Instruction Design for **Recycling**

Basic Principles

The Task of Optimisation

Recycling comprises a key element of all strategies for achieving a circular economy. Particularly for short-lived products – such as plastic packaging – recycling is an important step in reducing demand for primary materials, avoiding negative environmental impacts (including CO_2 emissions) related to the production of primary material as well as reducing the volume of waste by closing the loop of material flows.

Requirements

Recycling Friendly Framework Conditions

Optimisation of packaging design regarding its suitability for recycling only achieves the desired environmental effects if the packaging is also ultimately fed into the appropriate recycling processes.

That is why the following requirements for the market region in question must be reviewed:

- Does a functioning waste collection system exist in the market region?
- Is (plastic) packaging waste in the region being collected as a waste fraction that is collected and sorted for subsequent recycling?

If the answer to the first of the two questions is negative, consideration must be given to whether a company's own functioning return system can be implemented. Otherwise, the marketing of plastic packaging in this region should be reconsidered, taking into account the following aspects.

In some regions with poor waste collection, there are (informal) well-functioning waste picker communities that sort and collect rubbish. If the packaging corresponds to the plastic waste that is systematically collected there because it has economic value (e.g. HDPE packaging), it can be assumed that the packaging will be collected and recycled and will not remain in the environment. In regions where waste infrastructure is being established, a simple packaging design can be a solution that is compatible with existing technologies and can be used for energy recovery with no potential harmful emissions.

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From an ecological perspective, it can be concluded that *recycling of plastic packaging can be regarded as successful when most of the materials are being converted into secondary materials that are used in the production of new products*.

Thus, recyclability is not a static technical characteristic of packaging, but instead closely linked to existing collection, sorting and recycling technology.

In order to ensure the recyclability of packaging, it is necessary either to have in-depth knowledge of collection, sorting and recycling technologies and to know the market for secondary materials in the affected region or to use appropriate (region-specific) recycling tools and guidelines.

Optimisation Approaches

Regardless of the need to take into consideration regional infrastructure and conditions, the following aspects should always be taken into account in a “design for high-quality recycling” as they can have a significant impact on the recyclability of packaging.

Optimisations at System Level

Implementation of a packaging-specific return system: A separate collection/return system for particular types of packaging, either at company level or at the level of a packaging sector, resulting in adequate collection of similar kinds of packaging, make it possible to use very specific recycling technologies. As a rule, this leads to a significantly higher recycling rate and, in particular, to clearly better defined quality and, consequently, better sales potential of the recycling materials.

The European model for collecting and recycling PET beverage bottles via deposit systems etc. is an example of a well-functioning closed loop system of packaging materials.

Optimisations at Packaging Level

Making plastic packaging identifiable as such: In order to make recycling possible, it is crucial that consumers properly dispose of plastic packaging. In order to do this, consumers must be able to recognise plastic packaging as such. If plastic consumer packs are not readily distinguishable from other forms of packaging made of other materials, these may enter the wrong waste stream.

One example is plastic cups with a paper-like surface, which fail to enter the plastic recycling loop because they are disposed of as waste paper.

Avoiding material combinations which make orderly sorting more difficult: Combinations of plastic and other types of material (paper, cardboard, metal, ...) should be avoided, especially if they cannot be easily separated by consumers or when being sorted or shredded. If two packaging components cannot be separated and these components are correctly identified during sorting (such as plastic + paper/cardboard, metal ...), the entire package may not be recyclable. Fillers that alter the density of the polymeric material can also hinder proper sorting/recycling.

Selecting polymers: Selecting one of the following (from most packaging types) polymers that are easy to recycle increases the likelihood that the packaging material is recycling ready in most regions: PE-HD, PE-LD, PP and – for soft drink bottles – PET. For other polymers, a specific assessment of the kind and function of the packaging and the existing secondary material flows in the particular region must be carried out.

Minimising the number of polymers: Minimising the number of polymers used in packaging increases recyclability. If functionally feasible, only one polymer type should be used for the entire package. If this is not possible:

- Reduce the number of different polymers as much as possible.
- Make sure that different types of polymers can easily be separated.
    - If combinations of different polymers are unavoidable, try using materials of different densities to facilitate separation.
    - Make sure that components can be easily separated, for example, that shredding leads to separation of various polymer materials.
- If PET recycling is likely for the specific type of packaging, do not use combinations of different types of PET (PET-G and PET-A) as they are not compatible for recycling.
- Avoid using composites made of incompatible polymers (recyclable exceptions are PP/PE composites with an EVOH or PVDC barrier).

Minimising the use of pigments in plastic packaging: Unpigmented polymers are more valuable than pigmented ones as recycling material. In other words, plastics without pigments should be used to the greatest extent possible. Carbon black should be completely avoided because its use prevents proper sorting or the recycling material is processed to the point where it has only limited use in very restricted low-price applications.

Minimising the contamination of secondary materials: The carryover of functional additives, glues, print dyes and coatings can lead to problems in the reuse of secondary materials. Consequently, such carryover should be avoided, for instance by assisting the separability of printing inks and inks or printed components during recycling (shredding, friction washing, filtration etc.).

Avoiding packaging involving very small components: Excessively intricate designs should be avoided if this is compatible with the purpose of the packaging. Packaging elements <2 cm are typically removed and not recycled. However, this does not mean that packaging should be oversized.

Ensuring that complete emptying of packaging is possible: Residual quantities remaining in the packaging can hinder collection and sorting and lead to disruptive contamination in the recycling process. For this reason, packaging should be designed so that it can be completely emptied.

Limits of Optimising Recyclability

Implementing Functional Key Requirements

As part of “design for recycling” optimisation, it must be ensured that functional key requirements (protection of packaged goods, information, marketing and logistics) are fulfilled at the level previously defined for the packaging project by all modified or newly developed packaging options.

Contrary to this basic premise, it may be useful to examine whether one or more of the core requirements can be modified if attempts to optimise the recyclability of the packaging under given limits do not lead to a satisfactory result. Such review and, if necessary, modification of core requirements must, however, be carried out in an orderly process, because the key requirements regularly play a role in other parallel optimisation processes of the entire packaging project, such as in logistics optimisation.

No Impairment of Resource Efficiency

If optimisation of the packaging for recycling is only possible by using relevant quantities of additional material (e.g. because only this ensures necessary barrier functions), this can lead to unintended environmental effects. Consequently, in such cases, critical review of optimisation is necessary. For this purpose, the following questions can be asked:

- What effort is required in order to optimise packaging for recycling?
- How much (environmental benefit) is achieved through recycling?
- What is the relative cost for maximum (material) reduction of packaging?

In an initial simplified test, the cumulative energy demand (CED) of packaging optimised for recycling less the CED of the secondary material recovered through recycling can be compared with the CED of packaging with minimised material usage. A realistic recycling rate should be used (e.g. 60 to 70 per cent).

Even in situations where it cannot be guaranteed that plastic packaging put into circulation will be completely recycled, in accordance with the concept of resource protection – in addition to design for high-quality recycling – the Eco design strategy elements “Design for Optimised Resource Use” should also be checked.

Facilitating the Use of Residual Materials for Energy

Depending on the efficiency of the sorting and recycling infrastructure in the particular delivery/disposal region, significant amounts of sorting and recycling residues may occur, even if the packaging itself is in principle easy to recycle. In the interest of resource conservation, packaging should consequently be designed in such a way that the highest possible proportion of the energy input bound in it can be recovered through thermal utilisation of such residual fractions. In keeping with this, the energy expenditure from the production of the packaging material should, if possible, not be too far above the calorific value of these materials, which is the decisive factor in thermal utilisation.

Consequently, for example, the use of materials that contribute nothing to thermal utilisation or even interfere with it should be avoided. For instance, this applies to layers of metallic laminate.

Procedure

In order to complete a review of a packaging option with regard to high-value recycling optimisation as part of an Eco design project, **four review steps** must be completed while carrying out the procedure described above:

1) **Reviewing the underlying framework conditions** of the end-of-life situation of the packaging in the various regions of use
2) **Reviewing recyclability** in reference to the existing sorting and recycling structures
3) **Reviewing energy recovery useability** of waste/scrap from sorting and recycling
4) **Reviewing a reduction of substance risks due to improper disposal**

Step 1: Reviewing the underlying framework conditions

At the outset, it must be checked whether there is any functioning waste collection system in the intended delivery region(s). An (orderly) waste collection system is a prerequisite for subsequent recycling. One general indicator of functioning waste disposal can, for instance, be that more than 90 per cent of household waste can be disposed of in an orderly manner. Furthermore, for effective recycling, it is important to ensure that a majority of waste packaging is sorted into separate fractions for recycling.

If the questions outlined for the (individual) delivery regions are answered in the negative, intensive consideration should be given to whether private collection and sorting structures can be set up. If necessary, these can be established in cooperation with other market players and possibly increased in their effectiveness by further incentives (such as deposit solutions).

Packaging that can be recycled well even using simple techniques (“recycling ready”) also provides important incentives for regional players to set up appropriate recycling structures. It is important that there are functioning recycling/marketing streams for all materials in the packaging (polymers).

The following are the review questions for the corresponding checklist:

Question	Instructions	Result
Is there a functioning waste collection system in the supply region?	If **YES**: continue. If **NO**: reconsider the decision to deliver to the region. Set up a private collection system (for example, a private deposit system). If necessary, state reasons and continue.	[Please fill in]
Are plastics in the total packaging waste material being sorted into separate fractions for recycling?	If **YES**: continue. If **NO**: consider setting up your own sorting/collection system. Check whether there may be an incentive for establishing sorting and recycling processes in the supply region through the use of *recycling ready* packaging *(i.e. strict application of step 2)*. Depending on regional disposal structures, packaging	[Please fill in]

Question	Instructions	Result
	should also be designed for energy production *(i.e. application of step 3)* or in the case of poorly developed forms of disposal with exceptionally low levels of pollutants *(i.e. application of step 4)*.	
Is there an established recycling stream for the main plastic material (in the recovery region)?	If **YES**: continue (*step 2*). If **NO**: select another primary plastic material for which a recycling stream exists in the supply region. Then continue (*step 2*).	[Please fill in]

As a result of these review steps, the waste disposal situations in the various supply regions and existing approaches to improvements to the situation that might be necessary have been examined and, if applicable, implemented.

Step 2: Reviewing Recyclability

Following an assessment of the basic conditions for the collection, sorting and recycling infrastructure in step 1, step 2 aims at establishing the prerequisites for successful sorting and high-quality recycling through a corresponding design of the packaging.

On the one hand, attention must be paid to suitable design (including labelling) of the packaging surface. This is a prerequisite in particular for correct disposal by the consumer but is also relevant for 'proper' sorting in sorting plants. Here, automated sorting technology detects the surface of the packaging, so that, for instance, an outer paper layer (or paper sleeve) can lead to incorrect sorting.

On the other hand, with regard to the actual recycling process:

- the materials used (i.e. the type of polymers and non-plastic components)
- material combinations (e.g. composite materials) that are difficult to or cannot be separated
- possible disruptions of the recycling process or the remnants of the recycling materials (e.g. from dyeing, ink adhesions or adhesive and foreign material residues) and
- avoidable fragmentation into very small parts

should all be tested and modified by means of appropriate optimisations in order to make them suitable for recycling.

It is a good idea to carry out this review of recyclability and further optimisation using tools or checklists that take into account the existing sorting and recycling structures in the particular disposal region or with the aid of experts familiar with these framework conditions.

The decisive review questions in the checklist for checking the recyclability of the packaging itself are shown below.

Question	Instructions	Result
Have readability and comprehensibility of information on the packaging regarding proper disposal been improved?	If **YES**: document changes made and continue. If **NO**: state reasons.	[Please fill in]
Is the surface of the packaging designed in such a way that the	If **YES**: document changes made and continue. If **NO**: state reasons.	[Please fill in]

Question	Instructions	Result
consumer/user can identify it as plastic?		
Has (if necessary) the surface of the packaging been adapted to enable sorting into the plastics fraction?	If **YES**: document changes made and continue. If **NO**: state reasons.	[Please fill in]
Can other polymers be used in order to increase recyclability?	If **YES**: document changes made and continue. If **NO**: state reasons.	[Please fill in]
Can the number of different polymers (taking the previous question into account) be reduced?	If **YES**: document changes made and continue. If **NO**: state reasons.	[Please fill in]
Have material combinations that are incompatible with recycling been avoided?	If **YES**: document changes made and continue. If **NO**: state reasons.	[Please fill in]
Has the pigmentation or dyeing of the packaging been reduced?	If **YES**: document changes made and continue. If **NO**: state reasons.	[Please fill in]
Has the pollution of the recycling material stream with dyes, glues and foreign material residue been reduced?	If **YES**: document changes made and continue. If **NO**: state reasons.	[Please fill in]
Has a compartmentalised design of the packaging been avoided?	If **YES**: document changes made and continue. If **NO**: state reasons.	[Please fill in]
Has it been determined that the packaging was recycling ready?	If **YES**: the packaging has a recycling-ready design. If **NO**: if necessary, modify the key requirements or review the design leeway and carry out recursion. Otherwise, the packaging is not recycling ready.	[Please fill in]

As a result of this review step, one or more packaging solutions which have (also) been tested for recyclability and, if necessary, modified are available => “recycling ready”.

Step 3: Reviewing Energy Recovery Useability

In the final step, not only is a review carried out to determine whether efficient energy recovery useability is possible with materials such as sorting and recycling residues, but also whether the risks of improper disposal exist and have been avoided as far as possible. The latter is particularly relevant for supply and disposal regions with imperfect disposal structures.

An appropriate standard for testing the efficiency of orderly thermal utilisation (e.g. in an incineration power plant) is the ratio of the energy used in the extraction and production of the packaging materials – expressed as “cumulative energy demand” (CED) – to the calorific value for thermal utilisation – expressed as “lower calorific value” (LCV). Both values can normally be provided by the subsuppliers. However, they are usually also included in the information about the material in life cycle assessment databases.

The following checklist has the corresponding review questions.

Question	Instructions	Result
Has the calorific value/CED ratio of the packaging been checked?	For a calorific value/CED **>50%:** the packaging is able to make a worthwhile contribution to energy recovery when used in appropriate plants. For a calorific value/CED **<50 %:** continue to the next question.	[Please fill in]

Question	Instructions	Result
Can the share of materials with a low caloric value–CED ratio be reduced?	If **YES**: carry out the new design and check the calorific value–CED ratio again. If **NO**: the packaging is not making any real contribution to energy recovery.	[Please fill in]
Is the packaging free of any further substances which could lead to environmental and health problems if improperly disposed of (especially if used as household heating material)?	If **YES**: packaging is "low in problematic substances". If **NO**: no supplying to regions with "critical" disposal structures or targeted changes to the composition/formula of packaging materials.	[Please fill in]

This review step results in one or more packaging solutions that have (also) been reviewed for their energy recovery useability and, if necessary, modified.