Achieving more circularity in the future global plastics agreement:

Common criteria to improve packaging design

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Executive Summary

Plastic has become the material of choice for protecting consumer goods as it offers advantages over other packaging materials. However, the amount of waste generated and in particular its durability have led to global challenges, with most mismanaged plastic waste being packaging and single-use plastics. While the lack of proper waste management systems and associated funding is one part of the problem, mismanagement is rooted in design choices for plastic products and packaging which can reduce or prevent their recyclability. Better management of plastics and plastic waste therefore requires smart measures along the whole value chain from design and production to collection, sorting and treatment.

As the design phase of a plastic product or packaging determines its ecological impact and suitability for high-quality recycling, circular product design and eco-design approaches have been generally acknowledged as playing a key role in tackling plastic pollution and enabling the transition to a circular economy.

Eco-design is an umbrella term used to describe the 'integration of environmental aspects into the product development process, by balancing ecological and economic requirements. Eco-design considers environmental aspects at all stages of the product development process, striving for products which make the lowest possible environmental impact throughout the product life cycle' (EEA Glossary). For packaging and plastic waste, it covers various strategies aiming to minimise the environmental impact caused during manufacturing, use and disposal. It involves optimising certain packaging features ranging from recyclability and the use of recyclates to packaging and product redesign.

Circular product design is a term derived from the eco-design approach and refers to a method developed by analysing existing research on eco-design principles and then categorising them into five groups reflecting circularity at the component and/or material level. For more complex products, the focus is on lifespan extension, ease of disassembling, and product and/or component reuse. For products with a short or very short in-use phase, such as sales and service packaging, design features that facilitate material recycling, that is, those that enable materials to be easily identified, separated and recycled, are the most relevant.

Circular product design and eco-design principles have been successfully applied to electrical and electronic equipment products, which are typically more complex than packaging. This report focuses specifically on fast-moving items such as packaging to examine which circular design and eco-design strategies and mechanisms can be applied to increase their recyclability and/or the use of recycled content as well as to decrease their overall environmental impact by reducing and substituting input materials.

Worldwide, there are over 100 sets of guidelines on product and packaging design that aim to promote recyclability and circularity. These standards vary significantly as they have different focus areas and are not always fully consistent in scope and detail. Moreover, the potential for implementing some of these guidelines beyond the country for which they were developed will be limited, and they will be subject to national constraints. As yet, no mandatory standard on design for recycling has been implemented for any type of product anywhere in the world.

However, under the future global plastics treaty, standards will have to be harmonised. To this end, from a global perspective, the following common principles and measures for optimising design for recycling can be identified:

- avoiding full sleeves and sleeves covering more than 60% of the container;
- avoiding opaque PET;
- ensuring components are easily separable in the recycling process;
- keeping labels as small as possible;
- not using barriers, additives and fillers that are detrimental to the quality of the recycled plastic because, for example, the plastic materials have different melting points;
- phasing out PVC labels;
- prioritising mono-materials over multi-layer materials;
- prioritising simple packaging design;
- using removable caps and lids;

- using transparent or lightly coloured packaging;
- using water-soluble inks and adhesives.

In order to use these common principles as a starting point to improve plastic packaging, they need to be considered in the light of various other aspects and aligned with them. They include the following:

- **product protection** and other general functions of packaging of secondary importance and how to meet these requirements, which vary between countries depending on conditions such as temperature and humidity;
- **alignment with the waste hierarchy** and the various ranked options as a key guiding tool for prioritising product and waste management solutions;
- **alignment with the national waste management infrastructure in place**, which varies between countries.

Since design options largely depend on the waste management structure (e.g. collection, sorting, recycling and disposal) and the environmental legislation of the country or region in which the packaging is ultimately disposed of, the issue of eco-design and circular design is also tied to marine litter prevention and mitigation. Recent studies reveal that leakage and littering are influenced by various socio-economic and cultural factors and therefore vary significantly from one place to another. The interplay of factors such as national income (i.e. a country's wealth), the value of built infrastructure, population density in proximity to rivers and the coast, the overall waste management system and cultural aspects affects how much and what types of plastic waste eventually become litter.

This means that littering differs significantly from one city or region to another, and this variation is a result of socio-economic differences. Predictably, wealthier countries are generally better able to finance costly waste management than lower-income countries. Since litter clean-up activities are very burdensome and cost-intensive, intervening to address the 'root cause' and improving waste management is crucial, particularly in countries that struggle to finance action in this area. Waste management policies that provide for the required financing are therefore a key tool for mitigating marine litter and preventing its generation in the first place. Effective measures against marine litter generation inevitably require improved waste management practices. Changing packaging or product design using design for circularity and/or eco-design approaches has no direct impact as it does not contribute to financing waste management. It can, however, have an indirect impact by facilitating the development of infrastructure – as recyclable plastic waste will be generally available – and eventually improve waste management.

The impact of eco-design can be further increased by using mandatory instruments, such as phase-outs and bans, mandatory design regulations, taxation, and extended producer responsibility (EPR) schemes. If carried out properly, eco-design and circular design measures can be a powerful tool for accelerating the transition to a circular economy.

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Abbreviations

AA ....Acetaldehyde
APET ....Amorphous polyethylene terephthalate
CE ....Circular economy
CPA ....Circular Plastics Alliance
EC ....European Commission
EEA ....European Environmental Agency
EEE ....Electrical and electronic equipment
EFSA ....European Food Safety Authority
EPR ....Extended producer responsibility
EPS ....Expanded polystyrene
EU ....European Union
EuPIA ....European Printing Ink Association
EVA ....Ethylene vinyl acetate
EVOH ....Ethylene vinyl alcohol
FCM ....Food contact material
HDPE ....High-density polyethylene (plastic polymer type)
JRC ....European Commission Joint Research Centre
KASA ....Malaysian Ministry of Environment and Water
LDPE ....Low-density polyethylene (plastic polymer type)
LLDPE ....Linear low-density polyethylene (plastic polymer type)
LMICs ....Low- and middle-income countries
NGO ....Non-governmental organisation
PA ....Polyamide
PAC ....Pro-oxidant additive containing
PE ....Polyethylene (plastic polymer type)
PET ....Polyethylene terephthalate (plastic polymer type)
PETG ....Polyethylene terephthalate glycol
PEX ....Cross-linked polyethylene
PO ....Polyolefin (plastic polymer group)
POM ....Polyoxymethylene
PP ....Polypropylene (plastic polymer type)
PPWD ....Directive 94/62/EC on packaging and packaging waste (packaging and packaging waste directive)
PS ....Polystyrene (plastic polymer type)
PVC ....Polyvinyl chloride (plastic polymer type)
PVDC ....Polyvinylidene chloride
SMEs ....Small and medium-sized enterprises
SUPs ....Single-use plastics
TPE ....Thermoplastic elastomer
UNEP ....United Nations Environment Programme
UV ....Ultraviolet

1 Introduction

In recent decades, plastic has become a ubiquitous material in many sectors, with uses ranging from applications in buildings and construction to vehicles, textiles, and packaging. It has become the material of choice for protecting consumer goods as it offers advantages over other packaging materials. These include, for instance, high protection, low weight, low price, and endless shaping possibilities. However, the amount of waste generated and, in particular, its durability have led to global challenges, with most mismanaged plastic waste being packaging and single-use plastics (SUPs). While the lack of proper waste management systems and funding to develop them is one part of the problem, mismanagement is rooted in design choices for plastic products and packaging which can reduce or prevent their recyclability. **Better management of plastics and their waste therefore requires smart measures along the whole value chain from design and production to collection, sorting and treatment.**

The global discussion on improving plastic waste management and increasing circularity highlights how important the design of products and packaging is. The design phase is key in determining the product's ecological impact and suitability for high-quality recycling once it reaches the end-of-life phase. This is also reflected in circular product design and eco-design approaches, which have been widely recognised as playing an important role in enabling the transition to a circular economy (CE), for instance, by the European Commission (EC) (European Parliament, 2022).

Circular product design and eco-design principles have been successfully applied to electrical and electronic equipment (EEE) products (e.g. through the Eco-Design Directive 2009/125/EC), which are typically more complex than packaging and SUP items. This report focuses specifically on fast-moving items such as packaging to examine which circular design and eco-design strategies and mechanisms can be applied to increase their recyclability and/or the use of recycled content and to decrease their overall environmental impact by reducing and substituting input materials. In addition, **amendments to product or packaging design always need to be considered in the context of other potentially competing aspects,** including protection of the packaged item, marketing and logistics and, most importantly, economic considerations.

Moreover, design options largely depend on the waste management structure (e.g. collection, sorting, recycling and disposal) and on the environmental legislation of the country or region in which the packaging is ultimately disposed of and are also relevant for addressing the generation of marine litter. Effective measures against marine litter inevitably require improved waste management practices. Changing the design of packaging or products using design for circularity and/or eco-design approaches can contribute by providing incentives to use products longer, enable their reuse or increase their recyclability so that waste is recycled instead of being disposed of at landfills.

Considering the transboundary nature of marine litter and the global need to act, particularly in light of a future global agreement to curb plastic pollution, the aim of this report is to provide guidelines for improving the design of plastic packaging by drawing on both circular product design and eco-design principles to achieve more circularity. It informs stakeholders and decision-makers from the private sector, public institutions and governments on the potential of improved product design as a way to prevent plastic pollution and drive more circularity, as required in different national, regional, and global initiatives.

2 Outline and definition of scope

To analyse the potential of circular product design and eco-design for plastic packaging and SUPs, especially with a view to recommendations for a global plastics agreement, this report will present:

- definitions for a common understanding of the most relevant terms (see Chapter 3);
- existing standards for recyclability which will be analysed for their suitability in a global context, with a view to developing generally applicable guidelines on design for recycling (see Chapter 4);
- the three key pillars that must be considered when preparing to redesign packaging to achieve a more circular design (see Sections 5.1, 5.2 and 5.3);
- a matrix showing how the design of packaging can be changed according to the filling (see Section 5.4).

As mentioned above, most mismanaged plastics are packaging and SUPs. To create an aligned understanding on what types of plastic waste are involved, the report defines the following terms:

- Single-use plastics are packaging or products that are made wholly or partly from plastic and that are not designed to go through multiple life cycles after being placed on the market, for example, by being returned to a producer to be reused for the same purpose for which they were originally designed. SUPs can be both packaging (e.g. beverage bottles or plastic containers for take-away food or drinks) and non-packaging items (e.g. plastic cutlery).
- Sales packaging is packaging used to contain and protect a product and is handled by the end consumer of the product or a comparable entity; it includes, for instance, any packaging used for products sold in supermarkets and e-commerce packaging.
- Service packaging is packaging used for handling and delivering the product to the end consumer and is filled at the point of sale. It includes any form of take-away packaging.

Both sales and service packaging can be SUPs.

Given the very broad range of non-packaging SUPs and the wide variety of applications, the report cannot give specific design recommendations on them in the matrix in Section 5.4. However, the elements described in Sections 5.1 to 5.3 can also be applied to non-packaging SUPs and therefore offer guidance on such products. The items included in the scope of this report are therefore SUP sales and service packaging (see also Figure 1).[1]

Figure 1: Single-use plastics (scope of this report)

[1] Multiple-use and refillable packaging are not covered in this report. As they generally contribute to the avoidance of packaging waste, it is recommended to evaluate this approach as a matter of priority.

3 Definition for a common understanding of the terminology

3.1 Design strategies

Both circular product design and eco-design are umbrella terms covering various design strategies that aim to achieve a certain objective. While eco-design is a well-defined term used by organisations such as the United Nations Environment Programme (UNEP) and the European Union (EU), in their approaches to sustainable product design (e.g. in the Eco-Design Directive 2009/125/EC), circular design is a more novel concept that groups together all design strategies that promote CE practices (EC, 2019).

Eco-design is an umbrella term used to describe the 'integration of environmental aspects into the product development process, by balancing ecological and economic requirements. Eco-design considers environmental aspects at all stages of the product development process, striving for products which make the lowest possible environmental impact throughout the product life cycle' (EEA Glossary). For packaging and plastic waste, it covers various strategies aiming to minimise the environmental impact caused during manufacturing, use or disposal. It involves optimising certain packaging features ranging from recyclability and the use of recyclates to packaging and product redesign, as illustrated in Figure 2.[2]

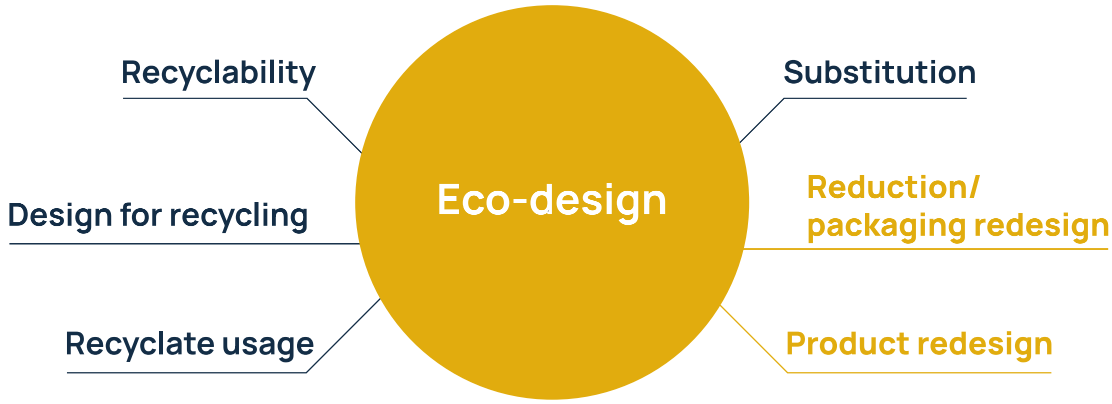


Figure 2: Overview of eco-design – focus on strategies shown in orange

Circular product design is a term derived from the eco-design approach and refers to a method developed by analysing existing research on eco-design principles and then categorising them into five groups reflecting circularity at the component and/or material level (see Figure 3). For more complex products, the focus is on lifespan extension, ease of disassembling, and product and/or component reuse (EC, 2019). For products with a short or very short in-use phase, such as sales and service packaging and SUPs, design features that facilitate material recycling, that is, those that enable materials to be easily identified, separated, and recycled, are most relevant to the scope of the report, as shown below.[3]

[2] Reduction and product redesign are not included in the scope of this report as they require evaluation for each specific item. As they generally contribute to the avoidance of packaging waste, it is recommended to evaluate this approach as a matter of priority.
[3] Extending lifespan, easy disassembling and promoting product and component reuse are not addressed in this research since these strategies apply to products that are more complex than packaging, for example, EEE.

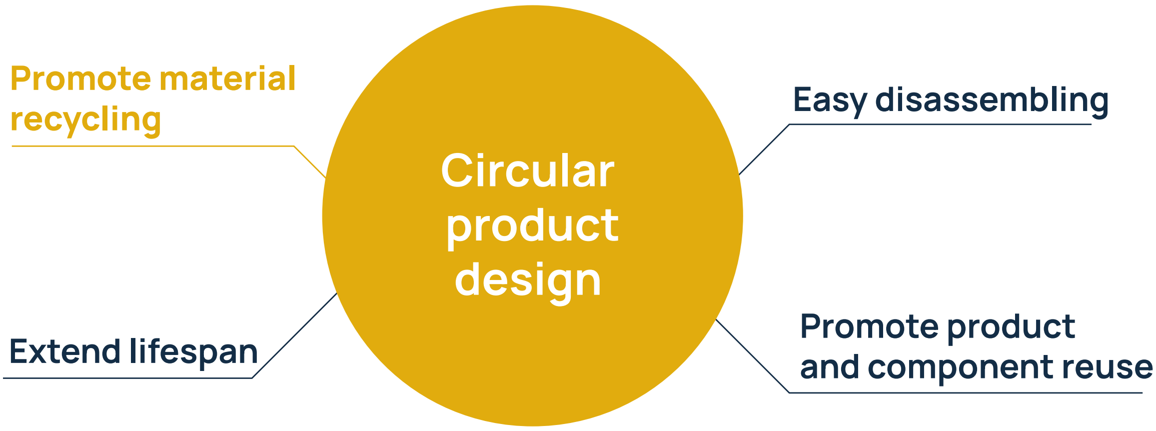


Figure 3: Overview of circular product design – focus on strategy shown in orange

Eco-design and circular product design are therefore related concepts. **Applied to sales and service packaging, both concepts strongly overlap as recyclability/design for recycling, substitution and the use of recyclates are key strategies for achieving them.**

As the aim of the report is to provide guidelines to improve packaging design. Reuse is not considered any further, given that the main challenge for reuse is not design but reverse logistics infrastructure and the corresponding management of financial flows. Providing recommendations on stepping up packaging reuse is outside the scope of this report although this does not mean that measures and actions enabling increased reuse are not critically important.

Note

Recent studies reveal that leakage and littering are influenced by various socio-economic and cultural factors and therefore vary significantly from one place to another (e.g. Hardesty et al., 2021). The interplay of factors such as national income (i.e. a country's wealth), the value of built infrastructure, population density in proximity to rivers and the coast, the overall waste management system and cultural aspects affects how much and what types of plastic waste eventually become litter.

This means that littering differs significantly from one city or region to another, and this variation is a result of socio-economic differences. Predictably, wealthier countries are generally better able to finance costly waste management than lower-income countries. This, in turn, leads to higher amounts of mismanaged waste and plastic litter generation (Hardesty et al., 2021). Since litter clean-up activities are very burdensome and cost-intensive, intervening to address the 'root cause' and improving waste management is crucial, particularly in countries that struggle to finance action in this area. Waste management policies that provide for the required financing are therefore a key tool for mitigating marine litter and preventing its generation in the first place (GIZ, 2022)

As marine (and terrestrial) litter mainly depends on the waste management facilities in place, eco-design and circular product design have no direct impact as they do not contribute to financing waste management. They can, however, have an indirect impact by facilitating the development of infrastructure – as recyclable plastic waste will be generally available – and eventually improve waste management.

The implementation of circular product design and eco-design requires strategies and mechanisms to determine how changes in the design of a product can reduce its environmental impact. The different types of plastic and the main plastic waste treatment processes are explained below as they are factors in the effectiveness of design strategies and bans. Special challenges that may arise in this context are also examined. The most important definitions are presented below to facilitate a common understanding of the issues addressed in the following chapters.[4]

Recyclability

Recyclability is the actual ability of an item of packaging or product in the post-use phase to **substitute for virgin material** in new items; 'actual' is used here to indicate that the necessary industrial-scale collection and processing infrastructure is available.

When determining recyclability, it is necessary to take into account product or packaging design (e.g. ensuring that there are no recycling incompatibilities) **and the waste management infrastructure in place,** checking whether:

- the packaging or product can be captured through an existing efficient countrywide collection system;
- the packaging or product can be segregated and forwarded to recycling through existing sorting and treatment infrastructure;
- the processing of components is technically and economically feasible.

Recyclability therefore depends on the country or region where the packaging/product is used and becomes waste.

Design for recycling

Design for recycling is an approach that focuses on ensuring that the packaging or product fulfils design criteria that facilitate recycling, including choice and composition of materials and shaping. In contrast to recyclability, this term does not take into account waste management aspects, such as functioning collection, sorting and treatment infrastructure.

Recyclate/recycled content

Recyclate or recycled content refers to the portion of materials used in packaging or a product that has been diverted from the solid waste stream through a recycling process. If these materials are diverted during the manufacturing process, they are referred to as pre-consumer or post-industrial content. If they are diverted after consumer use, they are referred to as post-consumer content.

Substitution

Substitution is the replacement of one object or material with another. The objective of substitution in product or packaging design is to create a more ecologically compatible alternative, for example, by replacing plastic with paper.

In order to avoid negative rebound effects, substitution measures have to be carefully evaluated. The suitability of a substitution is dependent on local contexts. Local factors, such as climate, have a strong impact on packaging design; for example, replacing plastic packaging with paper packaging is less suitable in a humid tropical climate as conditions warrant the use of plastic packaging, which offers higher protection against humidity, to ensure product safety.

[4] Please note that the focus is on plastic packaging, which is why approaches such as reparability or reassembly, which are important for more complex products such as EEE, are not considered here.

Reduction

Reduction refers to lowering the amount of resources used for products or packaging. This can involve (i) right-sizing packaging if filling has not been optimised and (ii) reducing packaging material (e.g. small wall thickness).

To implement such a design strategy, it is necessary to evaluate items individually. It is not, therefore, included in the scope of this report and will not be further addressed as high-level recommendations cannot be made aside from emphasising the importance of assessing the potential of packaging reduction. In this context, it should be noted that the reduction of packaging material can lead to a trade-off with recyclability and the resulting effects should be weighed against the benefits.

Product redesign

Product redesign essentially refers to changing the design of the product itself or the filling (of packaging), which can have an ecologically positive influence on the packaging design and, for instance, allow a different type of packaging to be used. Good examples of this are soaps and detergents.[5]

Similarly to reduction, it is necessary to evaluate items individually to implement this design strategy and therefore it is not included in the scope of this report. High-level recommendations cannot be made aside from emphasising the importance of assessing the potential of redesigning the product that is packaged.

[5] An example of product redesign would be a liquid cleaning detergent redesigned as a dry powder to which water is added by the consumer at the time of use. Changing the product from a liquid to a dry powder means that different packaging can be used, e.g. paper instead of plastic. Product redesign is influenced by other contextual factors, making it impossible to provide generally applicable recommendations on it within the scope of this report.

3.2 Types of plastic

Virgin plastics

Virgin plastics primarily refer to those that are newly manufactured using fossil resources, such as crude oil (fossil-based plastics), and to those made from biological raw materials grown for this purpose.

Production involves a refinery process. Virgin plastic is plastic resin that has not yet been used. In contrast to recycled (secondary) plastics, virgin plastics are 'newly' introduced into the material cycle.

Recycled plastics

Recycled plastics are those that have already been used before in a product or packaging and that after being disposed of, collected and recycled are eventually fed back into the production cycle as raw materials for new products.

Bioplastics

Bioplastics is a term used to refer to both biodegradable plastics and bio-based plastics. It is a broad term for a variety of materials and is often used incorrectly.

Biodegradable plastics are characterised by their ability to be broken down by microorganisms into water, carbon dioxide (or methane) and biomass. They can be manufactured from both fossil and renewable resources. They can be foamed into packing materials, extruded and injection-moulded in modified conventional machines. (European Bioplastics, n.d.). The term '(bio)degradable' is often incorrectly used synonymously with 'compostable'[6]. The Group of Chief Scientific Advisors recommends limiting the use of biodegradable plastics to specific applications for which reduction, reuse and recycling are not feasible (EC, 2020).

In contrast, the term **bio-based plastics** only takes into account the origin of the material and is used to refer to plastics made partially or fully from renewable sources, such as sugar cane. Durable plastic polymers, such as bio-based polyethylene (PE) and polyethylene terephthalate (PET), are derived from renewable raw materials. They possess properties identical to those of their conventional versions and cannot be distinguished from conventional plastics other than by scientific analysis (European Bioplastics, n.d.). They can be created as non-degradable or degradable plastics.

Generally speaking, there are three categories of bioplastics:

- **bio-based non-degradable/durable plastics** (see Figure 4, upper left);
- **bio-based biodegradable plastics** (see Figure 4, upper right);
- **fossil-based biodegradable plastics** (see Figure 4, lower right).

[6] Biodegradable and compostable materials can be broken down by microorganisms into water, carbon dioxide, mineral salts and new biomass within a defined period of time. Whether a biodegradable or compostable plastic item biodegrades and how quickly that happens largely depends on the conditions it is exposed to during disposal. Factors include temperature, duration and the presence of microorganisms, nutrients, oxygen and moisture. Compostable materials break down into natural elements, such as humus, upon degradation within a specific time frame and require certain conditions, such as those found in industrial composting facilities, to do so. When using the term 'compostable', manufacturers must have scientific evidence demonstrating that all materials become usable compost in a timely manner. In contrast, a biodegradable product will eventually break down into organic materials under the right conditions (not necessarily those of industrial composting facilities).

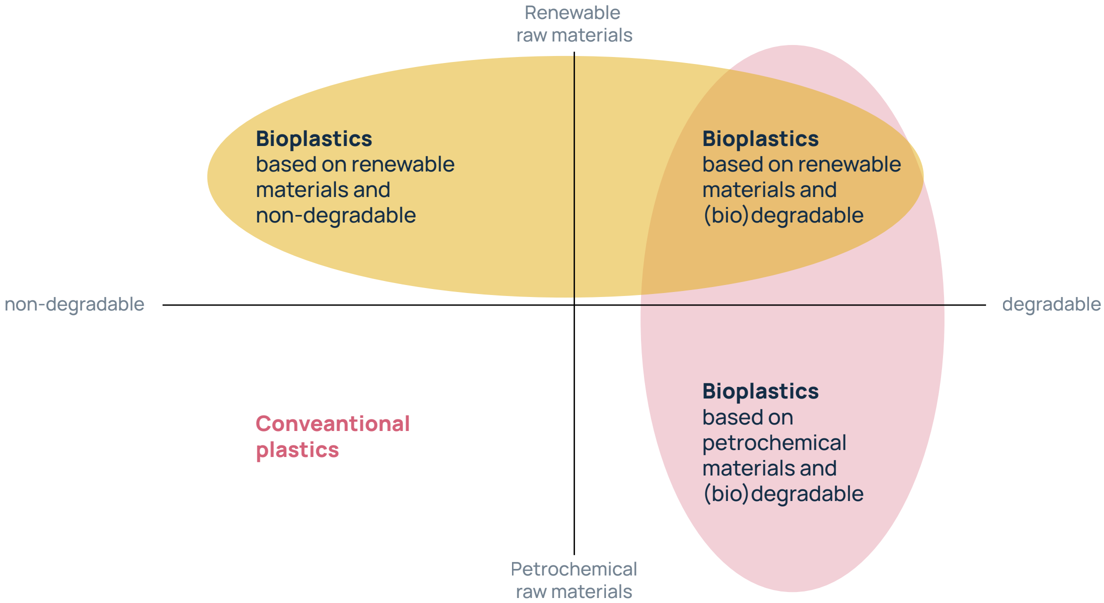


Figure 4: Overview of bioplastics

Oxo-degradable plastics

Oxo-degradable, oxo-fragmentable or oxo-biodegradable plastics are conventional plastics which include additives designed to promote the oxidation of the material to the point where it becomes brittle and fragments. It is claimed that this is followed by biodegradation by bacteria and fungi at varying rates depending on the environment. These materials are also referred to as pro-oxidant additive containing (PAC) plastics, a term that describes the material's physical make up without implying any presumption as to how it will behave in different environments (EC, 2016). Oxo-degradable plastics are most commonly used for plastic carrier bags.

The EU has banned these plastics in its Single-Use Plastics Directive, and other states are considering doing so, due to issues related to biodegradation (for more information, see EC, 2016).

3.3 Plastic waste treatment

Plastics can be treated and recovered in different ways, and recovery processes can be ranked according to sustainability, with 'preparation for reuse' at the top and including recycling, energy recovery and final disposal. **It is important to note that, in this context, the term 'recovery' encompasses recycling, preparation for reuse and energy and other recovery processes.** This prioritisation of waste treatment and recovery processes is defined in the waste hierarchy and is one of the core principles underlying EU waste management (see Figure 5). In other regions, a guiding principle for waste management and the transition to a CE is the 3R principle – reduce, reuse and recycle.

It is also important to take into account that recovery strategies depend heavily on the prevailing conditions in the country in which the packaging or products are disposed of.

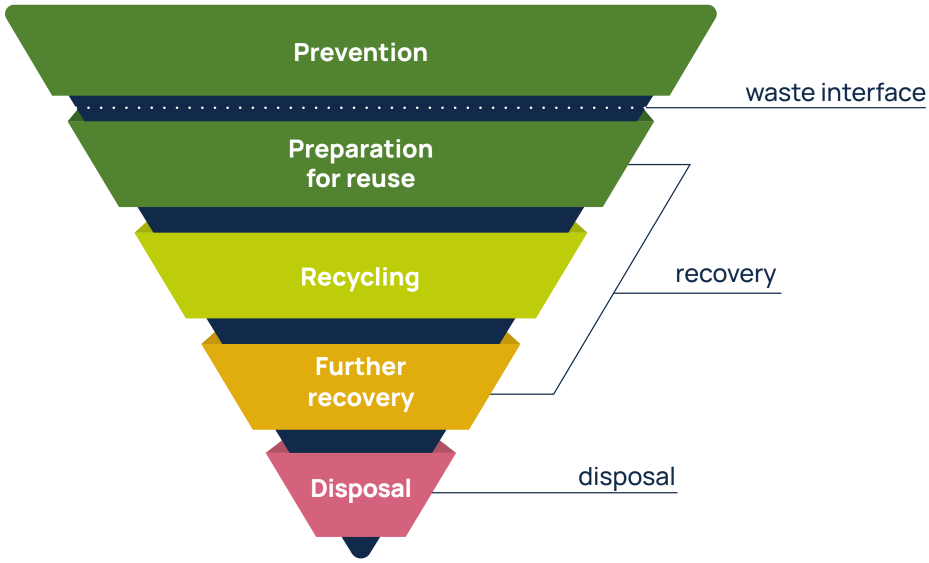


Figure 5: The waste hierarchy

With regard to 'reuse', the waste hierarchy distinguishes between actual reuse and preparation for reuse. In the EU's guiding legislation on waste management, the Waste Framework Directive, these terms are defined as follows:

> **'reuse'** means any operation by which products or components that **are not waste** are used again for the same purpose for which they were conceived.

In this definition, **'reuse' is considered as one aspect of the prevention level of the waste hierarchy.** It is not part of waste management because it promotes the reutilisation of resources and a reduction in the production of new goods (EUROPEN, 2014). 'Preparing for reuse' constitutes a waste recovery process of significantly higher quality than recycling or recovery and is defined as follows:

> **'preparing for reuse'** means checking, cleaning or repairing recovery operations, by which products or components of products **that have become waste** are prepared so that they can be reused without any other pre-processing.

In conclusion, it is important to understand that the terms 'reuse' and 'preparing for reuse' are not the same and refer to two very different concepts. However, even experts appear to use the terms interchangeably. The key difference is that, in the case of preparing for reuse, the packaging cannot be reused again as packaging without any preparation because it has been damaged (EUROPEN, 2014; see also Figure 6). For example:

- **reuse:** a glass bottle is returned to a designated collection facility. Once it has been washed and refilled, the bottle will re-enter the market. Since the packaging (glass bottle) was taken back through a deposit scheme, it did not become waste.
- **preparation for reuse:** a multiple-use packaging item (plastic pallet) is damaged and therefore no longer suitable for further use. The pallet has become waste because – as specified in the definition of waste – there is an intention to discard. If the plastic pallet is fixed (e.g. by replacing damaged components) in order to recondition it for its original purpose, it has undergone a preparation for reuse process.

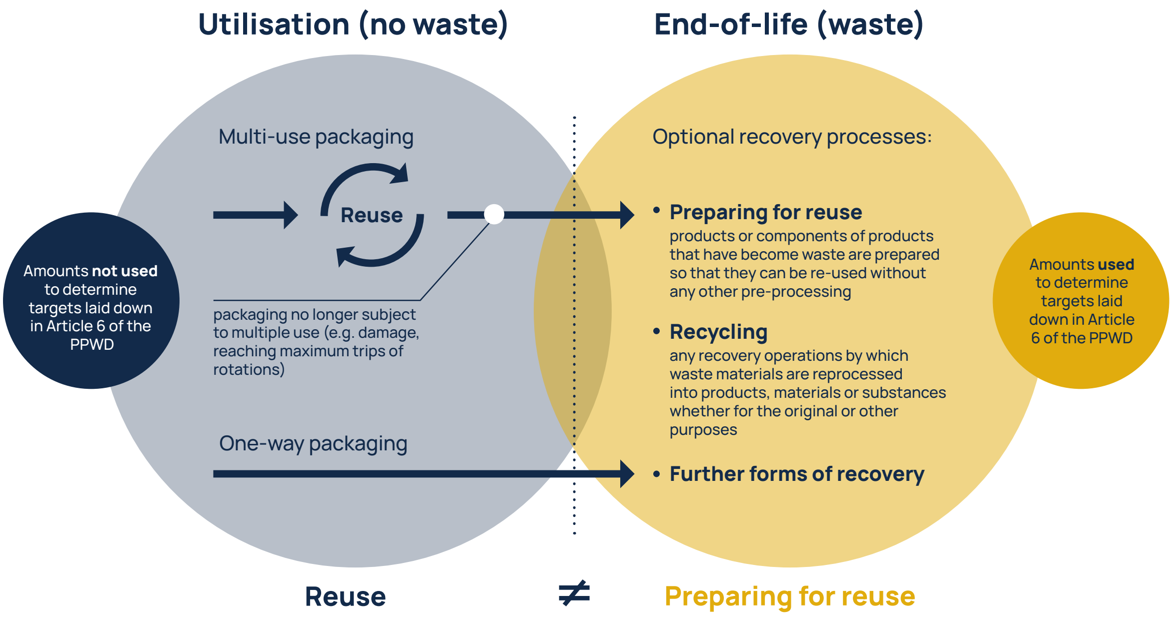


Figure 6: Difference between reuse and preparation for reuse (modified after © cyclos)

As mentioned above, the other commonly used principle for waste management is the 3R principle. In this model, there is no distinction between 'reuse' and 'preparation for reuse'.

Compliance with the waste hierarchy and/or the 3R principle is a central element of the CE. Producers can influence the 3Rs/the first three levels of the waste hierarchy:

- With regard to packaging, prevention refers to the reduction or elimination of unnecessary packaging, packaging components and/or packaging mass (before it becomes waste). Prevention is also achieved through reuse because the packaging does not become waste when it is reused for the same purpose. Such measures are also in line with the reduce and reuse principles of the 3Rs.
- Preparation for reuse is a complementary waste management measure relating to reuse. Producers can, for example, prepare items for reuse by taking them back and preparing them to be reused for the same purpose. Such measures are also consistent with the 3Rs reuse principle.
- Recycling[7] depends on the recyclability (design and infrastructure in place) of the packaging or products. The use of secondary materials from recycling (post-consumer content) strengthens circularity.

Mechanical recycling in its various forms (e.g. for PE and PP film) is an established process and, in specific areas, suitable for food-grade applications (e.g. PET bottles). This process requires (rather) clean, ideally mono-type input materials or various subsequent processing steps. **Most established large-scale recycling processes for packaging (regardless of material) and other products (if collected) are mechanical.**

Chemical recycling aims to recover the building blocks of the material. The polymer chains are broken down into shorter hydrocarbons by the effects of heat, catalysts, solvents and hydrogen and in a partially oxidising atmosphere. Through this process, monomers, petrochemical raw materials and synthesis gas can be obtained. Due to the wide variety of chemical structures, properties of materials and the diversity of waste streams, different processes are suitable for specific applications. Chemical recycling is increasingly being discussed and tested to process materials that are currently difficult or impossible to recycle. However, at present, its disadvantages compared to mechanical recycling include the following, among others (Schlummer et al., 2020):

- variability in the quality of use;
- economic break-even;

[7] There is an important difference between material and chemical recycling. Material recycling, also referred to as mechanical recycling, applies to processes that leave the polymers of the plastic material intact, while chemical recycling reverses the original process of producing plastics. It involves breaking up the chemical polymer structure of the plastic waste into simpler structures.

- elaborate pre-treatment and sorting;
- lower yields;
- plant engineering difficulties in scaling up.

Further recovery processes, such as incineration with energy recovery, should only be used if other measures cannot be applied since materials from the waste will be lost from the product cycle (no circularity). It should also be noted that incineration (regardless of whether energy recovery takes place) is banned in some countries.

The proportion and composition of waste disposed of at landfills or released into the environment depends on how well other waste management and treatment processes have been implemented and on the overall waste management infrastructure (Hardesty et al., 2021).

3.4 Special challenges

Recommendations for products and packaging design are also influenced by special challenges that apply in certain contexts.

Food contact

Food contact materials (FCMs) are all materials and objects intended to come into contact with food, such as packaging and containers, kitchen equipment, cutlery and dishes. FCM safety must be assessed as chemicals can migrate from materials into food (EFSA, n.d.).

Materials and items made partially or fully from recycled plastic that come into contact with food should only be obtained from processes that have been safety-assessed by the European Food Safety Authority (EFSA) and approved by the EC.[8] At present, the only recognised processes are those for producing PET recyclates.

Halal

'Halal' is Arabic for permitted or permissible under Islamic law. In relation to food, 'halal' means that the food itself and the commercial process is permitted under Islamic law and that the food may be consumed by Muslims. Halal food must meet the following requirements:

1. it must not come from or consist of any part of animals that are forbidden to Muslims by Islamic law or animals that have not been slaughtered according to Islamic law;
2. it must not contain any substance that is considered impure in Islamic law;
3. it must be prepared, processed and manufactured using equipment and utensils that are free from impurities as defined by Islamic law;
4. in preparation, processing and storage, it must not come in contact with or be stored near any kind of food that does not meet the above requirements or any substances that are considered impure under Islamic law (Sulaiman et al., 2014).

When recyclates are used in packaging for **halal food, they must come from packaging intended for halal-compliant filling.** Certification schemes are being developed for halal recyclates, such as the one in Malaysia (KASA, 2021).

Contaminants

Plastic is such a versatile material because of the countless ways in which its properties can be changed by additives with different functions, for example, imparting colour to the plastic. Other substances are also added to the packaging, such as when different packaging components need to be joined (e.g. adhesives used to attach labels to plastic bottles).

[8] Regulation (EC) No. 282/2008 establishes regulations for the approval of processes for recycling such materials in the EU.

Some additives have harmful effects on the packaged content and therefore on the consumer and are being gradually phased out and banned as 'hazardous contaminants' of packaging.

A critical issue, from a recycling perspective, is the problem of contaminants that cannot be separated in established operations in recycling treatment plants. This degrades the quality of the recyclate, making it unusable or resulting in a significant loss in value or disproportionately high processing costs.[9] Depending on the type of plastic to be recycled, examples include:

- non-water-soluble adhesive applications combined with wet-strength paper labels (general);
- non-compatible layers (general);
- non-separable silicon components (general);
- foamed non-thermoplastic elastomer components (general);
- PET sleeves with density < 1 g/cm³ (for PE/PP recycling);
- foreign or multi-layer plastics in density range 1.00-1.08 g/cm³ (for PS recycling);
- polyethylene terephthalate glycol (PETG) components; polyvinyl chloride (PVC) components; ethylene vinyl alcohol (EVOH) layers; polyamide (PA) layers; PVC, polystyrene (PS), PETG/S labels/sleeves; other blended barriers; PA additives (amorphous polyethylene terephthalate (APET) copolymers); non-soluble adhesive applications (in water or alkali at 80 °C); non-ferromagnetic metals;
  elastomer components with density > 1 g/cm³; and direct printing except expiration date and batch number (for PET bottle transparent recycling).

A good grasp of the terms defined in Chapter 3 provides an informed basis for understanding the guidelines and recommendations discussed in the following sections.

[9] For more details, see https://www.cyclos-htp.de/publications/r-a-catalogue/

4 Guiding recyclability: overview of existing standards and design guidelines and common principles

Standards and guidelines have been developed to guide decisions on eco-design. These will be reviewed in this chapter. As the aim is to contribute to a reduction in plastic litter in the marine and terrestrial environment through eco-design by increasing recycling, these standards focus on design for recycling and recyclability.

4.1 Assesement of existing standards

Worldwide, there are over 100 sets of guidelines on eco-design, most of them with a specific focus on design for recycling and recyclability. They have been developed by different organisations, companies and experts with different areas of focus, level of detail, product categories and scopes and for different audiences. One of the most extensive reviews is the EC's Joint Research Centre (JRC) report Support to the Circular Plastics Alliance in establishing a work plan to develop guidelines and standards on design-for-recycling of plastic products (JCR, 2020). In light of the wider EU Plastics Strategy, the JRC was commissioned to conduct a study reviewing existing design for recycling standards and – based on the findings – develop guidelines and standards on design for recycling for plastic items (JRC, 2020). Drawing on this review, a second study by GIZ (GIZ, 2021) assessed how these EU-focused insights could be transferred to the Southeast Asian context and, in particular, to Thailand, Indonesia and Malaysia. **The results of the JRC study will be used as the basis for this assessment, with complementary insights from the GIZ report.**

The JRC report first emphasised that existing standards vary significantly, making it difficult to assess and compare the effectiveness of design for recycling guidelines measured in terms of recycling rates or market uptake.[10] Moreover, despite the large number of standards, **as yet no mandatory standard on design for recycling has been implemented for any type of product anywhere in the world** (JRC, 2020).

Most of the guidelines have a specific focus in terms of product and/or polymer type. The analysis of existing standards revealed that '68% apply to specific product types (e.g. bottles, trays, etc.) and 36% apply to product groups (e.g. all packaging, flexible packaging, etc.). Looking at this in more depth, 20% of the guidelines apply to bottles, 16% to trays, 28% to films and 28% to containers. Of the product groups (or packaging types), 28% apply to all packaging types, whilst 12% apply specifically to flexible packaging and 4% to rigid packaging. Most of the shortlisted guidelines are specific to either one or several polymers. Only in one case, no polymer type is specified. 64% of the shortlisted guidelines cover PP, 56% cover PET, whilst 68% apply to HDPE, LDPE or PE in general, to name only the most frequently covered polymers.' (JRC, 2020, p. 22).

This variety in standards and the differences in what exactly is assessed also lead to several challenges, such as (JRC, 2020, p. 36):

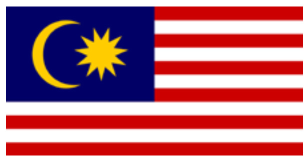
- A **lack of transparency, precision and consistency in the criteria applied** in assessments of recyclability, notably in the context of fee modulation in extended producer responsibility schemes.
- **If guidelines focus on a specific country, their implementation beyond that country will be limited and they will be subject to national constraints** (e.g. certain polymer streams are recycled in some countries but not yet in others). Some stakeholders see a country focus as a key barrier because an EU-wide harmonised approach provides transparency and economies of scale (product design for the whole EU market). However, collection, sorting and recycling are not harmonised across Member States or globally, which could at least in the short term be a barrier to harmonised guidelines. Circular Plastics Alliance (CPA) design coordinators also acknowledged that country specificities need to be respected, but an EU-harmonised approach was still seen as key by most consultees.

[10] Please refer to the JRC study for further details. It shortlists 25 standards for further in-depth analysis. See Annex 1 for an overview of these shortlisted standards and Table 6 in Annex 2 for a high-level overview of five standards.

- It was highlighted multiple times that, in some cases, it is a **challenge to combine (full) recyclability with (full) product functionality,** for example, different requirements relating to filling goods for product protection or brand manufacturers' marketing requirements.
- **There is a lack of guidelines for the use of recycled polymers in certain applications** (e.g. cosmetics and detergents). This point was highlighted by two CPA design coordinators who identified new products in the construction sector and the automotive sector as examples.

As acknowledged in both reports, the majority of existing standards are for the EU context. However, these standards can also be used as guidelines for non-EU countries when careful consideration is given to the context of the country in question, as in the GIZ initiative to develop guidelines for the Malaysian context (GIZ, 2021).

4.2 Country example – Malaysia



In its recent 12th five-year plan 2021-2025, Malaysia recognised the introduction of CE principles in production and trade along the waste hierarchy as an essential solution, although prevention strategies have only recently become a policy focus. Approaches for accelerating the CE transition focus on various components, such as the gradual introduction of EPR, bans on certain SUP products, recycling market development (e.g. reducing barriers and stimulating post-consumer recycled content in products) and supporting eco-design (World Bank, 2022). The steps and measures required to accelerate this transition for plastics have been further specified in the Malaysia Plastics Sustainability Roadmap 2021-2030 (KASA, 2021).

Eco-design in the Malaysia Plastics Sustainability Roadmap 2021-2030

Malaysia's Plastics Sustainability Roadmap for the period from 2021 to 2030 was developed to sustainably address plastic pollution in Malaysia, promoting economic development, environmental protection and societal wellbeing. It provides guidance and promotes sustainable business practices to achieve plastics circularity and sustainability through the CE approach and seeks to harmonise actions along the plastics value chain with the adoption of the life cycle approach (see Figure 7) (KASA, 2021).

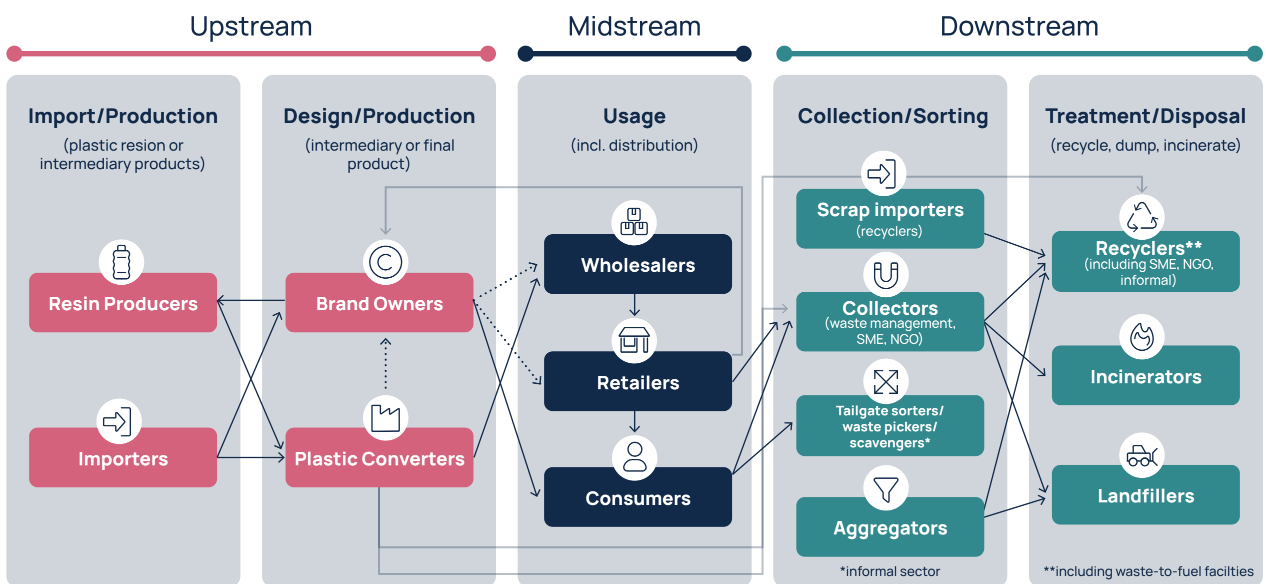


Figure 7: Main players in the value chain, including sustainable production and eco-design (graphic modified after KASA, 2021)

Malaysia's Roadmap covers five types of resin: PP, PET, high-density polyethylene (HDPE), low-density polyethylene (LDPE) and linear low-density polyethylene (LLDPE). These resins are the most produced and disposed of in Malaysia and are commonly used for single-use packaging with short application lifetimes. In the case of Malaysia, the main sectors identified as plastic end users are the packaging, electrical and electronics, construction and automotive sectors. The Roadmap identifies the main strategies for packaging, which are to be implemented from 2024 onwards:

The first is **mandating sustainable design.** Packaging accounts for 48% of the revenue of all plastics consumed in Malaysia. Without fundamental redesign and innovation, about 30% of plastic packaging will never be reused or recycled (EMF, 2017). The expected outcome of this strategy is for 50% of plastic packaging to be recycled. The Roadmap suggests that government responsibilities need to be shared between the Malaysian Ministry of International Trade and Industry, which will lead the process to prepare the standards that support the sustainable design initiative, and the Malaysian Ministry of Environment and Water (KASA), which will provide technical advice for their development. The private sector is working towards the adoption of a sustainable design standard and its implementation based on the guidance available (industry). Furthermore, non-governmental organisations (NGOs) can assist through advocacy, awareness raising, capacity building and outreach efforts (KASA, 2021).

The second is **increasing the demand for recycled materials during the period from 2024 to 2030.** The expected outcome is a rise in domestic demand for local recycled materials. Various actors, including government institutions, particularly those concerned with revising standards and the Malaysian Ministry of International Trade and Industry, need to be involved to provide and promote incentive schemes for halal products so as to encourage industry uptake. The private sector could contribute by complying with applicable standards and starting to incorporate recycled materials into production (KASA, 2021).

In addition, **the Roadmap suggests setting minimum thresholds for recycled content in packaging from 2025 onwards.** The main aim is to ensure 15% recycled content in packaging by 2025. To achieve this, KASA could lead and provide technical input for the incorporation of recycled content as feedstock during manufacturing processes. The industry would set targets collectively for recycled content in packaging (KASA, 2021).

Finally, the Roadmap highlights the importance of ensuring sustainable funding for research, development and innovation in order to increase local innovation and adopt CE solutions. The idea is to improve access to funding for plastics circularity projects and solutions through government institutions, such as the Ministry of Science, Technology and Innovation, the Ministry of Higher Education and Malaysian Technology Development Cooperation, so that private companies invest more in research, development and innovation for plastic circularity solutions and start-ups and small and medium-sized enterprises (SMEs) become involved in the process by applying for funds. This can support the design and development of better products, innovation with new technologies to improve recycling, the adoption of alternatives with a view to phasing out problematic plastic products and packaging redesign to make it sustainable (KASA, 2021).

In addition to all these strategies aiming to promote eco-design, Malaysia intends to develop a mandatory packaging EPR system and implement it from 2026. This instrument will serve as a legal umbrella for the improvement of product design and the whole product value chain (KASA, 2021).

While the country is clearly moving towards more sustainable management of plastics in general and eco-design in particular, there are still challenges and gaps that must be addressed.

Challenges of packaging eco-design in Malaysia

Several challenges related to eco-design and upstream innovation of plastic packaging products were identified in the Malaysia Plastics Sustainability Roadmap, such as the lack of clarity around using recycled content in food-grade applications, the lack of domestic research and development on sustainable design and material innovation for end products (extrusion technology, eco-resins, etc.), gaps in the legal framework (e.g. EPR) and the lack of circularity integration in the steps of product design, procurement and production due to concerns over cost, quality and performance (KASA, 2021).

The World Bank report on the plastic market in Malaysia (2021) identified a number of problems facing recyclers in Malaysia. Recyclers interviewed for the study reported a contamination rate of up to 30% of the feedstock they receive from within Malaysia. This includes contaminants due to poor segregation practices and also to poor packaging design.

Issues include but are not limited to the following:

- coloured plastic cannot be reverted back to its natural colour, and when plastics are coloured, it affects the value of recycled products;
- fillers/additives lead to contamination issues, for example, calcium carbonate ($CaCO_3$) added to HDPE increases the contamination of post-consumer HDPE bottles as they change the density of the HDPE flakes;
- composite and multi-layer materials are not easily disassembled (electronic waste, multi-layer flexibles, etc.) and cannot be recycled.

Taking into account the challenges identified and the specific country context, the following recommendations, as set out in the GIZ report (GIZ, 2021), can guide eco-design in Malaysia.

Recommendations to guide eco-design in Malaysia

The overall insights provided in the JRC report (JRC, 2020) were adapted to the specific Malaysian context to formulate the following recommendations (GIZ, 2021, p. 21):

- Knowledge gaps relating to the transparency of recycling processes could be addressed by starting with guidelines that are effective for certain products and then adapting them to address whole product families. Different guidelines for the same product or packaging type (e.g. PET bottles and polymers) should be avoided.
- Guidelines should be regularly updated by incorporating developments in plastic product design and disruptive recycling technology and taking into account consumption trends.
- It was indicated that increased recyclability may lead to decreased functionality. Guidelines will only be accepted by the market if a level playing field is ensured by involving all stakeholders and if precise standards are formulated, for example, by recognised standardisation bodies. Consistency with other initiatives and regulatory requirements is also important.
- Testing processes are needed for all sectors and products to assess recyclability and to demonstrate compliance with guidelines through protocols. Measures must also be introduced to reduce the financial burden imposed by lab testing and auditing.
- The guidelines must be promoted along the value chain, for example, through awareness raising campaigns, the involvement of industrial stakeholders in the development of the guidelines and creation of a label.

4.3 Identifying commonalities and general principles

Considering these key aspects for eco-design guidelines in Malaysia, the general insights on existing standards (see previous sections) and the findings of other studies in the field (e.g. Sharma, 2019), a number of general principles can be identified for design for recycling (see Table 1). A few observations need to be made about these principles: firstly, existing standards have different areas of focus and are not always fully consistent in scope and detail, which is why there is only a small number of generally applicable principles; secondly, it must be acknowledged that, as principles intended to be generally applicable worldwide, they are the low hanging fruit; and thirdly, as chemical recycling is not an option available at scale for packaging and SUPs, the common principles all refer to mechanical recycling.

Table 1: Common principles/measures to optimise design for recycling

Principle/measure	Comment
Avoid full sleeves	Full sleeves or sleeves that cover more than 60% of a container can lead to errors in identifying the material used for the container itself and can also cause quality issues (full sleeves hinder detection in automated sorting processes; avoidance reduces the material used in the first place).
Avoid opaque PET	Opaque PET leads to colour contamination of the recycling stream. In addition, it is often not compatible with high-value recycling processes.
Barriers, additives, fillers	The use of barriers, additives and fillers that are detrimental to the quality of the recycled plastic (because the plastic materials have different melting points, for example) should be avoided. How different barriers, additives and fillers impair different types of plastic is shown in Annex 3 (Table 7). For instance, calcium carbonate should not be used as an additive in HDPE.
Mono-materials preferred over multi-layer materials	High-quality recycling is polymer-specific (with the exception of PE/PP). Other non-targeted polymers hinder or even deteriorate the recycling process and therefore the final recyclate generated.
Optimised labels	Labels should be kept as small as possible and made of a different material which can be easily separated from the packaging. PVC labels should be avoided.
Phase-out of PVC packaging and labels	The chlorine in PVC leads to acid formation during oxidation processes, which is harmful to plant components (primarily in thermal processes).
Removable caps and lids	Plastic bottle caps and container lids should be easily and completely removable to fully separate the material streams. Closure systems have been identified as one of the main challenges for the recyclability of HDPE and PP containers and for polyolefin (PO) pots, tubs, blisters and trays. However, with a view to combating marine litter, some guidelines make it mandatory to use tethered caps for PET single-use bottles instead of removable ones (trade-off between marine litter prevention and recyclability).
Separability of components in the recycling process	To feed individual components made of different materials into their respective recycling streams, they must be easily separable (preferably mechanically as it is not feasible to separate everything manually).
Simple packaging design	The increasing complexity of packaging and decoration (e.g. heavily printed films) creates a number of challenges for recycling.
Transparent or lightly coloured packaging	Pigmented polymers, coloured printing and opacifiers may hinder automated sorting and may not be recyclable to the same degree and quality as transparent polymers.
Water-soluble inks/ adhesives	Water-soluble inks/adhesives Inks and adhesives should be water-soluble to ensure that paper-based labels and other materials can be easily removed from the plastic in the washing process and do not enter the recycling process as impurities. Inks used in the EU must comply with the requirements established by the European Printing Ink Association (EuPIA, 2020).

These common principles to improve packaging design for recycling should be further triangulated with context-specific information to increase their impact, as explained in the next chapter.

5 Choosing the most appropriate design

Deciding on and choosing the most appropriate packaging design is a complex process which involves combining and assessing various aspects. The application of the common principles for design set out above must be based on a careful analysis of these aspects, which can be categorised into three pillars (see Figure 8):

- Pillar 1: Product protection and other general functions of packaging of secondary importance and how to meet these requirements, which vary between countries depending on conditions such as temperature and humidity.
- Pillar 2: Alignment with the waste hierarchy and the various ranked options.
- Pillar 3: Alignment with the national waste management infrastructure in place, which varies between countries.

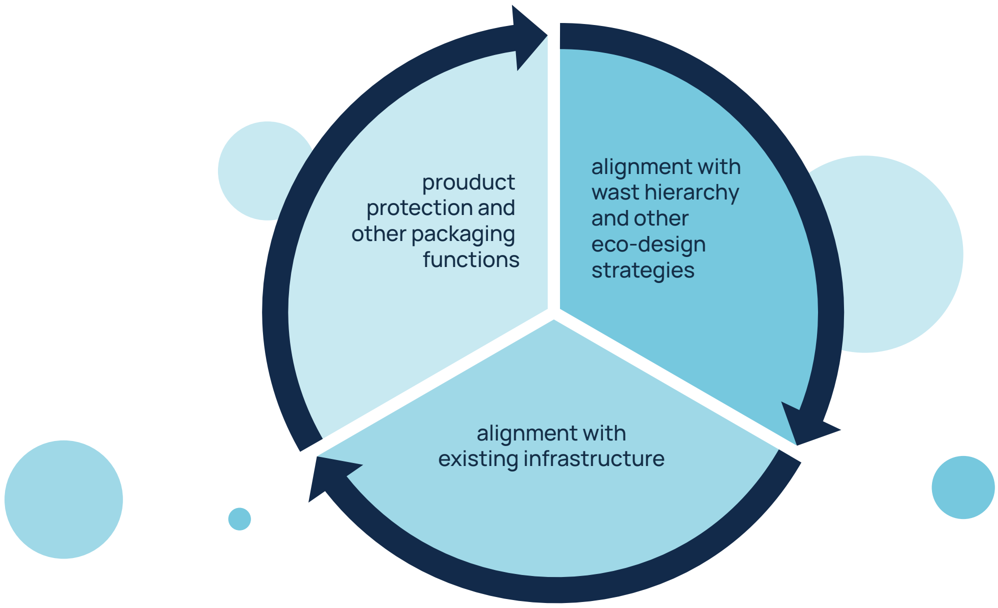


Figure 8: Three pillars guiding decision-making on packaging design

It is important to note that the pillars affect each other and have implications for packaging design, as explained below. All three pillars are equally important and must all be fully considered in order to achieve the most appropriate packaging design in a given context. Each pillar and its implications for packaging design are presented in the next three sections (Sections 5.1, 5.2 and 5.3). Drawing on these analyses and insights from Chapter 4 on generally applicable elements for eco-design, Section 5.4 provides a matrix detailing how packaging, categorised according to its filling, can be improved. Lastly, Section 5.5 gives an outlook on how the wider framework can accelerate the implementation of improved packaging design.

5.1 Product protection and other packaging functions

Packaging can serve several functions, including protection of the goods/filling packaged, apportionment and advertising. **They are not, however, equally important in terms of the CE and resource protection. Product protection is an obligatory criterion which must always be met, as is containment in the case of fillings that could not otherwise be distributed** (i.e. anything not solid). This means that, regardless of how packaging design is changed, product protection must always be ensured. These aspects are therefore included in the matrix in Section 5.4.

The other packaging functions are, in comparison, of secondary importance and are not included in the matrix. An overview of all packaging functions and their different aspects is provided in Table 2

Table 2: Overview of packaging functions

Importance	Packaging function	Aspects
Crucial, must be met	Protection against ambient conditions	• Light • Humidity • Oxidation • (Heat) • (Odour)
	Containment	• Enabling distribution of filling
	Protection **against shock/ mechanical stress** to prevent damage to the filling	• Shock
	Protection against **biological factors** which could degrade the filling	• Parasites • Mould • Bacteria
Secondary	Apportionment	• Needs-based sizes • Individual choices • Single-portion units (often used by low-income population in LMICs)
	Information[11] and advertising	• Content description • Branding • Labels (e.g. sorting instructions, certificates)
	Practicability in handling	• Portability (other than containment) • Stability • Light weight • Easily removable

5.2 Aligning packaging design with the waste hierarchy and other eco-design strategies

Redesigning packaging for the CE and eco-design approach based on sustainability. As described in Section 3.3, the waste hierarchy is a key guiding tool for prioritising options for product and waste management. This is complemented by alignment with other eco-design strategies, specifically substitution and the use of recyclates. Following the levels of the waste hierarchy, packaging should be redesigned according to the steps shown below.

[11] Some information is mandatory on packaging, such as ingredients and potential allergens, as specified in the applicable legal framework. What specific information is mandatory varies between countries.

Table 3: Alignment with the waste hierarchy and other eco-design strategies

Waste hierarchy		Other eco-design stategies
Waste preventon	**Step 1: Can the packaging be avoided altogether?** Ideally, no packaging at all would be used, avoiding the generation of packaging waste altogether. However, for a wide range of products and/or regions, this would be impossible or very difficult to achieve and could result in the product itself becoming waste (e.g. increased food waste).	None
	Step 2: Can the packaging be partially avoided? A packaged item sold to consumers sometimes has several separate layers of packaging (e.g. wrapped candy inside sealed plastic bags). In some cases, it is possible to use less packaging units for a single sales unit and in this way contribute to waste prevention. Another option for partially preventing packaging waste is to use less packaging material. However, it is important to note that using thinner material might lead to trade-offs in the recyclability and reusability of packaging.	Is it possible to partially avoid the adverse impact of packaging through substitution with a different material (without causing a negative rebound effect)? Is it possible to use recyclates in the packaging so that less virgin material is needed?
	Step 3: Can reusable packaging be used? Reuse requires a reverse infrastructure, which is the main challenge for reusable packaging rather than the design of the packaging per se. If the required reverse infrastructure is not in place, it would have to be set up. Reusability and infrastructure are discussed in more detail in Chapter 3.	Is it possible to make reuse an option through substitution with a different material? Is it possible to use recyclates in the packaging so that less virgin material is needed?
Preparation for reuse	**Step 4: Is preparation for reuse an option for the packaging?** In contrast to Step 3, action is taken in Step 4 when the packaging has become waste and needs to be treated before it can be reused. As discussed in detail in Section Fehler! Verweisquelle konnte nicht gefunden werden., preparation for reuse is not usually applicable to packaging; it is more common for more complex products. NB: not usually applicable to packaging	Is it possible to make preparation for reuse an option through substitution with a different material? Is it possible to use recyclates in the packaging so that less virgin material is needed? NB: not usually applicable to packaging
Recycling	**Step 5: Can the packaging be recycled?** Whether or not packaging can be recycled depends on its design features, as some elements significantly reduce recyclability or prevent recycling altogether (see Section 4.3). Recyclability also depends on whether the infrastructure required to channel waste into the appropriate recycling streams is in place. However, a 'theoretically' recyclable packaging design can incentivise the setting up of waste management streams for recycling.	Is it possible to increase recyclability through substitution with a different material? Is it possible to use recyclates in the packaging so that use less virgin material is needed?

Whether Steps 1 to 4 can be implemented largely depends on the specific characteristics of the packaging and its filling, the regions where it will be put on the market and infrastructure requirements. **As the aim of this report is to provide generally applicable design options, the focus is on recommendations for design for recycling (Step 5).** As emphasised in the objective of this pillar, if Steps 1 to 4 are feasible, they should be preferred over Step 5. If none of the steps can be applied, the packaging will be incinerated or disposed of at a landfill as a last-resort waste management option. However, since these options are not CE enablers, they are not covered in this report.

5.3 Infrastructure requirements

While design choices certainly have an impact on treatment once the packaging has become waste, it is the waste management infrastructure in place that determines how the waste will be treated. If appropriate facilities for collection and/or take-back, transport, sorting and recycling do not exist, the packaging will not be reused or recycled however well it was originally designed (see also Section 3.1). **It is therefore crucial to distinguish between actual recyclability (recyclable design and corresponding infrastructure in place) and design for recycling. The same distinction also applies to actual reusability and design for reuse.**

Product and packaging design must therefore always take into account what infrastructure is in place, which differs considerably from one country to another. This is why recyclability also varies between countries. The most crucial factor that determines whether packaging or products are recycled at a high-quality level is the existence of waste segregation and separate collection facilities. While recyclables can be diverted from the mixed waste stream (e.g. from landfills), the potential for high-quality recycling is reduced as organic material and contaminants are detrimental to the plastic materials. In addition, **thorough waste segregation, collection and further treatment reduce plastic waste leakage into the environment and therefore also reduce marine litter** (GIZ, 2022).

Lastly, while design for recycling does not guarantee that plastic packaging and products will actually be recycled, as observed above, it can create incentives for the establishment of infrastructure – as recyclable plastic waste will be generally available – and eventually boost the waste management sector. This is, however, a lengthy process.

5.4 Eco-design guide (matrix)

The matrix provided below (Table 4) has been developed by combining the general principles for recyclable packaging design (see Section 4.3) with requirements for the product protection function and other key aspects mentioned above. The eco-design guide is structured according to filling, as it is this that largely determines the choice of packaging and specific protection requirements.

The matrix includes circular design measures (i.e. substitution with a material other than plastic, use of recyclate content and recyclability) and lists other 'established options' involving action at the higher levels of the waste hierarchy. All the options shown are real-world measures implemented at scale so as to provide practical guidance for implementing solutions based on proven experience. However, this does not mean that it is not important to investigate and pilot new options to accelerate circular design.

Lastly, it was not possible to include 'protection against biological factors' in the matrix, even though it is a crucial packaging requirement. Requirements for protecting the filling against biological factors vary significantly from one part of the world to another (owing to climate conditions where the product is sold, etc.) and are also strongly influenced by the product's value chain (for instance, apples locally grown and sold vs imported apples from other parts of the world). As the matrix is intended to provide generally applicable guidance, these differences could not be adequately incorporated and must be assessed on a case-by-case basis for the specific context.

Table 4: Eco-design matrix

Packaging	Main requirements	Plastic packaging solution	Substitution	Recycle content	Recyclability	Established options to consider	Comments
Food and beverage sales packaging							
water	✗ ambient conditions ✗ containment shock/ mechanical stress	PET bottle	• glass bottle[2,3] • liquid packaging board[1] • metal can[4]	possible	• bottle body APET • wtransparent, colourless • small compatible labels or sleeves (avoid PVC) • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • no additives or barriers • caps and/or closures PP/HDPE	• tap water[7]/ refillable water containers [prev.] • deposit (multiple use) [prev.]; [coll.] • deposit (single use) [coll.]; [recy.]	[1] check for existing collection and recycling [2] check for existing recycling infrastructure [3] glass deposit systems (multiple use) are well-known [4] check CO_2 footprint [5] check for food-grade recyclates [6] no established food-grade recyclate [7] only where tap water is potable
		PE/PP-based pouch or film (sachet)[1]		not possible	• mono-material PE/PP • minimised colours • small compatible labels or sleeves (avoid PVC) • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • no additives or barriers • if needed, compatible closures PP/ HDPE	• tap water[7]/ refillable water containers [prev.]	

Packaging	Main requirements	Plastic packaging solution	Substitution	Recyclate content	Recyclability	Established options to consider	Comments
soft drinks, alcoholic beverages, other carbonated beverages	X ambient conditions X containment shock/ mechanical stress	PET bottle	• glass bottle[2,3] • liquid packaging board[1] • metal can[4]	possible	• bottle body APET • transparent, colourless • small compatible labels or sleeves (avoid PVC) • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • no or compatible additives or barriers • caps and/or closures PP/HDPE	• deposit (multiple use) [prev.]; [coll.] • deposit (single use) [coll.]; [recy.]	[1] check for existing recycling infrastructure [2] glass deposit systems (multiple use) are well-known [3] check CO^2 footprint [4] check for food-grade recyclates
Juices	X ambient X containment shock/ mechanical stress	PET bottle	• glass bottle[1,2] • liquid packaging board[1]	possible	• bottle body APET • transparent, colourless • small compatible labels or sleeves (avoid PVC) • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • compatible additives and barriers • caps and/or closures PP/HDPE	• deposit (multiple use) [prev.]; [coll.] • deposit (single use) [coll.]; [recy.]	[1] check for existing recycling infrastructure [2] glass deposit systems (multiple use) are well-known [3] check for food-grade recyclates [4] needs food-grade PE recyclate

Packaging	Main requirements	Plastic packaging solution	Substitution	Recyclate content	Recyclability	Established options to consider	Comments
		HDPE bottle		not possible	• body PE • minimised colours • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • compatible additives and barriers	• PE recycling well-established	
milk	X ambient conditions X containment shock/ mechanical stress	PET bottle	• glass bottle[1,2] • liquid packaging board[1]	possible	• bottle body APET • transparent, colourless • small compatible labels or sleeves (avoid PVC) • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • compatible additives and barriers • caps and/or closures PP/HDPE	• deposit (multiple use) [prev.]; [coll.] • deposit (single use) [coll.]; [recy.]	[1] check for existing recycling infrastructure [2] glass deposit systems (multiple use) are well-known [3] check for food-grade recyclates [4] check CO² footprint [5] needs food-grade PE recyclate
		PP/(PE) bottle		under inves-tigation[4]	• body PE/PP • minimised colours • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • compatible additives and barriers • caps and/or closures PP/HDPE	• deposit (multiple use) [prev.]; [coll.] • deposit (single use) [coll.]; [recy.]	

Packaging	Main requirements	Plastic packaging solution	Substitution	Recyclate content	Recyclability	Established options to consider	Comments
		PE-based pouch or film (sachet)		not possible[5]	• body PE • minimised colours • small compatible labels (avoid PVC) • wash-off adhesives • no direct printing; inks on labels acc. to EuPIA • no additives or barriers • if needed, compatible closures PP/HDPE		
condiments, sauces	✗ ambient conditions ✗ containment shock / mechanical stress	PET bottle	• glass bottle[1] • liquid packaging board[1]	possible	• bottle body APET • transparent, colourless • small compatible labels or sleeves (avoid PVC) • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • compatible additives and barriers • caps and/or closures PP/HDPE		[1] check for existing recycling infrastructure [2] check CO_2 footprint [3] check for food-grade recyclates [4] needs food-grade PE recyclate

Packaging	Main requirements	Plastic packaging solution	Substitution	Recyclate content	Recyclability	Established options to consider	Comments
		HDPE bottle	• glass bottle[1] • liquid packaging board[1]	not possible[4]	• body PE • minimised colours • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • compatible additives and barriers • if needed, compatible closures PP/HDPE		[1] check for existing recycling infrastructure [2] check CO_2 footprint [3] check for food-grade recyclates [4] needs food-grade PE recyclate
		HDPE tube	• metal tube[2]	not possible[4]	• body PE • minimised colours • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • compatible additives and barriers • if needed, compatible closures PP/HDPE		
fruits, vegetables	ambient conditions containment[1] shock / mechanical stress[2]	PET tray[3]	• paper[5]	limited[6]	• body APET • transparent, colourless • small compatible labels or sleeves (avoid PVC) • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • no or compatible barriers • if needed, closures LDPE or PET film	• packaging avoidance as far as possible (loose) • substitution with PP tray as comparably better recyclable solution	[1] depending on size and quantity [2] depending on how quickly rotting process starts [3] in most countries currently no recycling infrastructure [4] check for existing collection and recycling

Packaging	Main requirements	Plastic packaging solution	Substitution	Recyclate content	Recyclability	Established options to consider	Comments
		PP tray or cup	• paper[5]	not possible	• body PP • transparent, colourless • small compatible labels or sleeves (avoid PVC) • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • no or compatible barriers • if needed, closures LDPE film	• packaging avoidance as far as possible (loose)	[5] check for existing recycling infrastructure, avoid composites and multi-material composition [6] from PET bottle recycling (food-grade) [7] needs food-grade PE/PP recyclate
		PE/PP-based pouch or film[4]		not possible	• body PP • transparent, colourless • small compatible labels or sleeves (avoid PVC) • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • no or compatible barriers • if needed, closures LDPE film	• packaging avoidance as far as possible (loose)	
meat, fish, cheese	✕ ambient conditions ✕ containment[1] shock/ mechanical stress	PET tray[2]	• paper[4]	limited[5]	• body APET • transparent, colourless • small compatible labels or sleeves (avoid PVC) • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • no or compatible barriers • if needed, closures LDPE or PET film	• refillable containers [prev.] • substitution with PP tray as comparably better recyclable solution	[1] depending on size and quantity [2] in most countries currently no recycling infrastructure [3] check for existing collection and recycling [4] check for existing recycling infrastructure, avoid composites and multi-material composition

Packaging	Main requirements	Plastic packaging solution	Substitution	Recyclate content	Recyclability	Established options to consider	Comments
		PP tray	• paper[4]	not possible[6]	• body PP • transparent, colourless • small compatible labels or sleeves (avoid PVC) • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • no or compatible barriers • if needed, closures LDPE film	• refillable containers [prev.]	[5] from PET bottle recycling (food-grade) [6] needs food-grade PE/PP recyclate
		PE/PP-based pouch or film[3]			• body PE/PP • minimised colours • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • compatible additives and barriers • if needed, compatible closures PP/HDPE	• refillable containers [prev.]	
yoghurt, cream, other dairy products	✕ ambient conditions ✕ containment shock/mechanical stress	PET tray[1]	• glass bottle[3,4] • iquid packaging board[3]	limited[5]	• body APET • transparent, colourless • small compatible labels or sleeves (avoid PVC) • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • no or compatible barriers • if needed, closures LDPE or PET film	• substitution with PP tray or cup as comparably better recyclable solution	

Packaging	Main requirements	Plastic packaging solution	Substitution	Recycle content	Recyclability	Established options to consider	Comments
		PP cup	• glass bottle[3,4] • liquid packaging board[3]	not possible[6]	• body PP • transparent, colourless • small compatible labels or sleeves (avoid PVC) • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • no or compatible barriers • if needed, closures LDPE film		[1] in most countries currently no recycling infrastructure [2] relatively small share in plastic packaging composition and therefore limited recycling infrastructure [3] check for existing recycling infrastructure [4] glass deposit systems (multiple use) are well-known [5] from PET bottle recycling (food-grade) [6] needs food-grade PP/PS recyclate
		PS cup[2]			• body PS • transparent, colourless • small compatible labels or sleeves (avoid PVC) • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • compatible additives and no barriers • lid or lidding film same material	• substitution with PP tray or cup as comparably better recyclable solution	
frozen food	✗ ambient conditions ✗ containment shock/ mechanical stress	PE/PP-based pouch or film[1]	• no possible substitution	not possible[3]	• body PE/PP • minimised colours • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • compatible additives and barriers • if needed, compatible closures PP/HDPE		[1]check for existing collection and recycling [2] applies mainly to ice [3] needs food-grade PE/PP recyclate

Packaging	Main requirements	Plastic packaging solution	Substitution	Recyclate content	Recyclability	Established options to consider	Comments
		PP tray or cup[2]	• no possible substitution	not possible[3]	• body PP • transparent, colourless • small compatible labels or sleeves (avoid PVC) • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • no or compatible barriers • if needed, closures LDPE film		[1] check for existing collection and recycling [2] applies mainly to ice [3] needs food-grade PE/PP recyclate
dry cereals, pasta, noodles, rice; sweets, snacks	✗ ambient conditions ✗ containment shock/ mechanical stress	PE/PP-based pouch or film[1]	• paper[2]	not possible[3]	• - body PE/PP • - minimised colours • - wash-off adhesives • - no direct printing; inks on sleeves and labels acc. to EuPIA • - compatible additives and barriers • - if needed, compatible closures PP/HDPE	• refillable containers [prev.] • avoid additional paper wrapping	[1] check for existing collection and recycling [2] check for existing recycling infrastructure, avoid composites and multi-material composition [3] needs food-grade PE/PP recyclate
		PP tray or cup			• body PP • transparent, colourless • small compatible labels or sleeves (avoid PVC) • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • no or compatible barriers • if needed, closures LDPE film	• refillable containers [prev.]	

Packaging	Main requirements	Plastic packaging solution	Substitution	Recyclate content	Recyclability	Established options to consider	Comments
Bread, other baked goods	✕ ambient conditions containment shock/ mechanical stress	PE/PP-based film[1]	• paper[2]	not possible[3]	• body PE/PP • transparent, colourless • small compatible labels or sleeves (avoid PVC) • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • no or compatible barriers	• packaging avoidance as far as possible (loose)	[1] check for existing collection and recycling [2] check for existing recycling infrastructure, avoid composites and multi-material composition [3] needs food-grade PE/PP recyclate
ready-made meals, convenience foods	✕ ambient conditions ✕ containment shock/ mechanical stress	PET tray[1]	• laminated paper[3]	limited[4]	• body APET • transparent, colourless • small compatible labels or sleeves (avoid PVC) • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • no or compatible barriers • if needed, closures LDPE or PET film	• packaging avoidance as far as possible (loose) • ´product redesign	[1]in most countries currently no recycling infrastructure [2] check for existing collection and recycling [3] not usually recyclable [4] from PET bottle recycling (food-grade) [5] needs food-grade PE/PP recyclate
		PP tray		not possible[5]	• body PP • transparent, colourless • small compatible labels or sleeves (avoid PVC) • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • no or compatible barriers • if needed, closures LDPE	• packaging avoidance as far as possible (loose) • product redesign	

Packaging	Main requirements	Plastic packaging solution	Substitution	Recyclate content	Recyclability	Established options to consider	Comments
		PE/PP-based film[2]	• laminated paper[3]	not possible[5]	• body PE/PP • transparent, colourless • small compatible labels or sleeves (avoid PVC) • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • no or compatible barriers	• packaging avoidance as far as possible (loose) • product redesign	[1] in most countries currently no recycling infrastructure [2] check for existing collection and recycling [3] not usually recyclable [4] from PET bottle recycling (food-grade) [5] needs food-grade PE/PP recyclate
Non-food and beverage sales packaging							
toiletries, cleaning detergents, personal care (liquids)	ambient conditions containment shock/ mechanical stress	PET bottle	• glass bottle/ jar[2] • metal can[3]	possible	• bottle body APET • transparent, colourless • small compatible labels or sleeves (avoid PVC) • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • compatible additives and barriers • caps and/or closures PP/HDPE	• product redesign	[1] check for existing collection and recycling [2] check for existing recycling infrastructure [3] check CO_2 footprint
		PE/PP bottle			• body PE/PP • minimised colours • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • compatible additives and barriers • caps and/or closures PP/HDPE	• product redesign	

Packaging	Main requirements	Plastic packaging solution	Substitution	Recyclate content	Recyclability	Established options to consider	Comments
		PE/PP-based pouch[1]	• glass bottle/ jar[2] • metal can[3]	possible	• body PE/PP • minimised colours • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • compatible additives and barriers • if needed, compatible closures PP/ HDPE	• product redesign	[1] check for existing collection and recycling [2] check for existing recycling infrastructure [3] check CO_2 footprint
toiletries, cleaning detergents, personal care (pasty)	ambient conditions containment shock/ mechanical stress	PET cup	• glass jar[2]	possible	• body APET • transparent, colourless • small compatible labels or sleeves (avoid PVC) • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • compatible additives and barriers • caps and/or closures PP/HDPE	• product redesign	[1] check for existing collection and recycling [2] check for existing recycling infrastructure
		PE/PP cup or jar		possible	• body PE/PP • minimised colours • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • compatible additives and barriers • caps and/or closures PP/HDPE	• product redesign	

Packaging	Main requirements	Plastic packaging solution	Substitution	Recyclate content	Recyclability	Established options to consider	Comments
		PE tube		possible	• body PE • minimised colours • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • compatible additives and barriers • caps and/or closures PP/HDPE	• product redesign	
		PE/PP-based pouch[1]	• glass jar[2]	possible	• body PE/PP • minimised colours • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • compatible additives and barriers • if needed, compatible closures PP/ HDPE	• product redesign	[1] check for existing collection and recycling [2] check for existing recycling infrastructure
toiletries, cleaning detergents, personal care (dry)	✕ ambient conditions ✕ containment shock/ mechanical stress	PET tray[1]	• paper and carton[3]	possible	• body APET • transparent, colourless • small compatible labels or sleeves (avoid PVC) • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • no or compatible barriers • if needed, closures LDPE or PET film	• refillable containers [prev.]	[1] in most countries currently no recycling infrastructure [2] check for existing recycling infrastructure [3] check for existing recycling infrastructure, avoid composites and multi-material composition

Packaging	Main requirements	Plastic packaging solution	Substitution	Recyclate content	Recyclability	Established options to consider	Comments
		PE/PP cup or jar	• paper and carton[3]	possible	• body PE/PP • minimised colours • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • compatible additives and barriers • caps and/or closures PP/HDPE	• refillable containers [prev.]	[1] in most countries currently no recycling infrastructure [2] check for existing recycling infrastructure [3] check for existing recycling infrastructure, avoid composites and multi-material composition
		PE/PP-based pouch[2]		possible	• body PE • minimised colours • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • compatible additives and barriers • caps and/or closures PP/HDPE		
chemicals, automotive and garden (liquids)	ambient conditions containment shock/ mechanical stress	PET bottle	• glass bottle/ jar[2] (non-hazardous filling) • metal can/ container[3] (hazardous filling)	possible	• bottle body APET • transparent, colourless • small compatible labels or sleeves (avoid PVC) • no direct printing; inks on sleeves and labels acc. to EuPIA • compatible additives and barriers • caps and/or closures PP/HDPE • resistant marking needed for hazardous content	• separate collection for packaging with hazardous filling (no recycling)	[1] check for existing collection and recycling (only non-hazardous filling) [2] check for existing recycling infrastructure [3] check CO_2 footprint

Packaging	Main requirements	Plastic packaging solution	Substitution	Recyclate content	Recyclability	Established options to consider	Comments
		PE/PP bottle	• glass bottle/ jar[2] (non-hazardous filling) • metal can/ container[3] (hazardous filling)	possible	• body PE/PP • minimised colours • no direct printing; inks on sleeves and labels acc. to EuPIA • compatible additives and barriers • caps and/or closures PP/HDPE • resistant marking needed for hazardous content	• separate collection for packaging with hazardous filling (no recycling)	[1] check for existing collection and recycling (only non-hazardous filling) [2] check for existing recycling infrastructure [3] check CO_2 footprint
		PE/PP-based pouch[1]		possible	• body PE • minimised colours • no direct printing; inks on sleeves and labels acc. to EuPIA • compatible additives and barriers • caps and/or closures PP/HDPE • resistant marking needed for hazardous content	• separate collection for packaging with hazardous filling (no recycling)	
chemicals, automotive and garden (dry)	ambient conditions containment shock/ mechanical stress	PET tray[1]	• paper and carton[3] • glass • metal can/ container[4] (hazardous filling)	possible	• body APET • transparent, colourless • small compatible labels or sleeves (avoid PVC) • no direct printing; inks on sleeves and labels acc. to EuPIA • no or compatible barriers • if needed, closures LDPE or PET film • resistant marking needed for hazardous content	• separate collection for packaging with hazardous filling (no recycling)	[1] in most countries currently no recycling infrastructure [2] check for existing collection and recycling (only non-hazardous filling) [3] check for existing recycling infrastructure, avoid composites and multi-material composition [4] check CO_2 footprint

Packaging	Main requirements	Plastic packaging solution	Substitution	Recyclate content	Recyclability	Established options to consider	Comments
		PE/PP cup or jar	• paper and carton[3] • glass • metal can/ container[4] (hazardous filling)	possible	• body PE/PP • minimised colours • no direct printing; inks on sleeves and labels acc. to EuPIA • compatible additives and barriers • caps and/or closures PP/HDPE • resistant marking needed for hazardous content	• separate collection for packaging with hazardous filling (no recycling)	[1] in most countries currently no recycling infrastructure [2] check for existing collection and recycling (only non-hazardous filling) [3] check for existing recycling infrastructure, avoid composites and multi-material composition [4] check CO_2 footprint
		PE/PP-based pouch[2]		possible	• body PE • minimised colours • no direct printing; inks on sleeves and labels acc. to EuPIA • compatible additives and barriers • caps and/or closures PP/HDPE • resistant marking needed for hazardous content	• separate collection for packaging with hazardous filling (no recycling)	
everyday items (e.g. EEE, batteries, toys, books, textiles)	✗ ambient conditions containment ✗ shock/ mechanical stress	PET tray[1]	• paper and carton[4]	possible	• body APET • transparent, colourless • small compatible labels or sleeves (avoid PVC) • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • no or compatible barriers • if needed, closures LDPE or PET film	• packaging avoidance as far as possible (loose) • substitution with PP tray as comparably better recyclable solution	[4] check for existing recycling infrastructure, avoid composites and multi-material composition [5] generally possible; considering [2], not recommended

Packaging	Main requirements	Plastic packaging solution	Substitution	Recyclate content	Recyclability	Established options to consider	Comments
		PP tray		possible	• body PP • transparent, colourless • small compatible labels or sleeves (avoid PVC) • wash-off adhesives • no direct printing; inks on sleeves and labels acc. to EuPIA • no or compatible barriers • if needed, closures LDPE film	• packaging avoidance as far as possible (loose)	
		PVC tray[2]	• paper and carton[4]	not recom-mended[5]	• no need	• packaging avoidance as far as possible (loose) • substitution with PP tray as comparably better recyclable solution	[4] check for existing recycling infrastructure, avoid composites and multi-material composition [5] generally possible; considering [2], not recommended
		PE/PP-based film[3]		possible	• body PE • minimised colours • wash-off adhesives • no direct printing • no additives or barriers	• packaging avoidance as far as possible (loose)	

Packaging	Main requirements	Plastic packaging solution	Substitution	Recyclate content	Recyclability	Established options to consider	Comments
Food and beverage service packaging							
take-away meals	ambient conditions[1] containment shock/ mechanical stress	PET tray[2]	• paper and carton[4] • metal tray/ container[5]	possible	• body APET • transparent, colourless • no labels or sleeves • no printing • no or compatible barriers • if needed, closures LDPE or PET film	• packaging avoidance as far as possible (e.g. for direct consumption) [prev.] • refillable containers [prev.] • deposit (multiple use) [prev.]; [coll.] • substitution with PP tray as comparably better recyclable solution	[1] thermal protection packaging solutions to keep meals hot/cold should be used in returnable, multi-use systems only [2] in most countries currently no recycling infrastructure [3] check for existing collection and recycling [4] check for existing recycling infrastructure, avoid composites and multi-material composition [5] check CO_2 footprint [6] needs food-grade PE/PP recyclate
		PP tray or cup		not possible[6]	• body PP • transparent, colourless • no labels or sleeves • no printing • no or compatible barriers • if needed, closures LDPE film	• packaging avoidance as far as possible (e.g. for direct consumption) [prev.] • refillable containers [prev.] • deposit (multiple use) [prev.]; [coll.]	
		PE/PP-based film[3]		not possible[6]	• body PE • minimised colours • no labels or sleeves • no printing • no additives or barriers	• packaging avoidance as far as possible (e.g. for direct consumption) [prev.]	

Packaging	Main requirements	Plastic packaging solution	Substitution	Recyclate content	Recyclability	Established options to consider	Comments
take-away ice	ambient conditions[1] containment shock/ mechanical stress	PET tray[2]	• paper and carton[3] • metal tray/ container[4]	possible	• body APET • transparent, colourless • no labels or sleeves • no printing • no or compatible barriers	• packaging avoidance as far as possible (e.g. cones) [prev.] • substitution with PP tray as comparably better recyclable solution	[1] thermal protection packaging solutions to keep meals hot/cold should be used in returnable, multi-use systems only [2] in most countries currently no recycling infrastructure [3] check for existing recycling infrastructure, avoid composites and multi-material composition [4] check CO^2 footprint [5] needs food-grade PE/PP recyclate
		PP tray or cup		not possible[5]	• body PP • transparent, colourless • no labels or sleeves • no printing • no or compatible barriers	• packaging avoidance as far as possible (e.g. cones) [prev.]	
		PS cup		not possible[5]	• body PS • transparent, colourless • no labels or sleeves • no printing • compatible additives and no barriers	• packaging avoidance as far as possible (e.g. cones) [prev.]	

Packaging	Main requirements	Plastic packaging solution	Substitution	Recyclate content	Recyclability	Established options to consider	Comments
take-away soup	ambient conditions[1] containment shock/ mechanical stress	PET tray[2]		possible	• body APET • transparent, colourless • no labels or sleeves • no printing • no or compatible barriers • if needed, closures PE film	• packaging avoidance as far as possible (e.g. direct consumption) [prev.] • refillable cup [prev.] • deposit (multiple use) [prev.]; [coll.] • substitution with PP cup as comparably better recyclable solution	[1] thermal protection packaging solutions to keep meals hot/cold should be used in returnable, multi-use systems only [2] in most countries currently no recycling infrastructure [3] relatively small share in plastic packaging composition and therefore limited recycling infrastructure [4] check for existing recycling infrastructure, avoid composites and multi-material composition [5] needs food-grade PP/PS recyclate
		PP tray or cup	• paper and carton[4] • metal tray/ container[5]	not possible[6]	• body PP • transparent, colourless • no labels or sleeves • no printing • no or compatible barriers • if needed, closures LDPE film	• packaging avoidance as far as possible (e.g. for direct consumption) [prev.] • refillable containers [prev.] • deposit (multiple use) [prev.]; [coll.]	
		PE/PP-based film[3]		not possible[6]	• body PE • minimised colours • no labels or sleeves • no printing • no additives or barriers	• packaging avoidance as far as possible (e.g. for direct consumption) [prev.]	

Packaging	Main requirements	Plastic packaging solution	Substitution	Recyclate content	Recyclability	Established options to consider	Comments
take-away beverages	ambient conditions[1] containment shock/ mechanical stress	PET cup[2]		possible	• body APET • transparent, colourless • no labels or sleeves • no printing • no or compatible barriers • if needed, closures PE film	• packaging avoidance as far as possible (e.g. direct consumption) [prev.] • refillable cup [prev.] • deposit (multiple use) [prev.]; [coll.] • substitution with PP cup as comparably better recyclable solution	[1] thermal protection packaging solutions to keep meals hot/cold should be used in returnable, multi-use systems only [2] in most countries currently no recycling infrastructure [3] relatively small share in plastic packaging composition and therefore limited recycling infrastructure [4] check for existing recycling infrastructure, avoid composites and multi-material composition [5] needs food-grade PP/PS recyclate
		PP cup	• paper and carton[4]	not possible[5]	• body PP • transparent, colourless • no labels or sleeves • no printing • no or compatible barriers • if needed, closures PE	• packaging avoidance as far as possible (e.g. for direct consumption) [prev.] • refillable containers [prev.] • deposit (multiple use) [prev.]; [coll.]	
		PS cup[3]		not possible[5]	• body PS • transparent, colourless • no labels or sleeves • no printing • no or compatible barriers	• packaging avoidance as far as possible (e.g. for direct consumption) [prev.] • refillable containers [prev.] • deposit (multiple use) [prev.]; [coll.] • substitution with PP cup as comparably better recyclable solution	

Packaging	Main requirements	Plastic packaging solution	Substitution	Recyclate content	Recyclability	Established options to consider	Comments
bags	ambient conditions ✗ containment shock/ mechanical stress	PE/PP film[1]	• paper[2]	possible	• body PE • minimised colours • no labels or sleeves • minimised printing, inks acc. to EuPIA • no additives or barriers	• packaging avoidance as far as possible (e.g. phasing out bags, bag levy, encouraging consumers to bring own bags) [prev.]	check for existing collection and recycling [2] check for existing recycling infrastructure; avoid composites and multi-material composition

5.5 Instruments to strengthen impact

Action is needed from manufacturers to apply eco-guidelines for more recyclable packaging design. However, as mentioned in Section 4.1, there are, at present, no legally binding design guidelines that companies must adhere to, which means that any action is taken voluntarily. There are voluntary targets, but governments cannot enforce them and not all companies meet them.

Greater impact could be achieved through mandatory instruments. There are four main types of instruments (Table 5): bans and phase-outs, design regulations, taxes and EPR.

Table 5: Common principles/measures to optimise design for recycling

Bans and phase-outs	Certain products and/or materials are prohibited from the market. Well-known examples include the EU's ban on plastic cotton buds, cutlery, plates, straws, drink stirrers and balloon sticks through the EU SUP Directive (EU/2019/904), the EU's ban on oxo-degradable plastics and India's recently introduced phase-out of certain SUP items, including packaging such as plastic wrapping or film around sweet boxes, invitation cards and cigarette packets (DTE, 2022).
Diesign regulations	Design restrictions affecting packaging and product design are mandated, for instance, the mandatory requirement for all PET beverage bottles put on the market in the EU to contain at least 30% recycled plastic from 2030 (EU/2019/904).
Taxes	A range of taxes can be imposed on products at different stages in the value chain. They can be divided into two main categories: first, revenue-raising taxes which create direct income from the industry and/or households through taxation or charges, for instance, a landfill tax; and second, revenue-providing taxes which create indirect income for industry and/or households by reducing charges or subsidies, such as tax rebates and variable VAT rates (KAM, 2019). An example of an eco-design tax is Kenya's Refunded Virgin Payments tax, which is a two-part measure: manufacturers of products consisting solely of virgin materials pay a fee that is refunded to manufacturers whose products contain a specified amount of recyclates. Therefore, manufacturers using more recyclates than their peers become net receivers of the refund, while manufacturers that mainly use virgin materials become net payers in this system. This tax has an upstream steering function on the use of recyclates (KAM, 2019).
Extended producer responsibility	A producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle, that is, when packaging becomes waste in an EPR scheme for packaging. When manufacturers and importers put their packaged products on the market, they are responsible for their packaging waste and its subsequent treatment. Therefore, manufacturers and importers pay a fee upfront when their packaged goods are placed on the market. The fee is used to pay for the collection, recycling and disposal of packaging waste and to cover other costs associated with maintaining the system. This revenue does not contribute to a country's general public budget. The fee paid varies depending on the material and weight of the packaging. In addition, an increasing number of countries are also introducing further eco-modulation of fees to achieve more positive upstream effects. Most often, a lower fee is charged for more recyclable packaging (bonus) and/or prices for non-recyclable packaging are higher (malus). Another form of eco-modulation is rewarding the use of recyclates (PREVENT Waste Alliance, 2020).

It is important to note that these instruments are not exclusive but can be combined to achieve a greater impact. However, each instrument must have a specific scope to avoid overlaps, such as applying both taxes and EPR fees to the same product or implementing an EPR scheme for products that are to be banned. The choice of instruments should be based on a careful assessment of the country context, taking into account the objective in that particular context, as different instruments have an impact at different steps in the life cycle of the product or packaging.

6 Conclusion

Better management of plastics and plastic waste requires smart measures along the whole value chain from design and production to collection, sorting and treatment. As the design phase of a plastic product or packaging determines its ecological impact and suitability for high-quality recycling, circular product design and eco-design approaches have been generally acknowledged as playing a key role in tackling plastic pollution and enabling the transition to a CE.

Worldwide, there are over 100 sets of guidelines on product and packaging design that aim to promote recyclability and circularity. These standards vary significantly as they have different areas of focus, are not always fully consistent in scope and detail and are designed for specific country or regional contexts. Implementation of such guidelines beyond the country for which they were developed will be limited, and they will be subject to national constraints. As yet, no mandatory standard on design for recycling has been implemented for any type of product anywhere in the world.

However, under the future global plastics treaty, standards will have to be harmonised. To this end, from a global perspective, the following common principles and measures for optimising design for recycling can be identified:

- avoiding full sleeves and sleeves covering more than 60% of the container;
- avoiding opaque PET;
- ensuring components are easily separable in the recycling process;
- keeping labels as small as possible;
- not using barriers, additives or fillers that are detrimental to the quality of the recycled plastic because, for example, the plastic materials have different melting points;
- phasing out PVC labels;
- prioritising mono-materials over multi-layer materials;
- prioritising simple packaging design;
- using removable caps and lids;
- using transparent or lightly coloured packaging;
- using water-soluble inks and adhesives.

In order to use these common principles as a starting point to improve plastic packaging, they need to be considered in the light of various other aspects and aligned with them. They include the following:

- **product protection** and other general functions of packaging of secondary importance and how to meet these requirements, which vary between countries depending on conditions such as temperature and humidity;
- **alignment with the waste hierarchy** and the various ranked options as a key guiding tool for prioritising product and waste management solutions;
- **alignment with the waste management infrastructure in place,** which varies between countries.

The impact of eco-design can be further increased by using mandatory instruments, such as phase-outs and bans, mandatory design regulations, taxation and EPR schemes. If carried out properly, eco-design and circular design measures can be a powerful tool for accelerating the transition to a CE.

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Annexes

Annex 1 – 25 shortlisted standards selected by the JRC (2020)

Name of guideline/ standard	Issuing body	Product type						Product group				Polymer								
		Bottles	Trays	Films	Containers	Other	Not specified	All packaging	Light/ flexible	Rigid	Not specified	PP	PS/ EPS	PVC	PET	LDPE	HDPE	PE	Other	Not specified
Borealis 10 codes of conduct for Design for Recyclability for Polyolefin Packaging Design	Borealis						■	■				■						■		
https://circularanalytics.com	Circular Analytics						■	■				■			■	■	■	■	■	
Circular Packaging Design Guideline	FH Campus Wien; Section of Packaging and Resource Management						■	■				■			■	■	■		■	
Citeo 2020 rate list for recycling household packaging	Citeo (France)						■	■				■	■	■	■			■		
cyclos-HTP	Institute cyclos-HTP			■				■				■	■		■	■		■	■	
Design 4recycling. Design plastic packaging so it can be recycled	Der Grüne Punkt	■							■	■		■	■		■	■	■	■	■	
Design for Recycling Guidelines	SUEZ.circpack®						■	■				■	■		■	■	■			
Design Guide for PET Bottle Recyclability	EFBW and UNESDA	■									■				■					
Designing for a Circular Economy Guidelines (draft)	CEFLEX			■					■			■						■		
European PET Bottle Platform initiative (EPBP)	EPRO, EuPR, Petcore, UNESDA, EFBW	■									■				■					
Packaging 4 Recycling	EXPRA's Sustainability and Packaging Working Group						■				■	■	■	■	■	■	■		■	
PETCORE Europe Design for recycling guidelines for PET thermoformed trays: Clear transparent to be recycled even in food applications	PETCORE (PET COntainers REcycling) Europe		■								■				■					
RECOUP	Recycling of Used Plastics Limited (RECOUP)	■	■	■							■	■	■		■		■		■	
Recyclability of plastic packaging: Eco-design for improved recycling	COTREP, France	■	■	■	■	■					■	■			■	■	■			
RecyClass design for recycling (HDPE Coloured Containers)	RecyClass / PRE				■						■						■			
RecyClass design for recycling (HDPE	RecyClass / PRE				■						■						■			

Name of guideline/ standard	Issuing body	Product type: Bottles	Product type: Trays	Product type: Films	Product type: Containers	Product type: Other	Product type: Not specified	Product group: All packaging	Product group: Light/ flexible	Product group: Rigid	Product group: Not specified	Polymer: PP	Polymer: PS/ EPS	Polymer: PVC	Polymer: PET	Polymer: LDPE	Polymer: HDPE	Polymer: PE	Polymer: Other	Polymer: Not specified
Natural Containers)					■						■						■			
RecyClass design for recycling (PE Coloured Flexible film)	RecyClass / PRE			■					■									■		
RecyClass design for recycling (PE Transparent Flexible film)	RecyClass / PRE			■					■									■		
RecyClass design for recycling (PO Pots, Tubs, Blisters & Tray)	RecyClass / PRE		■		■	■					■	■			■	■	■	■		
RecyClass design for recycling (PP Coloured Containers)	RecyClass / PRE				■						■	■								
RecyClass design for recycling (PP Natural Containers)	RecyClass / PRE				■						■	■								
RecyClass design for recycling (PP Transparent Natural Flexible film)	RecyClass / PRE			■							■	■								
Reuse and recycling of plastic packaging for private consumers	Network for Circular Plastic Packaging (on behalf of the Danish Plastics Federation)						■	■				■			■			■		
Round Table Eco Design of Plastics Packaging	IK Industrievereinigung Kunststoffverpackungen e.V.						■				■									■
Recycled plastics - Practical guide for integrating recycled plastics into the electrical and electronic equipment	Eco-systemes (France)					■					■	■	■						■	
	Total number	**5**	**4**	**7**	**6**	**3**	**8**	**7**	**3**	**1**	**16**	**17**	**7**	**2**	**14**	**8**	**10**	**10**	**7**	**1**

Source: JRC, 2020

Annex 2 – Overview of selected recyclability guidelines

Table 6: Overview of recyclability guidelines

	DIN EN 13430	Institut cyclos-HTP	RecyClass	RECOUP	FH Campus Wien
Type	Assessment catalogue	Assessment catalogue	Assessment catalogue + design for recycling guidance	Design for recycling guidelines	Design for recycling guidelines (recommendations)
Scope	All packaging	All packaging	Plastic packaging	Plastic packaging	All packaging
Applies or claims to apply to	EU	EU	EU	International (focus: Europe, US)	Austria, Germany, Netherlands
Reference standards	e.g. CR 14311; EN 13437	DIN EN ISO 14021; DIN EN 13430			
Definition of recyclability	Definition of recycling	Yes			
Object of assessment	Complete packaging	Complete packaging	Complete plastic packaging	Individual components of plastic packaging	Packaging components, characteristics
Assessment parameter	Material recyclability on a scale of 0% to 100%	Recyclability on a scale of 0% to 100%	Recyclability on a scale of A to F	Recycling compatibility on extended binary scale (traffic light system)	Classification of packaging components (good/moderate/poor)
Interface quantification	Delivery for reprocessing	Recyclate	Recyclate		
Reference	Material recovery	Recyclate applications	Packaging applications	Ideally designed packaging	Ideally designed packaging
Testing and assessment criteria	Based on process steps starting with production	Based on process steps starting with after-use stage	See design for recycling guidelines	Not explicitly stated; criteria derived from process-specific qualitative and quantitative requirements for the recycling step and, to a lesser extent, sortability	

Source: own compilation

Annex 2 – Overview of selected recyclability guidelines
Source: cyclos-HTP, 2021

Category 1:
Materials quantitatively separable in the treatment steps established in the recycling process. For Category 1, the proportion of contaminants leads to a quantitative limitation of recyclability.

Category 2:
Materials not separable in the treatment steps established in the recycling process that have little or no effect on recyclate properties in practice. This proportion is not added as valuable material for later recycling. Exceptions are polymers with additives and regular mixture components of the recyclate (alloy, blend, master batch), such as titanium dioxide content in HDPE or HDPE content in PP blends.

Category 3:
Materials not separable in the treatment steps established in the recycling process that degrade the quality of the recyclate, making it unusable or resulting in a significant loss in value or disproportionately high processing costs. For Category 3, the proportion of contaminants (incompatibility) is assessed "inseparable contaminants / material-conditional cross contamination", and the result is that the item is classified as unrecyclable (Factor 0).

Table 7: Overview of recycling contaminants

Plastic/ polymer type	Category 1 contaminants	Category 2 contaminants	Category 3 contaminants
Plastic film/ LDPE	Paper labels; water-soluble adhesive applications; non-PO plastic content	PP film*, EVOH layers**, ethylene vinyl acetate (EVA)**, metallisation, tie layer resins**	Non-water-soluble adhesive applications combined with wet-strength paper labels; PA layers***; cross-linked polyethylene (PEX) layers; polyvinylidene chloride (PVDC) layers; other non-PE polymer layers (except tie layer resins, adhesives, PP, EVA and EVOH), non-polymer layers (except silicon oxide and aluminium oxide)
PE	Paper labels; water-soluble adhesive applications; plastics with densities > 1 g/cm³	EVOH layers; PP* (e.g. caps, labels); other thermoplastic polymers with densities < 1 g/cm³ in low concentrations (e.g. EVA, , PO-based thermoplastic elastomers (TPEs))	Non-separable silicon components; foamed non-TPE components; non-water-soluble adhesive applications combined with wet-strength labels; PET sleeves with density < 1 g/cm³, PA layers; PEX components; PVDC layers, non-PO plastics with densities < 1 g/cm³

Plastic/ polymer type	Category 1 contaminants	Category 2 contaminants	Category 3 contaminants
PP	Paper labels; aluminium lids; water-soluble adhesive applications; plastics > 1 g/cm³	PE caps*; EVOH layers; LDPE* (e.g. labels); other thermoplastic polymers with densities < 1 g/cm³ in small concentrations (e.g. EVA**, PO-based TPEs), tie layer resins	non-separable silicon components; foamed non-TPE components; non-water-soluble adhesives combined with wet-strength labels; PET sleeves with densities < 1 g/cm³; PA layers; PVDC layers; non-PO plastics with densities < 1 g/cm³
PS	paper labels; aluminium lid foil; water-soluble adhesive applications; plastics < 1 g/cm³ and > 1.08 g/cm³		Foreign or multi-layer plastics in density range 1.0-1.08 g/cm³; non-water-soluble adhesive applications combined with wet- strength labels
PET bottles (transparent, clear/light blue)	Plasma coating (clear); water-soluble or alkali-soluble adhesive applications; paper labels; PE and PP labels and sleeves	Acetaldehyde (AA) blockers; ultraviolet (UV) stabilisers, PO-based TPEs	Non-separable silicon components; polyoxymethylene (POM) components; PETG components; PVC components; EVOH layers; PA layers; PVC, PS, PETG/S labels/sleeves; other blended barriers; PA additives (APET copolymers); non-soluble adhesive applications (in water or alkali at 80 °C); non-ferromagnetic metals; elastomer components with densities > 1 g/cm³; direct printing except expiration date and batch number
PET bottles, other	**Plasma coating (clear); water-soluble or alkali-soluble adhesive applications; paper labels; PE and PP labels and sleeves; PA mono-layer barriers	AA blockers; UV stabilisers, PA additives, APET copolymers, PO-based TPEs, EVOH barrier layers	Non-separable silicon components; POM components; PETG components, PVC, PS and PETG/S labels/sleeves; non-soluble adhesive applications (in water or alkali at 80 °C)****; non-ferromagnetic metals; elastomer components with densities > 1 g/cm³
Mixed plastics	Paper labels; components of PS, PET, PA, PVC, acrylonitrile butadiene styrene (ABS), PC, etc.	LDPE*; EVOH barrier layers**; PA layers; other thermoplastic polymers < 1 g/cm³ in small concentrations (e.g. EVA**, PO-based TPEs); bonding agents**	Non-separable silicon components; foamed non-TPE components with densities < 1 g/cm³; foamed non-PO components; layers; non-water-soluble adhesives combined with wet-strength labels

Source: cyclos-HTP, 2021

* Shares are accepted with 75 % as valuable material respectively deducted with 25 %

** Depending on the polymer structure, categorization of ethylene-based polymers may vary.

*** Coextruded layers made of polyamide 6 or coextruded polyamide 6/6.6) are recycling-compatible for PE-layer-recycling in recyclates for injection moulding and blown film applications The essential criterion is the use of PA in combination with a maleic anhydride-grafted polyethylene as tie layer in ratio of ≥ 0.5 g tie layer per g PA in a coextruded film. In addition, the tie layer must be certified for the use in coextrusion PA and PE.

**** This criterion is not applied as category 3 -criterion for mixed PET from household collection.

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