Swedish Environmental Research Institute

Design for recycling of products containing plastics

Pre-study: Towards a global standard which contributes to plastics circularity

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Summary

Plastic materials are important within our society and are useful in many applications. However, plastics are rarely used in a sustainable or resource efficient way. The global production of plastics stands at a staggering 400 million tons, with projections indicating a tripling of this demand by 2060 unless substantial policy measures are taken. Presently, only 9% of plastic waste is being recycled, highlighting an evident inadequacy of circularity in the plastic lifecycle. The concept of design for recycling is frequently mentioned as a crucial step towards increased circularity of plastic materials. However, there is a lack of knowledge on the fate of plastic products at the end of the lifecycle or how the design choices can affect the recyclability of the product.

One of the objectives of this project was to facilitate a dialogue between the design industry and the recycling industry in Sweden, establishing a knowledge sharing forum for different actors in the value chains. Furthermore, the project focused on identifying the challenges related to product design which inhibit the recycling of plastic material, and mapping of available guidelines that promote design for recycling concept. This was implemented to understand the gaps and suggest different focus areas where standardised criteria would facilitate the transition to circular management of plastic materials. To understand the challenges that the industry is facing, interviews were carried out both with different companies that use plastic materials in their products and with different recycling industries. The results from the interviews were discussed during a workshop and thereafter used to suggest design areas which can be refined into general design for recycling guidelines/criteria for plastic products, presented in this report.

Contents

Abbreviations

ABS	Acrylonitrile butadiene styrene
EPS	Expanded polystyrene
HDPE	High density polyethylene
LDPE	Low density polyethylene
PA	Polyamide
PBT	Polybutylene terephthalate
PC	Polycarbonate
PE	Polyethylene
PET	Polyethylene terephthalate
PLA	Polylactic acid/Polylactide
PP	Polypropylene
PS	Polystyrene
PVC	Polyvinyl chloride
PVDC	Polyvinylidene chloride

1 Introduction

Plastics are common materials in our society. They are used in an increasing number of industries and product areas due to their low price and versatility, as their properties can be varied for a wide range of applications. Plastics are used in everything from simple applications like plastic bags to more advanced applications in sectors such as construction, the automotive industry, electronics, and healthcare. They are great materials that have brought benefits to the society and many industries. However, plastics are rarely used in a sustainable or resource efficient way today. They are often used unnecessarily or in material combinations that create barriers for material recycling and circular use. This results in the production and use of increasing amounts of virgin fossil-based plastic. The global plastic production is currently around 400 million tons, but the OECD estimates that it will triple by 2060 without rapid policy measures.[1] The same applies to the amount of plastic waste generated every year. OECD also reports that the plastic lifecycle is far from circular today. Globally, only 9 percent of plastic waste is recycled and large quantities end up in the oceans.[2] OECD points to the need for global-level policy measures to guide plastic usage towards circularity.[1]

The Swedish Environmental Protection Agency describes in a government assignment that there are several reasons for the low recycling rate for plastics today. The four identified main obstacles are:

- a lack of incentives for design for recycling,
- difficulties in sorting different types of plastic waste,
- low demand for recycled materials,
- poor traceability for recycled materials.[3]

The choices made during the design phase of a product are crucial for whether plastic products are recyclable or not. For example, the choice of material combinations, the colour, the presence of additives, how easily products can be disassembled, all affect the recyclability of the products. It is often difficult to separate plastic from other materials that are part of a product or to separate different types of plastic. This in turn affects the quality and economic value of the recycled plastic materials.

Design companies, which design plastic products, rarely know what happens to the products they design at the end of the product's lifecycle or how the design choices affect the possibility of recycling the products. There is a lack of knowledge among designers and consumers considering how to recycle plastic products when they become waste. There is a gap in the dialogue between the design industry and the recycling industry regarding the challenges of recycling plastic and the necessary actions.

Design for recycling exists as a concept, but it is not widely applied and is implemented differently for different product groups since there are no standard criteria for what makes a plastic product recyclable. To promote the use of design for recycling in practice, clear and general guidelines are needed, as well as extended dialogue and collaboration between actors designing the plastic products and those who are responsible for recycling them.

A total of 175 countries of the United Nations decided in March 2022 to begin working towards a binding global agreement to reduce plastic pollution. The agreement will impact the entire lifecycle of plastic. One of the approved resolutions emphasises the importance of better design of plastic products and materials to increase opportunities for reuse and recycling, and to preserve the value of plastic in the economy as much as possible.[4]

Swedish Environmental Protection Agency also highlights that design criteria for plastic products should be standardised to move closer towards a more circular use of the material and contribute to international actions to reduce the environmental impact of plastic.[5] Also the EU's Strategy for Plastics in a Circular Economy emphasizes the significance of design for circularity for plastic products and describes standardisation as a vital tool to achieve this.[6]

Many industry organisations, both nationally and at the EU level, are working on designing standards for recycled plastic material and how plastic products and packaging should be designed for recyclability. Many standards are highly product-specific and focus on different types of plastic. For example, the European Commission and the Circular Plastics Alliance (CPA) developed guidelines for design for recycling for 26 different product categories and submitted them as a basis to the European Committee for Standardization (CEN).[7]

For many plastic products, standards for design for recycling or the use of recycled plastic in new products, are still lacking. Since plastic materials from all sectors are

managed in global value chains, there is a need for a common description of design criteria that are general for all sectors that use plastic and that apply globally in terms of an international standard, as also highlighted by SIS-ISO in a technical report.[8] The plastic industry is often global, and a global standard can help increase circular flows worldwide. A widely accepted standard would also simplify the use of procurement criteria that drive demand for recycled plastic and recyclable plastic products.

This report presents the work and the results from the project *National cooperation between the design and recycling industries for the standardization of design for recycling.*[1] The objectives of the project include:

- facilitate dialogue between the design industry and the recycling industry in Sweden;
- map the challenges related to product design which make recycling of plastic difficult;
- develop a foundation for general criteria for design for recycling of plastic products as a first step towards an international standard which can facilitate increased circularity of plastics.

2 Methodology

The project was structured as a pre-study and was based on cooperation between eleven Swedish actors representing both the design industry on the one side and the waste and recycling industries on the other side. The eleven organisations collaborating in the project were IVL Swedish Environmental Research Institute, SVID, Swedish Industrial Design Foundation, the waste and recycling companies Remondis, PreZero, Carl F, the industry organisation Waste Sweden (Avfall Sverige), as well as the design and plastic manufacturing companies Noun Design Studio, BAS ID, HL Display (represented by Akriform Plast from the beginning of the project), Mape Plastics and Duni. However, the project was open to other participants as well, and a range of other companies also participated in the project activities. The aim with having an open project was to give the possibility to as

[1] Original project title in Swedish '*Nationell kraftsamling mellan design- och återvinningsbranschen för standardisering av design för återvinning*'

many companies as possible, both within the design and the recycling, to contribute with their knowledge and perspective to the project results.

A literature review was performed to gather information on existing guidelines and standards for design for recycling for plastic products and identify the knowledge gaps. This was followed by interviews with 14 companies in Sweden from different sectors and varying size. An overview of the interviewed companies is presented in Table 1. The purpose for the interviews was to understand the challenges that the industry is facing when trying to make their products more recyclable and to identify what is limiting the recycling industries from recycling a higher share of the plastic placed on the market.

The results from the interviews were compiled and discussed during a workshop where the interviewed companies were invited to participate. The results have been formulated into suggestions for design areas, which can be refined into general design for recycling guidelines/criteria of plastic products, presented in chapter 5 in this report.

Table 1. Overview of types of stakeholders which participated in the interviews.

Company type	Main type of products	Most used plastics
Design bureau 1	Packaging, on demand design	PET, non-woven PP or PE, laminate on paper
Design bureau 2	Food packaging, designing mainly print and labels for customers with already specified packaging material	PE, PET
Design bureau 3	Design a wide range of products for their customers, such as: chain saw handle, MedTech products, automotive-diagnostics equipment	ABS/PC, PP, PA
Producer of plastic container for pick and mix and other containers in retail	Containers for pick and mix, visors, specific molding based on customer demand	Acrylic plexiglass, PET (not bottles), other thermoplastics free of additives
Producer of single use food containers and table setting	Take-away mugs, napkins, cutlery etc.	PE and PLA, sometimes biobased PE

Company type	Main type of products	Most used plastics
Furniture producer	Chairs, armchairs, tables, and other interior design objects	PP, PA, ABS, often the PP is glass fiber reinforced
Heavy vehicles	Heavy vehicles such as trucks, busses, and components such as engine	Interior often PP, Exterior in PBT
Electronics	Wide range of electronic household appliances	ABS, PP, engineering-plastics
Clothing retail	Mainly in packaging but also for example coat hangers, buttons, and other details	PP, PET in packaging
Reseller of primary plastic material	Products obtained through injection molding (focus om customer demand)	PE, PA, PC/ABS
4 organisations active withing waste management and plastic recycling	Both municipal and industry waste flows	All plastic streams that become waste

3 The concept of Design for Recycling and existing guidelines

This chapter discusses the findings from the literature review.

Most of the national and international guidelines and standards aimed towards increasing recyclability of plastic-containing products are focused on packaging. This is partly because a major part of the plastic used each year (around 40 percent) in Europe is used to produce packaging[9] and partly because there is law-enforced extended producer responsibility for packaging and packaging waste in the EU since the early 1990s[10]. Another explanation is also the fact that relatively clean plastic material (not including hazardous or potentially dangerous additives) is being used in packaging compared to other plastic-containing products because much of the plastic packaging comes in direct contact with food and consumer products. This makes the recycled plastic originating from plastic packaging more

appealing to use in different products compared to recycled plastic originating from for example electronics or construction products.

Design for Recycling (DfR), independent of sector or material, lacks explanations and definitions. Designing a product for recycling not only needs to mirror the criteria and demands for the product functionality. There is also a need of knowledge where the discarded product will end up, what sorting it will go through, what recycling technology will be applied and what next life product is foreseen for the material as a recyclate (recycled plastic material). DfR needs also to take into consideration the recycled content during the design phase of the product. Few product manufacturers or designers have the whole picture, nor control, over the infrastructure a product will go through before its end of life.

This becomes obvious when mapping existing DfR guidelines, primarily in Europe, where the vast majority concerns plastic packaging. The large number of varieties of DfR guidelines is indicative of the fact that there is no consensus on criteria. There are many local varieties of DfR guidelines, and it is not completely clear if the varieties are based on actual existing criteria for high quality recycling or if they are based on input given from brand owners/converters of already existing packaging.

DfR guidelines for packaging in Europe have been driven by the legislative demands in the Packaging and Packaging Waste Directive, that has been in force since 1994. The large number of DfR guidelines for packaging is driven by the existing Extended Producers Responsibility (EPR) demand in the legislation, and as every Member State had the freedom to implement this legislation according to their individual interpretation, the number of DfR guidelines is accordingly. These guidelines for packaging have been developed by various stakeholders in the value chain, from product/material associations and producers, business associations, waste collectors, EPR-systems, and research institutes.

Instrumental for any of the existing DfR guidelines is the lack of information of expected application of the recyclate generated from the product. Without this information, the recyclate can be used in any application, that can potentially lead to downcycling or uncontrolled waste management.

Another complexity in DfR is the question of available recycling technologies and how the infrastructure supports the new processes, dependent on availability. As it is normally unknown what path a plastic product may take, DfR needs to be

technology neutral, meaning that criteria set in the guideline need to be adequate to all available technologies. Specific technologies cannot be considered if not fully available on the market, for example de-inking, hot water washing, exclusion of certain additives or material mixes.

Table 2 below presents a few examples of existing DfR guidelines for packaging. The list is not exhaustive.

Table 2. Examples of DfR guidelines

System	Category	Product/material	Type of owner
COTREP[11]	Plastic packaging	Bottles, pots, trays, shampoo bottles, bags, sleeves, films, plastic boxes	French Producer Association
European PET Bottle Platform initiative (EPBP) [12]	Plastic bottles	PET bottler	Value Chain platform
RecyClass[13]	Plastic packaging	HDPE, LDPE, PET, PP	Value Chain platform
CEFLEX[14]	Plastic packaging	PE and PP (Phase 1), may be extended to multi-materials in Phase 2	Value Chain platform
cyclos-HTP[15]	Packaging and other similar products	LDPE, PE, PP, PS, PET, mixed plastics (rigid), mixed plastics (soft)	Test institute
Borealis 10 codes of conduct for Design for Recyclability for Polyolefin Packaging Design[16]	Plastic packaging	PE, PP	Polymer producer

System	Category	Product/material	Type of owner
Nestlé Design for Recycling[17]	Packaging	PE, PP, PET, and avoidance of PS, EPS, PVC, PVDC	Brand owner
CEN	Construction	EN 17410 Plastics - Controlled loop recycling of post-consumer (or post-use) PVC-U windows and doors	Standard

Existing legislation at EU level is part of the reason for the existing high number of DfR guidelines for packaging. There have been legislative demands for EPR systems both for electronics and for vehicles, but the number of existing DfR guidelines for plastic components in these products is close to none. The explanation is most likely due to the lifetime of the products, (short for packaging, medium for electronics and long for vehicles) together with cross-sectorial interchange of materials, where recycled packaging ends up in applications within other sectors and in combination with no requirements for dismantling/separation of components.

4 Identified challenges for design for recycling

This chapter summarizes findings from the interviews.

Insights from the actors within the design sector

The interviews revealed that the knowledge on design for recycling varies significantly between different sectors as well as between companies within the same sector. In many cases the representatives that participated in the interviews seemed to be quite knowledgeable regarding recyclability of plastics and they were aware that for example one should avoid mixing polymers and minimize the use of pigments and additives when possible. But a large challenge seems to be related to communication and coordination across the supply chain. In many cases customers or suppliers do not know which effect the choice of material has on the recyclability of the product at the end of a life management of the product.

Another related issue is the motivation to design for recycling, where understanding of the value created by making the products more recyclable is lacking. This is due to the fragmented market for recycling and the unclear routes for generated plastic waste flows. Also, the consumers are often challenged when considering proper waste handling due to low recycling rates of the materials or examples when even sorted waste gets mixed by operators during waste management[18].

Using recycled plastics instead of new raw materials is also often not prioritized because of the assumption by many stakeholders that the quality of the recycled material does not fulfil the requirements as well as the new raw material can. Furthermore, difference in price between using new and recycled plastic, recycled being more expensive, is still the dominating issue for many companies and ultimately not many are willing to compromise on this matter. Interviewees also highlighted that for companies to stay competitive regarding price and quality of the products it is important that the whole sector increases the cooperation efforts.

Insights from the actors within the waste management and recycling sector

When it comes to the recycling of products containing plastics, the interviewees highlighted several issues that make the recycling process more difficult. Some of the main challenges identified during the interviews:

- The plastic parts contain too many additives such as pigments and plasticisers without any possible traceability of the content.

- Problems with impurity either because of polymers blended with other polymers, composite materials or for example labels composed of different materials, such as paper, that are impossible to completely remove by washing. Paper labels are often glued with adhesives that are difficult to remove. Therefore, paper fibres are often still present to some extent in the recycled material. This can cause the material to degrade quicker and thus reduce the quality of new products containing recycled plastics.

- There is no mandatory system for labelling for many components to facilitate sorting for cleaner fractions.

- When it comes to complex assembled products, such as vehicles or electronics, high costs are associated with spending time on disassembling all the parts for recycling if these are not easily removed. It is too costly compared to what the recycled plastic is worth.

- There are insufficient volumes of homogeneous material, due to vast number of different types of plastics used in the design of the products, which also limits the possibility of effective recycling.

- PVC is sometimes mixed with olefins in certain products (for example electrical cables). This means that reasonably large volumes of polyolefins, which could be recycled, are not recycled because of the presence of PVC as a contaminant.

- It is very challenging to obtain a post-consumer recycled plastic which is clean enough for use in a wide range of new products. Problems could arise, for example, in relation to the purity requirements for food contact and traceability.

- There is not enough demand for design for recycling, the recycled plastic is not considered a valuable material on the market which limits the profitability of the recycled material.

5 Focus areas for general design for recycling criteria

To increase the recyclability for plastics in different product categories several measures must be taken. This chapter suggests several design areas for DfR, Table 3, which can be used regardless of industry sector or product category. It is crucial that representatives from different industries contribute to formulating the criteria for the type of products their industry produces, when related to type of choice of polymeric material and additives added.

Table 3. Suggested design areas which can be refined into general design for recycling guidelines/criteria for plastic products.

Addressed challenge	Suggested design areas which can be refined into Design for recycling criteria
Unnecessary wastage of materials and energy	**Increased resource efficiency in products:** Design products with minimum amount of material without compromising the function of the product. Avoid unnecessary use of materials. **Increase resource efficiency in the supply chain:** Design products to enable transport efficiency. For example, products that can be stackable in an efficient way to optimise transportation.
High amounts of additives and lack of material traceability	**Reduced number of additives**: Design plastic products with a focus on reducing the use of additives such as pigments and plasticizers. This not only simplifies recycling but also minimizes the potential negative impact on human health and the environment.
	Increased traceability and transparency in the value chain: Implement a traceability system that provides information about the composition of plastic used in the product. For example, QR codes, watermarks, or RFID tags can be used to identify plastic types and additives, making proper recycling easier.

Addressed challenge	Suggested design areas which can be refined into Design for recycling criteria
Combination of different polymers or material combinations in the same product	**Modular design:** Create products with modular components that can be easily separated by consumers or at recycling facilities. This enables the separation of different types of polymers.
	Material compatibility: Avoid combinations of polymers that are difficult to separate, such as polypropylene and polyethylene. If multiple polymer types are necessary, consider using materials with differences in density or melting points for easier separation. Avoid mixing PVC with polyolefins to avoid recycling issues caused by PVC.
Difficulty in disassembly and sorting of different materials which are part of the same product	**User-friendly disassembly:** Design products with user-friendly disassembly instructions or mechanisms to encourage consumers to separate and clean plastic components before disposal.
	Visible labelling: Incorporate visible labelling and standardise codes or symbols for identification that can be used for automatic sorting at recycling facilities.
High variety of plastics on the market	**Prioritize the use of common plastics:** use common plastic materials (such as PE (HDPE, LDPE) and PP) in products to increase the volume of homogeneous material for recycling, improving profitability.

Addressed challenge	Suggested design areas which can be refined into Design for recycling criteria
Labels and adhesives which hinder recycling	**Recyclable labels:** Use labels with adhesive properties that are water-soluble or easy to remove from plastic without leaving residues.
	Labels from the same material as the substrate: For example, use labels made of the same polymer material as the substrate to avoid issues with label residues weakening the recycled material, as is often the case with paper labels.
	Integrated labels: Explore direct printing or marking on plastic surfaces instead of using labels when possible. However, consider that printing can sometimes affect the purity of the recycled material, although avoiding the problem of weakened points that paper can create. This should be considered based on the type of product and the intended use of the recycled material.
Scepticism around recycling plastic	**Promote the use of recycled plastic:** Prioritize the use of recycled plastic in products to drive the demand and improve the market conditions for recycled plastic. Advocate for regulations or industry standards that require a minimum percentage of recycled plastic in new products.
	Educate the entire value chain, especially manufacturers: Create awareness among product manufacturers about the benefits of recycled plastic and its suitability for various applications.
	Consider design points such as colour: Does the product have to be homogeneously coloured/a specific colour? Often recycled plastic may have varying pigmentation, but this does not affect the quality of the material.

6 Recommendations for next steps

Catalyse and coordinate international cooperation and dialogue

The pre-study had a consortium of companies and organisations based in Sweden. Many stakeholders have shown a large interest in the topic at national level, which confirmed the need of a full-scale project/cooperation initiative.

The pre-study identified a set of design areas for criteria for design for recycling of plastic-containing products. However, there is a need to further develop these into definite criteria and discuss them internationally with a wide range of industries.

There is also a need to continue the work towards an increased dialogue between the design industry and the recycling industry both in Sweden and at international level as most value chains are global.

Join forces to create momentum

Join forces with international stakeholders which have identified the same needs to create an international movement and eventually a global standard for design for recycling of plastic-containing products.

Initiate and drive the standardization process

This project has identified areas to be investigated further related to design for recycling criteria in the value chains for plastic products, Table 3. Amongst them the necessity to provide an initial simplified check list for the stakeholders in the value chain to assess during the product design, production, usage, waste management and recycling. Even if the list is very simple and will not cover all necessary details, it reflects a starting point during the design phase of the product. The list can be the first input to a general Design for (or with) recycling of plastic products standard, which can include different steps needed for the design of circular plastic products, Table 4.

Table 4. Suggested steps for standardisation of Design for recycling of plastic products.

Nr	Step	Description
1	Elimination of product	Reduction of unnecessary plastic materials on the market
2	Logistic lifetime	Identified waste path, including market criteria in collection and sorting (local, national, global), recycling technology
3	Recyclability verification	According to an existing, revised or newly developed standard
4	Cradle to cradle/grave LCA	Standardised methods as decision criteria for product design
5	Product as recyclate	Intended uptake of the recyclate in closed or open loops

The initiation of a standard proposal should be done in *ISO Technical Committee 61 Plastics/ Sub Committee 14 Environmental aspects/ Working Group 1 Terminology, classifications and general guidance* via a National Standardization Body from a dedicated identified potential project leader, that is interested to lead the development of the standard. When proposing a standard, it is beneficial to present a rough draft to visualize the intentions of the standard for the members of the Sub Committee, that will approve of the New Work Item Proposal (NWIP).

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This report has been reviewed and approved in accordance with IVL's audit and approval management system.