Chapter 7. Considerations During the End-of-Use Phase

This chapter focuses on the end-of-use phase of the life-cycle and provides considerations for sustainable design from a chemicals perspective that are most relevant for this phase. Examples of trade-offs that arise in the end-of-use phase are presented.

During the end-of-use phase, the user dispenses with the plastic product, after which it is ideally collected, sorted and treated. The following considerations need to be taken into account.

A. Minimise the amount of waste at end-of-use through polymer selection.

B. Simplify designs to include as few different polymers as possible.

C. Maximise the production of high-quality recycled materials as output of the recycling process.

D. Minimise the amount of and exposure to chemical hazard at end-of-use through chemical selection.

E. Match the polymer selection to the waste management operations in the intended market.

F. Consider ways to mitigate the risk of littering.

G. Ensure transparency of chemical composition

7.1. Considerations during the End-of-Use Phase

In this section, the considerations for the end-of-use phase are further explained.

A. Minimise the amount of waste at end-of-use through polymer selection.

In a circular economy, resources are kept at their highest value and utility at all times. As a result, at the end-of-use, reuse, refurbishment, remanufacture and - at least – recycling should be enabled. Incineration and landfill should be avoided as much as possible (Ellen MacArthur Foundation, 2013). Therefore, to minimise the amount of waste at end-of-use, select polymers that are known to be collected, sorted, and at least recycled for the applicable product type in the intended market. For instance, for collected household appliances (white goods) in Western Europe, the polymers acrylonitrile-butadiene-styrene (ABS), high-impact polystyrene and polycarbonate are known to be sorted and recycled. Before introducing new polymers, that could have benefits in other life cycle phases, plans should be made for an appropriate sorting and recycling infrastructure.

B. Simplify designs to include as few different polymers as possible.

Next to using well-recycled polymers in a product, product designs should be simplified to include as few different polymers as possible in order to prevent contamination and mixed waste streams, which lead to large amounts of potentially recyclable polymers not being recycled. Although out of scope for this report, note the importance of the product design as mentioned in Chapter 2. Teams should consider if the product design facilitates maximum recovery and recycling of the materials. For example, if a product consists of different parts that are to be mounted together, consider a physical design of parts to avoid the need of glue. By such design choices, additional chemicals can be avoided and the product will more easily be reused or recycled.

Take the value of the recycled material into account. Consider if the design facilitates repair, reuse or disassembly. This includes conveying information on the chemical content of the product.

C. Maximise the production of high-quality recycled materials as output of the recycling process.

Use recyclable materials which will be recycled at the highest quality possible to become future secondary feedstock and close the loop (possibly product-to-product). There are several guidelines available to assess the recyclability of polymers used in packaging (See Annex A: Overview of Relevant Methods, Tools and Metrics).

Currently, most recycling processes are mechanical recycling processes, in which the plastics products or packaging are usually sorted, shredded, washed, and extruded to create granulate for new compounds. Presently, plastics containing certain additives (like fibreglass) or highly contaminated materials cannot be recycled mechanically into high quality recycled grades that can be used in the same applications they once were (TNO, 2021).

In this context, thermoplastics are generally easier to recycle at a high quality than thermosets.

Note that in the future, chemical recycling is likely to develop rapidly. However, bringing resources back to molecular level requires a lot of energy. Therefore, it is expected to still co-exist with mechanical recycling which is more energy efficient.

Plastics as fuel seems detrimental in geographic regions with both good waste management infrastructure and access to fuel. Nevertheless, it may have various social and environmental benefits in regions where these resources are lacking (i.e., reducing litter and providing fuel for cooking and tractors while avoiding cutting down trees). Although out of scope for this report, be mindful of social contexts.

Box 7.1. Examples specific considerations for the electrical and electronic equipment and automotive sectors during the end-of-use phase

Electrical and electronic equipment (EEE) sector: The EU's Waste Electrical and Electronic Equipment (WEEE) directive prohibits the disposal of EEE in household waste and promotes the separated collection of these products. Consider design for easy separation of each part in EEE. Mark parts to distinguish the polymer type.

Automotive sector: If safety and durability during use allow it, avoid using reinforced materials such as glass fibre, which cause difficulty for recycling.

D. Minimise the amount of and exposure to chemical hazard at end-of-use through chemical selection.

In the recycling process, the plastics will be shredded and re-melted. In this process, thermal degradation products are formed. The nature and amount of volatile organic compounds (VOCs) formed depend on the polymer type. In the example of polymers in household appliances, it can be noted that acrylonitrile-butadiene-styrene (ABS) and polystyrene will emit far more VOCs than polycarbonate (He, et al., 2015).

Chemical additives in plastics create their own degradation products during recycling and incineration. During incineration, the presence of flame-retardants in household products, for instance halogenated flame-retardants, can lead to the emission of dioxins and dioxin-like compounds.

Chemical additives can also create chemical hazards in landfills or unofficial disposal. Chemicals will leach from plastic products into the environment. Cadmium stabilisers used in the past in PVC construction products increase the lifespan of the product but are carcinogenic and toxic for aquatic lifeforms. Other PVC concerns include leaching of lead and phthalates. The exposure of workers to chemical hazards during collection, disassembly, shredding and repair should be prevented or minimised.

The use of substances that create hazardous degradation products or legacy chemicals in the recycled material should be avoided. The following two design guidelines can help prevent the exposure to chemical hazards from batteries or other hazardous components:

- Enable easy access and removal of hazardous or polluting components.
- Use material combinations and connections that allow easy liberation.

E. Match the polymer selection to the waste management operations in the intended market.

Every country, region or sometimes municipality has their own waste management system.

Feedstock selection benefits from matching to the end-of-life fate. If a material is a biodegradable/compostable plastic, for example, biodegradation/composting is a suitable fate. It is essential that design decisions take into account the actual outcomes (i.e. something is actually composted or biodegraded, with the appropriate infrastructure already in place) instead of their potential (compostable or biodegradable). If the selected end-of-life option is biodegradation or composting, ensure the absence of hazardous chemicals or hazardous chemical mixtures in the finished plastic, especially if they are persistent, as such chemicals will not degrade and will be dispersed when the plastics itself degrades. For products with long lifespans, consider developments in waste management and recycling technology.

F. Consider ways to mitigate the risk of littering.

In specific situations, where accidental littering (or shedding of microplastics) cannot be avoided, biodegradable, soil degradable or water-soluble plastics could be considered. However, at this moment, most biodegradable polymers can only degrade in industrial composting facilities; they will not degrade in the environment. Because labelling a product as "biodegradable" could increase the likelihood of littering behaviour, efforts should be made to improve awareness about proper disposal. An additional issue with littering of plastics is that there is also the risk of hazardous chemicals dispersing to the environment from the littered product.

G. Ensure transparency of chemical composition.

Information about the chemical composition should reach waste management services. Designers can consider material passports at chemical level. Blockchain with chemical markers, watermarks or QR codes are possible solutions. As a part of European Sustainable Product Initiative there is development of a digital product pass including information (also chemicals) for the value chain and information to consumers.

7.2. Trade-Offs within the End-of-Use

Table 7.1. Various trade-offs emerging from taking end-of-use considerations into account

Material innovation	*vs*	Availability of recycling infrastructure
Innovative materials which may be more sustainable usually do not have a recycling infrastructure in place. Bringing a new material to the market brings a responsibility in the adjustment (or creation) of the recycling infrastructure needed.		
Simplify designs	***vs***	**Usability and desirability**
Simplifying designs by including as few different polymers as possible could impact the aesthetics of the product or even the usability of a product, for instance by avoiding soft-touch handgrips in beer crates. But they can be easier to recycle.		
Low transport emissions	***vs***	**Recycling**
The availability of recycling infrastructure varies globally. Transporting materials long distances for recycling can lead to additional life cycle impacts that would need to be considered when reviewing trade-offs of mechanical or chemical recycling. In the design process, using inherently low hazard additives and mechanically recyclable plastics, along with programs to develop the necessary infrastructure, can foster a closed-loop system.		
Including in recycling streams	**vs**	**Permanent disposal**
"Dealing with legacy products, some of which contain chemicals of concern, versus new products containing safer chemicals is also a challenge. Products with highly hazardous or banned chemicals already on the market should be treated separately from newer material streams, and recycling may not be the best option. Trade-offs between permanent disposal, instead of inclusion in recycling streams, will need to be considered." (OECD, 2018a).		

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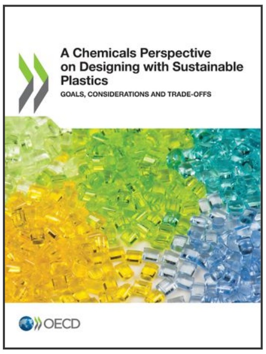

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