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## Summary

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# Environmentally-related balancing of "intelligent" and "active" packaging systems with regard to their recyclability and dialogue with stakeholders in the disposal and manufacturing industries

Summary

by

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## Application of active and intelligent packaging

Active and intelligent packaging systems provide extended functionality compared to traditional packaging. These technologies aim at improved product protection and/or enhanced information for the consumer. In recent years, increasing demands on product quality and safety could be noticed, accompanied by much R&D work on active and intelligent packaging systems.

The present study gives an overview of active and intelligent components used for packaging applications. Packaging systems based on plastics, metal, glass and paper were investigated. Passive barrier systems (e.g. EVOH layers or silicon oxide layers) were not included. The study investigated current and future application areas of active and intelligent systems. Their quantitative relevance for the German marketplace was estimated for the years 2015 and 2020, respectively.

**Active packaging systems** are systems which either deliberately emit (release) substances onto the packaging contents and/or into the packaging headspace or are systems which deliberately remove (absorb) specific substances. Examples of the former are antimicrobial systems. Examples of the latter include oxygen, moisture, ethylene, and odor absorbers.

Active packaging systems with oxygen and moisture absorbers are of particular relevance for the German marketplace. This is because of the importance of such packaging for many different pro-ducts. The following active systems are considered to have medium or high relevance for the current and future German marketplace:

- Bottle closures with sodium sulfite liners for beer
- Crown caps with sodium sulfite liners for beer
- Trays with iron-based absorbers for sterilizable ready-to-eat meals
- PET bottles with PA copolymer and cobalt catalyst for beer and fruit juice
- Sachets with moisture-absorbing substances for textiles, shoes, and electronic devices
- Absorbent pads with cellulose fibers and/or super-absorbers for fresh meat, poultry and soft fruit

In addition, polymer-based oxygen absorbers (polyoctenamers) may become important in the future for application in trays and films, for example, for meat.

There are other groups of active systems which are currently not used or little used in the German marketplace; no significant change is expected here over the next 5 years. One reason for this is current EU legislation which prescribes a relatively complex approval procedure for active materials. Indeed, there is much ongoing R&D work on antimicrobial systems, yet packaging materials with these systems are still not in widespread commercial use.

Active systems are mostly used in plastic packaging (see examples above) where they provide important additional functions. These functions include protecting the contents from oxygen or moisture which is not guaranteed by the plastics alone. Active systems are not widely used in glass or metal packaging because these materials have excellent intrinsic barrier properties. Only a few active systems are known for packaging made of paper, paperboard and cardboard and they are not in widespread market use.

**Intelligent packaging systems** make additional information available for consumers (and/or retailers). This may be information about the state of the packaging or contents or about the production date or storage conditions. This is achieved using various indicators (e.g. gas, freshness, or time-temperature indicators) and/or RFID transponders ("RFID tags").

Various types and designs of indicators are commercially available. The majority are labels containing indicator pigments which are attached to the inside or outside of the packaging by adhesives.

Such indicators are currently little used in the German marketplace but this is expected to change considerably over the next 5 years.

For cost reasons mostly passive RFID tags (without their own energy supply) are used for packaging. The use of RFID tags was investigated in 2009 in a study entitled "Impact of RFID tags on waste management" (Erdmann 2009). The main results of that study were confirmed by the present study. Accordingly, key future application areas with high expected growth rates are as follows:

- Postal items (parcels, letters)
- Textiles

With regards to primary and secondary packaging for foods and pharmaceuticals it is likely that volumes will be less than previous prognoses. The use of bar codes for identification continues to dominate in food retailing. For pharmaceuticals, systems without RFID technology are being trialed for traceability/protection against counterfeiting.

The mentioned intelligent systems can be combined with packaging made of various materials. Thus intelligent packaging systems based on paper, plastic, glass and metal are conceivable. Regarding the use of RFID tags, there are also applications in which the tag can remain in or on the product, for example textile labels attached to clothing

## The effects of active and intelligent packaging on the recovery of packaging wastes

Analysis of possible challenges is focused on the recovery paths and processes in which high-quality recycling of packaging currently takes place. High-quality recycling means recycling, the product of which replaces virgin material of the same type. Packaging which can be recycled with a high quality in this way are called recyclable.

Relevant designs of active and intelligent packaging are based on standard packaging plastics and are primarily collected in Germany via the so-called dual collection systems or rather, in the case of most drinks packaging are subject to mandatory deposit, via the retail and wholesale deposit system. Accordingly, active and intelligent packaging are sorted and recycled in the same systems as for the recycling of lightweight packaging (LVP) or rather drinks packaging (PET). In this study it was examined whether current and future use of active and intelligent packaging has a negative effect on the corresponding separation / sorting processes

- in relation to high-quality recycling of the active and intelligent packaging themselves and
- the process success of existing recycling streams, for example, with regard to quality and yield.

Generally, where active and intelligent components are used, the following groups of packaging systems occur, which can have a negative effect on high-quality recycling:

- composites and mixtures: multilayer packaging / polymer mixtures (blends) / solid polymer mixtures (additives in the plastic),
- fixed inserts / components bonded with the packaging,
- labels / RFID tags.

Recovery of these packaging systems can influence the following separation and sort criteria in particular:

- surface (chemical composition), e.g. in NIR grading,
- density, especially in float-sink separation,

- different melting temperatures in extrusion, including melt filtration.

The possible effects on high-quality recycling of currently relevant active and intelligent packaging are outlined in the following.

**Multilayer packaging / polymer mixtures (blends) / solid polymer mixtures**

High-quality recycling of plastic packaging is at present focused on providing recyclate made from standard packaging plastics (PE, PP, PET, PS). Packaging with multilayers, plastic blends or plastics mixed with additives often contain inseparable special plastics or non-plastic materials. As a result, regardless of any active or intelligent functions they may have, high-quality recycling of these packaging frequently does not exist.

In a multilayer composite, the active substance layers, for example oxygen or moisture barriers, are frequently located between other layers and can hardly be specifically detected by the usual surface measurement systems (NIR-sensor), and thus are not ejected from the process.

Effects on existing recycling processes can basically occur if composites, e.g. made of different plastic layers (multilayers), cannot be separated in the mechanical treatment and washing steps. The active and intelligent components contained in these composites can then not be separated from the target fraction in subsequent float-sink separation or in extrusion. Separation via float-sink methods is also not possible if the specific densities of the target fraction and the interfering substances are similar.

In the recycling process multilayers, blends and additives can be carried into the recyclate if their melting temperature is similar or lower than that of the original packaging plastic. If disturbing constituents such as multilayers, blends and additives get into the recyclate, among other things, they can have negative effects on its colour, mechanical properties and temperature resistance. This can lead to imperfections in the recyclate and these in turn to impairments during their use in production, for example, fracture of the preform for the production of PET bottles.

Problems for the actual recycling or treatment process can also result in extrusion, e.g. due to blocking of the nozzles or the melt filter and the associated additional cleaning work.

**Fixed inserts / components bonded with the packaging**

There is no high-quality recycling, either of fixed or loose inserts. Loose inserts such as sachets or absorbent inserts are separated during sorting and are ultimately recovered energetically. Fixed inserts, which are separated from the packaging body during crushing, are usually also removed with the residual materials of mechanical treatment.

Fixed inserts which cannot be exposed by crushing, can lead to quality and yield losses of the target fraction in subsequent float-sink separation or in extrusion.

**Labels / RFID tags**

Labels / RFID tags which detach are mainly removed with the residual materials of the treatment process and are then recovered energetically. Targeted recycling of labels / RFID tags therefore does not take place.

If they are input into the recyclate, among other things, labels / RFID tags can cause negative effects on its colour, mechanical properties and temperature resistance. Adhesive residues on packaging can result in discolouration of recyclates or, in the case of adhesives with low melting points, the formation of gas during extrusion.

The possible consequences for the respective material streams, which are associated with the use of active and intelligent packaging, can be very different. In addition, they do not become effective until

the fraction of active and intelligent packaging in the respective material stream increases significantly. Summarising, possible consequences are:

- Higher material and / or yield losses and a trend to larger quantities, which are excluded from high-quality recycling
- Mechanical and/or visual quality reduction in the recyclate, changes in the product properties (e.g. discolouration)
- Recycling cost increase due to higher treatment costs (e.g. due to additional sorting and / or washing stages)

Present day use of active and intelligent packaging does not create any noteworthy challenges for current sorting, treatment and recycling processes due to their predominantly small market share. In general, contamination e.g. of the recyclate is undesirable, especially if they result in a worsening of quality. Many of the problems listed, for example, density changes due to additives, are already a known problem in recycling, regardless of active and intelligent components of packaging.

## Recommendations for ensuring high-quality recycling

Based on an analysis of the possible effects of active and intelligent packaging on high-quality recycling and the involvement of experts from the packaging and disposal industry in interviews and in a dialogue event, the following recommendations for action were identified.

### Development of awareness, information and communication between the disposal and packaging industry and education and research

The design of packaging is subject to diverse requirements. Among other things, packaging should protect the product in the best possible way, be materially efficient and encourage people to buy. Recyclability frequently competes against such requirements or has a low priority from the outset in the packaging design. However, it often fails due to lack of or inadequate knowledge in the packaging industry, e.g. about existing recycling channels, about difficulties and requirements within the scope of sorting and recycling and especially about packaging design modification options, which enable improved recycling.

Two-way information and the development of knowledge about the demands and needs of participants in the life cycle of packaging are therefore central levers, which ensure the continued recyclability of packaging in the future which, for example, will also become increasingly more complex due to the use of active and intelligent components. It is essential to continue existing platforms or rather a suitable new platform for dialogue must be established. Possible platforms for increased dialogue are, for example:

- Web platforms
- Work groups
- Dialogue events
- Joint projects

### Matching packaging development to recycling requirements

Sorters and recyclers are basically aware of the challenges posed by specific packaging designs for recycling and have described these in corresponding design guidelines, such as the "European PET

Bottle Platform" (epbp.org) or the "Plastics Recyclers Europe" network (recyclass.eu), and have made them available to users.

For successful and across-the-board implementation of action it is important for the packaging manufacturers to adopt the recycling idea in their corporate philosophy and to win over packaging developers to the topic. In the company responsible persons should be named whose explicit focal tasks include the recyclability of packaging.

Reassessing the functionality requirements of packaging (e.g. maximum shelf life of the product) may open up options with regard to the use of more recycling-friendly materials. In particular, this requires internal and external persuading (e.g. of decision makers in the company, suppliers and customers), in order to increase the use of recycling-friendly solutions.

### Test series for specific products and materials to evaluate actual recyclability and effects on secondary products

Beyond the drafting of basic challenges and process solutions, the low quantity relevance makes it difficult to point out the problems which actually occur during recycling of specific packaging designs. In order to be able to assess these challenges better and to develop possible process adjustments, it is therefore constructive to analyse the actual recyclability or process effects of specific active or intelligent packaging and materials through tests in real sorting and recycling plants.

For implementation of these tests it is important that an incentive or the willingness to cooperation between packaging manufacturers and recyclers exists. It must be ensured that the required packaging materials are made available for appropriate test series. The test itself should be performed solely on the basis of changing parameters (e.g. fraction of active packaging in the input stream). On this basis reliable evaluation and assessment of the tests can be carried out and possible process adjustments and design recommendations can be deduced.

### Marketing for the use of recyclable packaging

The packaging requirements set by customers and thus, in particular, the trade, determine the packaging development and design significantly. However, few commercial enterprises or rather consumers nowadays attach specific importance to the ease of recyclability of packaging after use. In contrast, product marketing and functionality aspects are more important.

From the view of the recycling industry, manufacturers and packers, it is the retail and wholesale trade in particular which needs to be convinced of the need or advantages of the recyclability of packaging, with the objective that it in turn adopts recycling aspects in the corresponding requirements profiles for its packaging. It should also be informed of the interactions which certain functional requirements (e.g. longer shelf lives) can have on recyclability (e.g. the use of multilayers). If necessary, alternative design options should be suggested to commerce. Furthermore, consumers should also be provided with more information about recycling-friendly packaging, so that they can in turn indirectly motivate commerce to implement solutions.

One possibility for improving marketing specifically and for increasing the importance of the recyclability of packaging in the purchase decision is considered to be the creation of a seal or certificate, which provides information about the recyclability of packaging. Commerce could pick up on this and use the advantages of recyclable packaging for marketing its products to customers.

### Taking recyclability into account when calculating the licence fee for dual systems

Packaging manufacturers and distributors currently have no strong respectively economic incentive to pay greater attention to the recyclability of packaging. The licence fees which the distributors of sales packaging have to pay to the dual systems (in Germany) are an instrument which can develop basic influence on the design of packaging. However, at present the fee is calculated on the basis of a material-specific weight charge. Licence fee calculation could be extended to include the aspect of recyclability.

Compared to packaging solutions made of the same material but not suitable for recycling, good recyclable packaging can be recycled more easily, with better quality products and as a result in many cases more cost effectively. The resulting economic advantages should be reflected in the licence fees of the dual systems, in order to create an incentive for the packaging design of distributors.

The starting point for implementation is the model of material and weight-specific determination of the charges applied to date. Licence fee calculation is basically the responsibility of the dual systems. Additional consideration of recyclability therefore requires consultation with and harmonisation of all dual systems. One incentive for consideration of recyclability by the dual systems is provided by the working draft of the planned packaging law.