Webinar with Delara Burkhardt (MEP, S&D) and the German Environment Agency

How to make packaging more recyclable

Tools for measuring recycling compatibility and recyclability

Dr.-Ing. Joachim Christiani

Publicly appointed and sworn expert for packaging recycling
HTP Engineering company and Institute cyclos-HTP (CHI)

Thank you for the kind introduction and invitation to this conference.

The Environment Agency has invited me to give an overview about the instruments for measuring and assessing recyclability or recycling compatibility. This is a very abstract topic and I will try to illustrate basic methods and differences with some simple examples. On this basis, I would also like to classify the German minimum standard in the following.

Triggered by the media presence of the topic "packaging and environment" as well as political discussion and targets for the realization of a circular economy, recyclability of packaging has increasingly come into focus in the industry since 2018. The objective is uniform: packaging should be or become highly recyclable.

But what is recyclability and how is it to be measured?

Different perspectives, levels of knowledge, interests, **objectives** and **norm addressees** have in any case led to a large number of standards for the assessment. Some of these are contradictory at first glance.

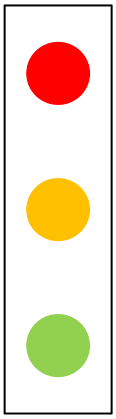
We may complain about this now; but, taking into account that the starting situations, addressees and objectives of tools can be quite different, this is already an understandable reason for differences.

To bring some order into the confusing situation, let me first define 3 basic types of standards.

Methodically, there are three basic types:

- Design for Recycling guidelines
- Design for recycling assessments
- Recyclability assessments

Design for Recycling Guidelines



Design for Recycling Guidelines are checklists for basically recyclable plastic packaging types in which the recycling compatibility of possible design and decoration details are evaluated. For other material types than plastics the use of guidelines is uncommon.

The usual evaluation scheme is simple: 3-level in traffic light colors.
Green for "**compatible**", orange for "**limited compatible**"; red means incompatible for a single property.

The norm addressees are packaging manufacturers and users of packaging.

Advantage is the easy handling without expert knowledge about recycling processes.

Disadvantage: rather theoretical; as a result of ordinal assessment actually only a qualitative instrument.

Examples: EPBP-, Recoup-, APR-, Ceflex-, COTREP-Guidelines

A simple example of a PET bottle with common equipment. The bottle has no barrier, has an innovative full-sleeve and a twist cap made of PP.

Shown below is the recycling compatibility classification of each feature according to the current EPBP Guidelines. The result:

2 times green and **3 times orange**; no property classified as red.
Can the colors be added together? Or what is the total result?
Guidelines do not provide an answer in this regard. Design for recycling assessments were being developed for this purpose.

Characterisation (fictitious)

- Material:	PET-A, transparent clear
- Additives:	UV-Stabilisers, AA-Blockers
- Closure-System:	PP-Cap, unfilled
- Liners, Valves:	-
- Direct printing:	Lot number and expiry date
- Sleeve:	Full-sleeve (PO, density < $1 g/cm^3$)
- Adhesives:	-

Classification according EPBP-Guidelines

- Material:	
- Additives:	
- Closure-Systems:	
- Liners, Valves:	-
- Direct printing:	
- Sleeve:	
- Adhesives:	-
Total score	**?**

Design for Recycling Assessments are therefore always guideline-based and link their ordinal classification with another ordinal evaluation scheme. As a result, the individual evaluations are summed up to a kind of school grade. Advantages and disadvantages are comparable to those of the Guidelines:

Advantage: Simple handling without the need of expert knowledge of recycling process technology. Easy to digitize.

Disadvantage: On a methodical point of view, purely qualitative assessment. Due to the double ordinal evaluation, certain distortions to reality are inherent in the system.

The best-known representative of D4R assessments is the RecyClass online tool.

1 x	-3	= -3
3 x	-1	= -3
4 x	0	= 0

Total score= -6

Our simple example in the fictional D4R assessment is shown in the next chart.

3 attributes were classified as orange in the underlying guideline and lead to deductions in the total score. The result is usually translated into plain text and means for example “conditional recycling compatibility”.

Characterisation (fictitious)

- Material:	PET-A, transparent clear
- Additives:	AA-Blocker
- Closure-System:	PP-Cap, unfilled
- Liners, Valves:	-
- Direct printing:	Lot number and expiry date
- Sleeve:	Full-sleeve (PO, density < 1g/cm^3)
- Adhesives:	-

Classification according (e.g.) EPBP-Guidelines

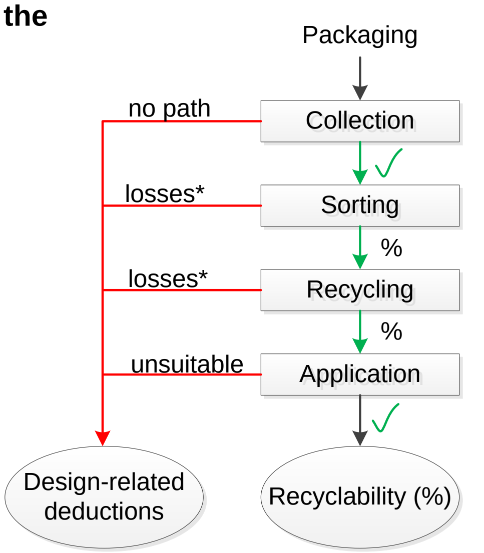
	Classification Step 1	Classification Step 2	
- Material:		x 0 =	0
- Additives:		x (-1) =	(-1)
- Closure-System:		x 0 =	0
- Liners, Valves:	-		-
- Direct printing:		x (-1) =	(-1)
- Sleeve:		x (-1) =	(-1)
- Adhesives:	-		-

Total score (-3) = limited compatibility

Recyclability Assessments

In science and technology, ordinal scales are avoided if possible. Quantitative measures are preferred because they are directly related to the actual economic and ecological impacts (for example life cycle assessment). Furthermore: If a company wants to claim recyclability, quantitative classifications are also required with reference to the relevant standards such as EN13430 and ISO14021. The central question to be asked:

Is the packaging recycled in practice and if so, how much does the packaging design allow?



Recyclability Assessment are used to answer this question. Recyclability assessments are therefore quantitative and qualitative accounting rules in comparison of the packaging properties with a reference process with intended recyclate use.

Thus, the result highly depends on the choice of the reference process.

The differences in this context:

- Are all stages included? That means collection - sorting - recycling - recyclate application?
- How are the single stages taken into account (for example, state of practice or BAT?).

Particularly important here is the definition of the **recyclate application used as a reference in a standard**, as this defines the qualitative process suitability of a packaging and thus existing incompatibilities.

In a figurative sense:

This defines the height of the hurdle that has to be overcome for the quantitative assessment parameter "recyclability". It is obvious that this hurdle is higher for an original application of the recyclate than for secondary or even non-specific applications.

For example: When evaluating an aluminium-based packaging, do you apply the level that aluminum packaging foil should become packaging foil again? Actually nearly impossible and not the practice. Or is it enough, if it is used to produce a cylinder head of an engine? Or is it even enough, if the metal is incorporated as oxide in cement clinker? Of course, the assessment of recyclability would be completely different for the applications named by example!

The rest is physics, and as we all know, physics is the same everywhere!

The methodological advantages of RAs are obvious: direct connection to the economic and ecological impact categories and maximum transparency. Furthermore, in principle, no subjective classification and limit value drawing are required.

Disadvantage: for a complex packaging not to be handled without expert knowledge of recycling processes.

Our simple example in the Recyclability Assessment, whereby a state-of-the-art recycling process for the use of recyclate in the original application is assumed as a reference.

A nationwide collection structure is given. It should be noted that sortability is also given (the fullsleeve does not interfere with the identification of the PET bottle). The sleeve can be easily separated in the recycling process, but is not recycled itself in practice. The sleeve share is deducted accordingly. The PET share of the bottle is in fact recovered. The additive contained cannot be separated, but does not significantly disturb the application in practice. The cap material is also separated and recycled in practice; it is therefore also credited. On balance, this results in a total score of 96 %.

Characterisation (fictitious)		**Composition**	
		weight	**%**
- Body:	PET-A, transparent clear, AA-Blocker	26,7 g	89 %
- Closure-System:	PE-Cap, unfilled	2,1 g	7 %
- Liners, Valves:	-		
- Direct printing:	Lot number and expiry date		-
- Sleeve:	Full-sleeve (PO, density < 1g/cm³)	1,2 g	4 %
- Adhesives:	-		

Evaluation according recyclability assessment
Reference process / application: bottle to bottle (or to film) state of the art process

	Description	**Evaluation**
Collection:	Nationwide available	✓
Sorting:	Sortable via NIR without restrictions	-
Recycling:	Sleeve can be separated but is not recycled; body is recycled, the cap material is also separated and recycled	+89 % +7 %
Application:	The minor direct printing and the additiv do not prevent the intended application	-
		Total score = balance 96 %

A brief interim conclusion:
The diversity of standards results not least from their different functions!

Further relevant facts have to be taken into account both for a development as well as for the application of a standard. In simple terms, recyclability means "conformity of packaging design with the requirements of the recycling process."

This does not end with the recycler but with the user! The standard is therefore largely determined by the intended recycling applications used for assessment.

These interdependencies are illustrated below using the example of the minimum standard.

The requirements for the minimum standard are derived directly from the German Packaging Act.

Here are the relevant extracts from the legal text in which the relevant specifications for the minimum standard are formulated:

The norm addressees are the dual systems. A set of regulations is required for ECO modulated fees; that means: for the interface between EPR system and the manufacturer. Furthermore, an instrument for all types of materials is required. The legislator obviously did not want any misdirection to be taken by privileging individual types of material.

Incentives are to be given for "**high percentage recovery**".

The reference system is also specified: The practice of sorting and recycling is to be used as a reference. Reference application is defined by the substitution of material-identical virgin material, meaning original or secondary use of recycled material is required.

Therefore, the minimum standard is already assigned to the Recyclability Assessments by law.

§ 21 packaging law: Ecological modulation of participation fees

(1) **Systems** are obliged to create incentives within the framework of the assessment of the participation fees, to ensure

1. the use of **materials and material combinations that allow the highest percentage possible to be recycled, taking the practice of sorting and recovery into account**

(3) In agreement with the Federal Environment Agency, the Zentrale Stelle publishes **a minimum standard for the assessment of the recyclability of packaging subject to system participation by September 1st of each year, taking into account the individual recycling paths and the respective material type.**

Note!: The minimum standard is a specific Recyclability Assessment and not a D4R-guideline

At the beginning of the work on the development of the minimum standard, in addition to a precise definition of recyclability by the expert group, an examination of the standards existing at that time was also carried out for compatibility with the legally required parameters. The result is shown in simplified way in the following table and can be summarized as follows:

No existing standard offered a satisfactory solution for the legal duties.

However, on this basis, the expert group consisting of representatives from brand manufacturers, retailers, dual systems, waste management companies, sorters, recyclers, packaging manufacturers and converters of all material groups developed the specific solution proposals.

In principle, the Minimum Standard is a Recyclability Assessment, whereby the national-specific features such as nationwide collection for all packaging types and materials are already integrated.

I have already explained the basic methodical features. There are two criteria with binary evaluation and two groups of criteria with analogue measurement. The qualitative requirements for the packaging design are defined by the definition of the "valuable material content" on the one hand and the incompatibilities specified for the reference process on the other.

	EN 13430	CHI-RA	RecyClass online-Tool	D4R-Guidelines (Recoup, COTREP, etc.)	PTS RH 021/97 inter alia
Quantitative measurement (percentage)	✓	✓	✗	✗	✗
Applicability to all packaging material types	✓	✓	✗	✗	✗
References High quality recycling / recyclate application	✗	✓	✓	✓	✓
Practice of sorting and recycling (in Germany)	✗	✓	(✓)	(✓)	(✓)
User-friendly (suitable for a large number of different packaging (sales) units)	✗	✗	✓	✓	✗

Some examples to illustrate the application of the minimum standard:

Example 1 is a plastic tube with filled laminate. This is sorted into the PP fraction in Germany; the washed, recycled PP generated from the process chain is used in injection moulding and thermoforming applications and substitutes virgin material here; thus, fulfils the qualitative requirement set in the minimum standard. The basic score according to the minimum standard corresponds to the PP content of the packaging; that means 94 percent. The yellow colored tube is easy to sort by NIR as PP. After grinding in the recycling process, however, laminate content is lost in the float-sink separation because it is highly filled. There are no incompatibilities that would lead to a total deduction of the recyclable material share according to the minimum standard.
Final result: 61 % Recyclability

Note: The minimum standard does not specify a threshold value above which packaging is considered recyclable. Users usually set a target value greater than 90 %.

Example 1

Composition:

Tube laminate (PP-EVOH-PP)	
PP (filler content 40 %)	33 %
EVOH – tie layer	5 %
PP-shoulder / head	19 %
Cap (PP)	42 %
Printing, lacker	1 %

Recyclability Assessment according minimum standard

Reference process & application in practice	PP-stream / PP-injection moulding or trays	
Basic score = valuable material content	PP-content	94 %
Path	Nationwide collection and sorting in PP-stream	✓
Sortability	Detectable and sortable via NIR	± 0 %
Separation (grinded material)	Loss of the laminate because of density >1g/cm³	- 33 %
Incompatibilities / reference application PP-injection moulding or trays	None	✓
Total score = available valuable material content = Recyclability		**61 %**

Example 2 the same tube, now with a lower filler content, so that the entire recyclable content can also be generated.
On balance: 94 %

Example 2

Composition:

Tube laminate (PP-EVOH-PP)	
PP filler content 8 %	33 %
EVOH, tie layer	5 %
PP-shoulder/head	19 %
Cap (PP)	42 %
Printing, lacker	1 %

Recyclability Assessment according minimum standard

Reference application in practice	PP-injection moulding or trays	
Basic score = valuable material content	PP-content	94 %
Path	Nationwide collection and sorting in PP-stream	✓
Sortability	Detectable and sortable via NIR	± 0 %
Separation (grinded material)	Loss of PP because of density >1g/cm³	± 0 %
Incompatibilities / reference application PP-injection moulding or trays	None	✓
Total score = available valuable material content = Recyclability		**94 %**

Another possible tube design would be to use an aluminum foil instead of EVOH as an oxygen barrier.

In practice, such a tube with an aluminum layer would be sorted into the aluminum stream. At best, the aluminum share of the packaging would then be recovered in the aluminum path. In practice, the recyclability of such a design would amount to a maximum of a few percentage points.

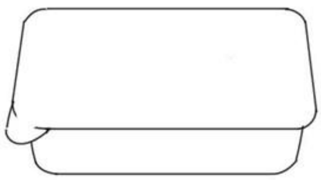
The last two examples are intended to illustrate the handling of incompatibilities in the Recyclability Assessment. Furthermore, the focus should also be directed to the fact that deficits concerning recyclability are not a plastics-specific issue.

Example 3 is a fictional paper composite packaging. Although there is a recycling path for this in Germany. The functional barrier and the wet-strength finish lead to significant deductions for this example. The recycling incompatible property of sticky formation finally leads to the result "zero percent".

Example 3

Composition:

Multilayer cartboard, kraft paper	80 %
Adhesives	5 %
Plastic coating	14 %
Lacquers	1 %



Recyclability Assessment according minimum standard

Reference process & application in practice	Paper composite stream / corrugated based paper	
Basic score = valuable material content	Fiber content	80 %
Path	Nationwide collection and sorting in the paper composite stream	✓
Sortability	Detectable as paper only from one side	-40 %
Separation (repulpability)	Low defibration (60 %) in practice due to wet strength design	-16 %
Incompatibilities	High stickyness	✗
Total score = available valuable material content = Recyclability		**0 %**

The last example is a glass packaging that is painted black for functional or for marketing reasons. The bottle body is made of soda-lime glass, which is basically recyclable and could be remelted into new container glass. However, the black lacquering leads to the total loss of the cullet, because it cannot be recognized as glass in an optical transmission measurement, which is state of the art as well as state of practice.

Example 4

Composition:

Bottle, soda-lime-glass	95 %
Plastic closure	3 %
Lacquering, direct printing	1,5 %
Tamper-proof seal	0,5 %

Recyclability Assessment according minimum standard

Reference process application in practice	Container glass	
Basic score = valuable material content	Glass content	95 %
Path	Nationwide collection and waste glass processing	✓
Sortability Separation	Not detectable in the optical (transmitted light measurement)	- 95 %
Incompatibilities	None	± 0 %
Total score = available valuable material content = Recyclability		**0 %**

I hope that these explanations have given you a first overview of the methods for measuring recyclability. You can find more about recycling and recyclability on our websites.

A final message from my side:

On the question of "How to make packaging more recyclable?", standards for measurement and classification of recyclability have a very important function, because they set the benchmarks for the development of ecologically optimized packaging design.

However, the function of standards is not to be understood in a one-sided way; they must be used as a functional dynamic tool to bring packaging design and recycling technology closer together, step by step.

Thank you for your attention.

Contact details

HTP GmbH & Co. KG
Maria-Theresia-Allee 35
52064 Aachen
info@htp.eu
www.htp.eu

Institut cyclos-HTP GmbH
Maria-Theresia-Allee 35
52064 Aachen
info@cyclos-htp.de
info@cyclos-htp.de