling system called Tray-to-Tray. Used food containers are born again as new ones, significantly reducing environmental impact by using less of the main raw material, crude oil. The system also reduces garbage processing costs and CO_2 emissions. FP Corporation is also starting to recycle transparent containers, which was previously extremely challenging, and PET bottles back into food containers.

However, FP Corporation would be unable to recycle used trays and PET bottles on its own. It relies on cooperation from consumers and recycling that involves everyone's participation. After being washed and dried, used trays are returned to collection boxes in supermarkets and other locations. Delivery trucks then return them to FP Corporation, where they are recycled.

Figures of FP Corporation's Tray to Tray, Bottle to Tray and their successful recycling value chain system can be found in section 3.3 "Innovative Packaging Technologies" (no. 10) on this report.

Column: Future strategy of Japan to reduce CO_2 emissions from plastic waste to zero by 2050

In August 2021, the Ministry of the Environment of Japan (MOEJ) announced future strategies to reduce CO_2 emissions from waste treatment and recycling to zero by 2050, including its strategy for plastics.[1]

Current generation of used plastics in Japan was around 8.3 million tons in 2020. Treatment options include incineration with energy recovery (38%), one-way chemical recycling or alternative fuel use (25%), mechanical Recycling (23%), incineration without energy recovery (8%), landfill (6%) and circular chemical recycling (1%).

In the strategy, MOEJ prioritizes to promote mechanical recycling and circular chemical recycling as much as possible to reduce CO_2 emissions from used plastics and increase their circularity. However, around half of all used plastics in 2050 will still be incinerated with energy recovery or used as alternative fuels, considering the technological limitations of mechanical recycling and circular chemical recycling. Since all CO_2 emissions from used plastics need to be minimized to around zero by 2050, biobased plastics, carbon neutral materials, need to be introduced. Considering the fraction of mechanical or circular chemical recycling until 2050, according to MOEJ, if 2.5 million tons of virgin biobased plastics are introduced, the amount of biobased plastics in recycled plastics (mechanically or chemically recycled plastics) would also reach 2.5 million tons and can contribute to reducing fossil CO_2 emissions to around zero. This example indicates that mechanical recycling and circular chemical recycling are key technologies for the treatment of used plastics. The necessary amount of biobased plastics are determined based on the progress of mechanical recycling and circular chemical recycling.

[1] Sound Material-Cycle Society Committee (38th committee, held on 5 August 2021), Central Environment Council, ‹http://www.env.go.jp/council/03recycle/post_217.html›

Figure 4.5. Amount of used plastics by treatment method until 2050

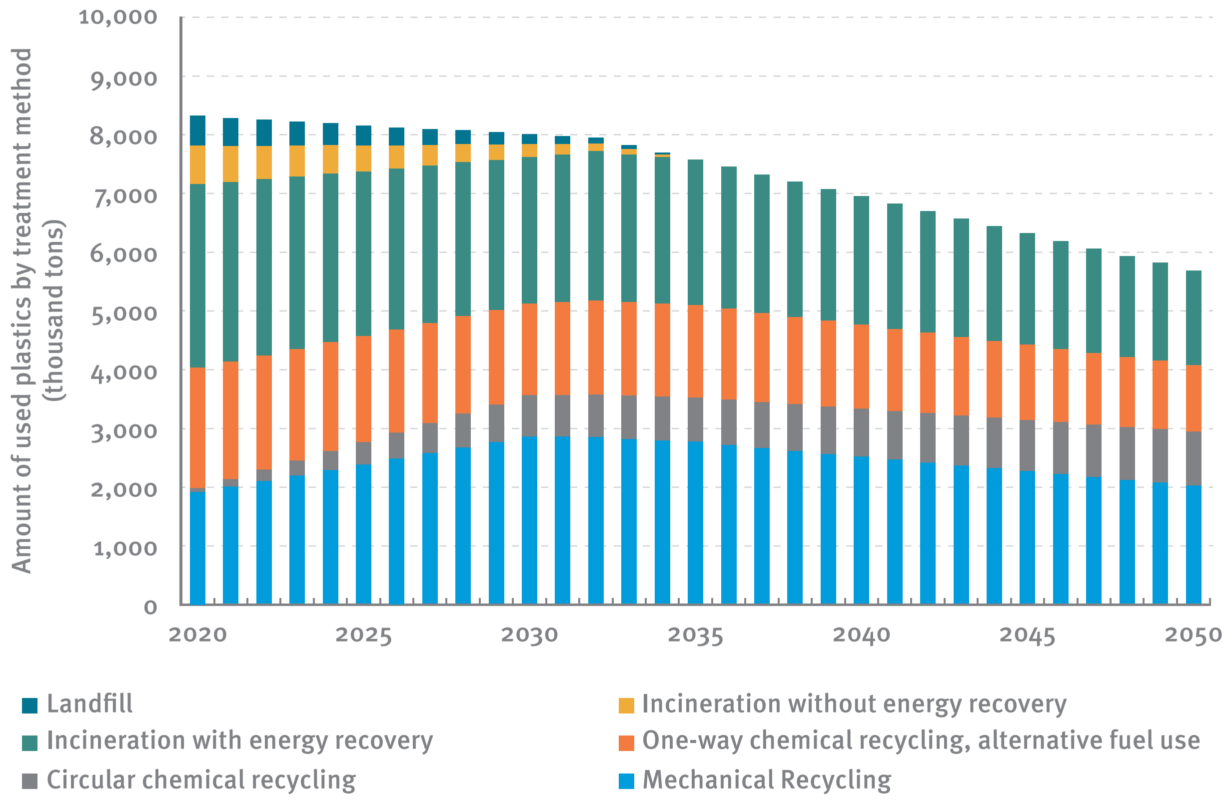
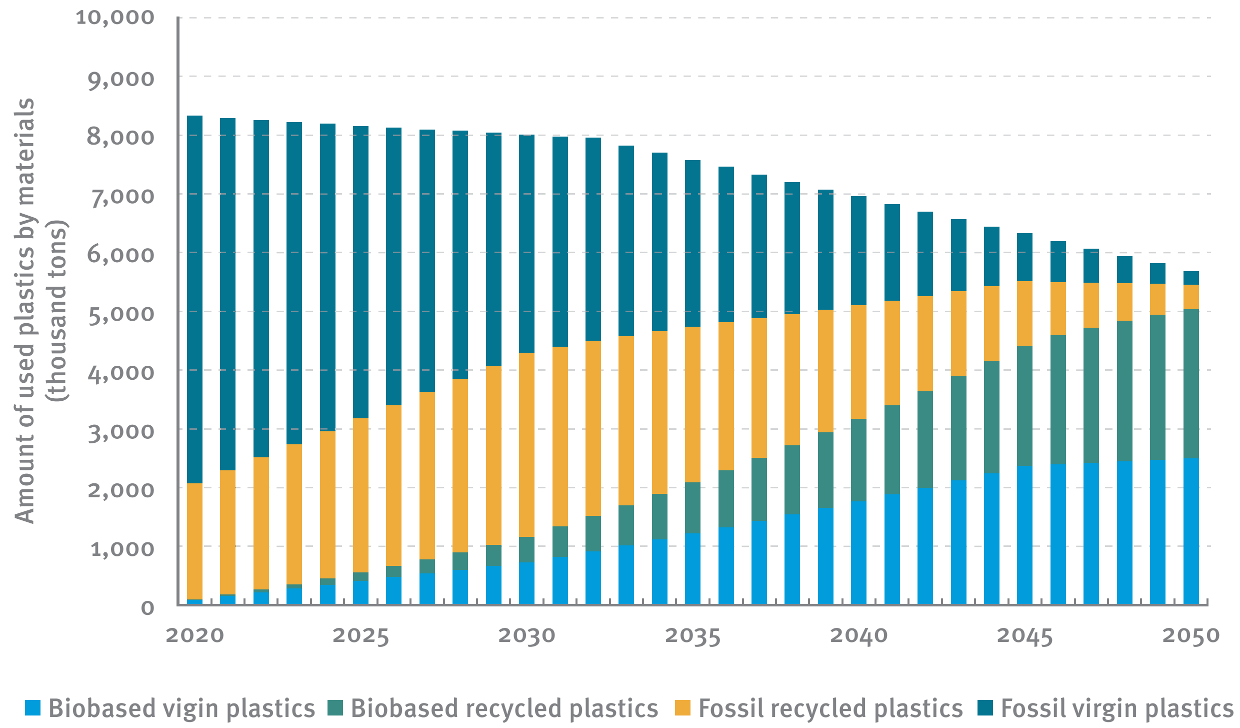


Figure 4.6. Amount of used plastics by materials until 2050

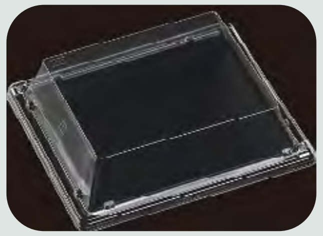


4.4. Examples of recycled materials in products

This section provides examples of unique products made from recycled plastics from mechanical recycling.

Company	AEON Topvalu Co., Ltd.
Plastic sources	Recycled plastic (PE)
Recycled material content	80 per cent
Products	Reusable shopping bag
Source	‹www.topvalu.net/items/detail/4549741893510/›

Company	FP Corporation
Plastic sources	Recycled PET
Recycled material content	100 per cent
Products	Food packaging
Source	• ‹www.fpco.jp/product/feature_function.html› • ‹www.fpco.jp/dcms_media/other/FPCO_Report_2020.pdf›



Company	Kao Corporation
Plastic sources	Recycled PET (chemical recycling)
Recycled material content	Missing data
Products	Cosmetics bottle
Source	‹www.kao.com/jp/corporate/news/sustainability/2021/20210526-001/›

Company	Canon Ecology Industry Inc.
Plastic sources	Recycled polystyrene
Recycled material content	More than 99.9 per cent
Products	Toner cartridges
Source	‹ecology.canon/business/tonercartridge-recycle.html›

Company	Kirin Holdings Company, Ltd.
Plastic sources	Recycled PET (mechanical recycle)
Recycled material content	100 per cent
Products	Drinks bottles
Source	‹www.kirinholdings.com/en/purpose/model/stories/case17.html›

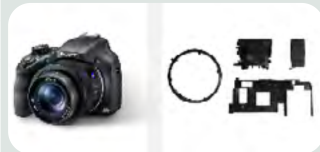
Company	Sapporo Breweries Ltd.
Plastic sources	Recycled PET
Recycled material content	100 per cent
Products	Wine bottles
Source	‹www.sapporobeer.jp/news_release/0000012355/›

Company	Suntory Holdings Ltd.
Plastic sources	Recycled PET (Flake to Preform technology)
Recycled material content	100 per cent
Products	Drinks bottles
Source	‹www.sapporobeer.jp/news_release/0000012355/›

Company	J&T Recycling Corporation
Plastic sources	Recycled PP and PE mechanical recycling
Recycled material content	100 per cent
Products	Pallets
Source	‹www.jt-kankyo.co.jp/business/products/plastic_pallet.html›

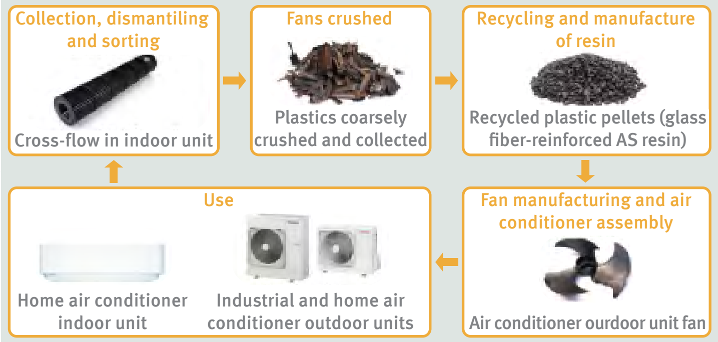
Company	Sekisui Chemical Co., Ltd.
Plastic sources	Recycled waste packaging
Recycled material content	100 per cent
Products	Container
Source	‹www.sekisui.co.jp/search/detail-3213.html›

Company	Sony Group Corporation
Plastic sources	Recycled Polycarboante
Recycled material content	99 per cent
Products	Cameras, televisions, etc.
Source	‹www.sony.com/ja/SonyInfo/csr/eco/technology/sorplas.html›



Company	Tomy Company Ltd.
Plastic sources	Recycled factory plastic
Recycled material content	50 per cent
Products	Toys
Source	‹www.takaratomy.co.jp/eco/introduction/ecotoy.html›

Company	Toshiba Corporation
Plastic sources	Recycled glass fibre-reinforced styrene acrylonitrile copolymer
Recycled material content	Unknown
Products	Fans for air conditioners
Source	‹www.toshiba.co.jp/env/en/products/recycled_plastic.htm›



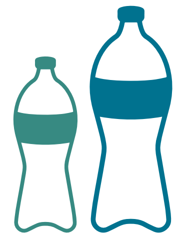
5 The adoption of innovative materials and packaging technologies

5.1. Introduction

The growing concern over problems caused by plastics, including marine plastic litter, means more and more brand owners and user companies are turning to more sustainable materials and packaging technologies. This section provides an overview of these trends in different industries. The trends and examples given are based on shifts by Japanese brand owners and user companies.

5.2. Beverage manufacturers

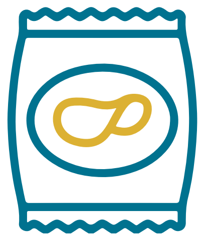
- A number of major companies have shifted to lighter and thinner drinks bottles or the use of alternative materials (recycled PET and bio-PET). Paper is also being used for drinks containers.
- Many companies have also made efforts to make bottle caps lighter, with some introducing bio-based materials.
- More recently, label-free bottles have been adopted by some manufacturers, mainly for online purchases.



✓ Thinner label or no label
✓ Bio-based plastic cap
✓ Lighter and thinner bottle / use of alternative materials

5.3. Food manufacturers

- There is a trend among major food manufacturing companies to shift to thinner, lighter and label-free food packaging, as well as make use of alternative materials (paper and bioplastics).
- There are also trends specific to product types. For example, a major instant noodle producer has replaced a polystyrene noodle container with paper and bioplastic. For oil and seasoning containers, many companies have redesigned their packaging and, in some cases, switched to alternative materials (paper and bio-PET).



✓ Reduced packaging volume, adoption of monomaterial

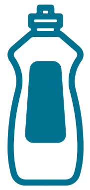
✓ Adoption of paper and bio-based plastic

5.4. Cosmetics and consumer goods

- There is a trend among major companies to redesign product packaging to reduce the materials used, to adopt refillable containers and to use alternative materials (recycled materials bio-PE and paper).
- For multi-material packaging, some companies are shifting to packaging that can be easily separated for recycling.
- In addition to the redesign of packaging, many companies have taken the initiative to downsize containers by concentrating the content inside the packaging (for example, washing detergent).

- ✓ Refillable and re-attachable container to reduce materials
- ✓ Easy shape to refill

- ✓ Reduced plastic usage concentrating the content
- ✓ Adopted recycled material



5.5. Supermarkets and convenience stores

- Major stores are increasingly seeking to make use of alternative materials (bio-PE or paper) for shopping bags.
- For food packaging, many companies have redesigned their packaging or adopted alternative materials (bioplastics, paper and recycled material).
- For other food-related products, such as straws and beverage cups, there is a trend to use alternative materials (bioplastics and paper for straws; and paper and recycled PET for beverage cups).
- For non-food packaging, many supermarkets have adopted refillable packaging and alternative materials (recycled PET).

- ✓ Bio-based shopping bag
- ✓ Adoption of recycled or bio-based materials

5.6. Cafés, fast food outlets and restaurant chains

- There is a trend among major chain stores to replace straws with alternative material (paper or bio-PE). In some places, straws are distributed on request.
- Many stores have also replaced takeaway bags with alternative materials (paper or bio-PE).
- There are also trends to adopt alternative materials for other food-related products. These include using paper for drinks cups and cutlery, replacing polystyrene containers with paper and adopting recycled PET for salad containers and food trays. One restaurant chain has replaced takeaway cutlery with bioplastics and customers are being asked whether cutlery is needed at the time of online purchases.

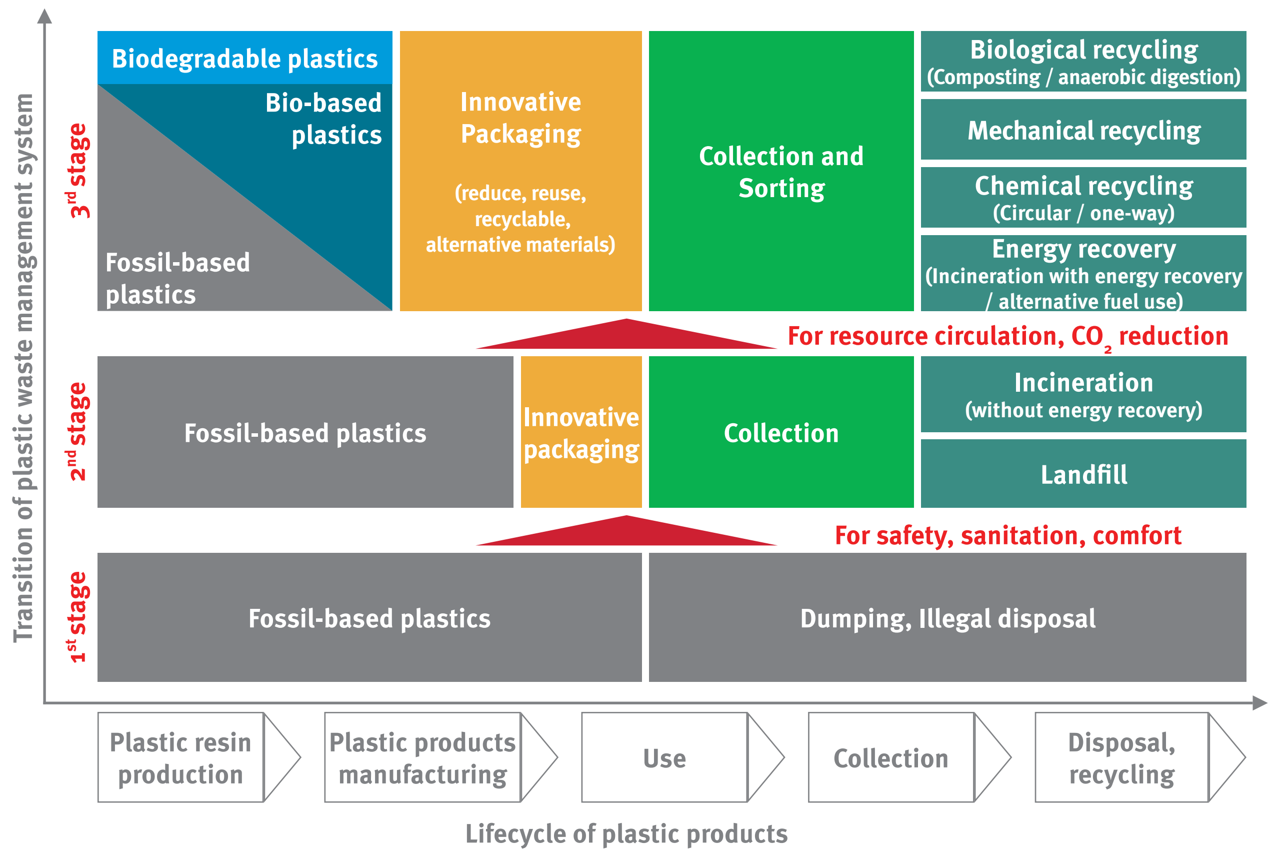
- ✓ Adopted FSC certified straw and paper cup
- ✓ Adopted bioplastic or paper takeout bag and cutlery

6 Technology selection

This report has introduced various technologies with the potential to help minimize the environmental impact from plastic waste, to promote recycling of plastic waste and to reduce CO_2 emissions from treatment of plastic waste in Africa.

The specific needs for technologies for plastic waste and their effectiveness varies by country. Figure 6.1 shows a schematic diagram of technology selection for each life cycle of plastic products based on the stage of the plastic waste treatment system.

Figure 6.1. Idea for the transition of plastic waste management systems



Stage 1 represents countries with insufficient waste management systems. In such countries, environmentally friendly technologies for plastic products, such as alternative materials to fossil plastics, innovative packaging, and recycling after appropriate waste collection and sorting systems, have not been developed, and conventional fossil-based plastics are still used. The immediate aim of waste management systems in such countries is to shift to safe, hygienic and comfortable waste disposal systems.

To achieve this target, it is first necessary to develop a waste collection system that includes plastic waste. The means of disposing of the collected waste would be sanitary landfill for the time being, but once the population reaches a certain level, sanitary landfill will no longer be sufficient to treat the necessary amount of waste alone. Waste incineration will then be introduced, following efforts to reduce waste. Plastic materials will still be fossil-derived plastics, but some fundamental packaging technologies, such as reducing plastic use, may be introduced for better plastic waste management.

The next stage of the waste management system will be aimed at resource circulation and CO_2 reduction. In this stage, material recycling and chemical recycling of plastic waste are important technologies. For chemical recycling, circular chemical recycling will become even more important compared with one-way chemical recycling. In addition, progress in biological recycling, such as composting and anaerobic digestion of organic waste, is also desirable, and biodegradable plastics can be utilized in this process. However, the amount of recovered plastic waste that can be applied in these efficient recycling systems is limited, and a certain amount of plastics must be incinerated. In such cases, electricity and/or heat recovery from waste incineration need to be introduced. Acceptable plastic waste varies depending on the purpose of recycling, so, to make recycling as efficient as possible, it is important to develop a source separation system for municipal waste or an automated sorting system for collected waste.

In this stage, biobased plastics will be effective for reducing fossil CO_2 emissions from plastic waste incineration. In addition, when biobased plastic products are recycled mechanically or chemically, the biobased contents are taken over in the recycled plastic products, thus promoting CO_2 reduction from plastic waste. Significant progress is also required in packaging technology to utilize these recycling systems and innovative materials.

The primary aim of this report has been to provide information on technologies that can be applied to promote circular economy practices to reduce plastic leakage to the environment. It also includes information to help understand which technologies are appropriate at different development stages of the waste management system. It is hoped that readers, particularly plastic-related stakeholders and policy makers, will make their technology choices taking into account the current status of waste management in their countries.

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