18 April 2024

Laminating Adhesives in Flexible Plastic Packaging Recycling - report (2024)

Contents

Background

Flexible packaging is a highly successful format for protecting a wide range of products, both consumer and industrial. Flexible packaging comes in very different sizes, from small candy packaging to large industrial bags and sacks, and in various performance levels from offering mainly protection from dust and water to sterile and high-barrier packaging that substantially extends the shelf life and safety of food, pharmaceuticals, and medical products.

Compared to rigid packaging made from plastics and other materials, **flexible plastic packaging** offers environmental benefits through its unique material efficiency (i.e., thinness and lightness).[1] At the same time, the recycling of flexible plastic packaging is today less developed than the recycling of rigid packaging. While studies show that even in the absence of recycling, flexible plastic packaging can, by nature of its lightness, outperform other packaging formats in terms of carbon footprint[1], concerns over littering and illegal waste exports to third countries have raised attention for the wide-scale implementation of an effective recycling system for flexible plastic packaging in Europe.

Across numerous platforms, a technical conversation on how to best design flexible plastic packaging for the existing and upcoming recycling infrastructure in the European market is ongoing. As part of this discussion, the **compatibility** of different elements in packaging designs, including adhesives, with the processes of waste sorting and recycling is actively discussed.

This report seeks to summarise the current state of play in terms of how a specific group of adhesives, namely **laminating adhesives,** are reflected in **design-for-recycling guidelines** and in **sortability and recyclability testing** for flexible plastic packaging. It includes suggestions on how the specification and recognition of laminating adhesives in these documents may be further improved, recognising both their importance for the manufacture of fit-for-purpose flexible plastic packaging and the needs of sorting and recycling operators.

Laminating adhesives

Most flexible plastic packaging is composed of two or more layers of plastic or non-plastic films, each fulfilling a specific function, such as sealability, product protection, and tear or puncture resistance. These layers need to be bonded together by laminating adhesives (liquid chemistry) or alternatively by coextrudable resins (solid chemistry) depending on the process and end-use requirements.

The most common technology in use is polyurethane laminating adhesives as they exhibit excellent adhesion to a wide range of film and foil substrates paired with resistance to filling goods (i.e., aqueous, greasy or spicy foods) and thermal stress (enabling pasteurisation or sterilisation inside the packaging), as well as low migration potential due to their inert nature, ensuring food safety. Polyurethane laminating adhesives are extremely versatile, allowing flexible packaging converters to design a variety of formats, from standard sachets to stand-up pouches and many others. The flexibility offered by laminating adhesives is of great value not only in the traditional multi-layer multi-material flexible structures, but also in mono-material versions, recently introduced, or in development with the objective to improve the overall recyclability of flexible packaging.[2] Also, in the case of multi-layer mono-materials, lamination enables the achievement of the necessary

[1] Flexible Packaging Europe (2024): Resource Efficiency - Prevention - Flexible Packaging Europe (flexpack-europe.org)
[2] CEFLEX Position Paper (September 2020): 'Accelerating the circular economy for flexible packaging – a recommendation for recyclable mono-materials'

mechanical and barrier properties fundamental to maintain the mechanical integrity along the entire supply chain and the effective preservation of the goods/food. Some examples of laminated mono-materials are reported in Fig. 1. Beyond polyurethane laminating adhesives, acrylic laminating adhesives can also be used to produce multi-layer laminates for flexible packaging.

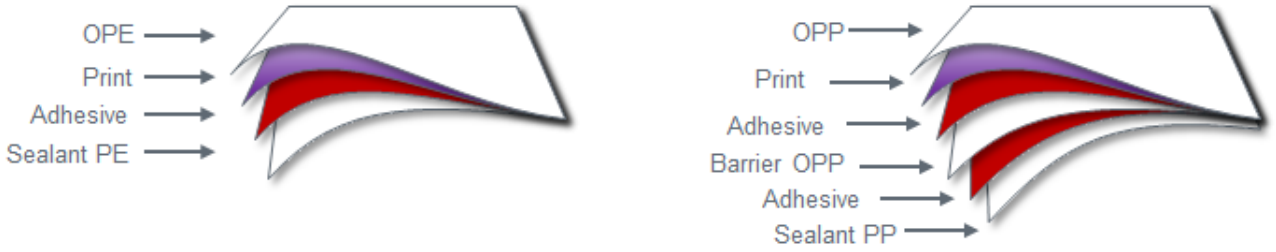

Fig.1: Examples of Polyethylene (PE) based and Polypropylene (PP) based mono-material structures.

A more detailed description of adhesives used in packaging can be found in the FEICA report 'Terminology and Definitions to Be Used in the Context of Adhesives in the Recycling of Packaging' [2].

Recycling of flexible plastic packaging

The aim of any recycling process is the recovery of a **target material** in highest possible yield and purity. In the specific case of recycling of flexible plastic packaging, the target material is generally either a specific polymer type, mainly low-density polyethylene (**LDPE)** or polypropylene (**PP),** or a combination of these two polymers.[3]

The dominant process for PE and PP plastic packaging recycling today is **mechanical recycling**, and this process is also applied for the recycling of flexible plastic packaging**.** This process can, in a simplified fashion, be described in terms of the sequential steps of:

1. **Collection** of packaging waste
2. **Sorting of packaging** in sorting facilities to create homogenous waste streams
3. **Shredding** of the sorted waste materials into flakes to prepare them for further processing
4. **Washing** of the plastic flakes, to remove contamination and, in some cases, labels
5. **Density-based separation** to remove non-target material[4]
6. **Extrusion** of the cleaned and sorted flakes into pellets of recycled plastic

The step of extrusion comprises several sub-steps which occur in line:

1. **Melting** of the plastic flakes through the action of temperature and mechanical shear
2. **Homogenisation** of the molten plastic
3. **Vacuum degassing** to remove volatile substances and gases from the melt
4. **Filtration** of the melt to remove non-thermoplastic materials and agglomerates
5. **Pelletisation**, through cooling and subsequent cutting of a solidified strand of the extruded plastic

[3] In certain locations, so-called 'mixedPO' recycling exists. This recycling pathway mixes PE and PP for recycling into a blend, potentially also blending flexible and rigid packaging waste. The term 'mixedPO' refers to the fact that the resulting recyclate is neither a pure PE nor a PP, but a mix of these two polyolefin (PO) polymers.

[4] In specific cases sensor-based sorting can be used to separate flakes that are made from other types of plastics than the target material. This can further improve the quality of the recyclate.

The **recyclability** of (flexible) plastic packaging is determined by any factor which negatively impacts one or several of these **processing** steps in terms of their yield, productivity or process stability, and by factors which negatively impact the **quality of the output**, i.e., the recycled plastic.

In addition to the primary material flow from plastic packaging waste to recycled plastic, side products / waste streams are created, for example, residues and wastewater from washing steps, materials that are removed by the melt filter of the extruder, and gases and volatiles removed in vacuum degassing**.** Recyclability considerations may include these side streams as well.[5]

Design guidelines for flexible plastic packaging

Over recent years, several guidelines have been published which describe design-for-recycling principles and requirements for flexible plastic packaging.[6]

These **design guidelines** describe which elements and features of a finished packaging, such as inks, coatings, decorations and adhesives, are considered either preferable or discouraged from the standpoint of recyclability in mechanical recycling processes. Design guidance is typically provided in terms of categories of '(full) compatibility', 'limited / conditional compatibility' and 'low compatibility'.

Table 1 provides an overview of entities that publish design guidelines for flexible plastic packaging in Europe and globally. Table 3 (see Annex) provides an overview of adhesive-related statements made in these guidelines.

Table 1: Non-exhaustive overview of design guidelines for flexible plastic packaging (guidelines marked in bold contain specific provisions for laminating adhesives).

	Europe	Global
LDPE	**CEFLEX[3]** COTREP[4] DSD[5] FH Campus Wien[6]* RECOUP[7]* **RecyClass[8], [9]** Suez[10] ZSVR[11]	**APR[12]** CGF[13] PACSA[14]* WPO[15]*
PP	**CEFLEX[3]** DSD[5] FH Campus Wien[6]* RECOUP[7]* **RecyClass[16], [17]** Suez[10] ZSVR[11]	CGF[13] PACSA[14]* WPO[15]*

* Mentions 'adhesives' but effectively refers to only labelling adhesives.

[5] Such considerations, however, are not (yet) implemented today in prevalent test methods or design guidelines.

[6] At the point of writing, no specific design guidance for the compatibility of plastic packaging designs with recycling technologies other than mechanical recycling is available publicly. Novel technologies such as physical (dissolution) recycling or chemical recycling may provide for wider windows of acceptance for certain non-target materials in plastic packaging (waste) but may also have specific requirements of their own. As mechanical recycling will remain a dominant, and often environmentally preferable, technology for some time, and since a designer of packaging cannot freely choose or determine which recycling process their packaging will eventually enter, it is unlikely that separate guidance will be developed for physical and chemical recycling technologies, unless a specific separate collection route exists. Rather, the specifications for packaging design in guidelines will consider compatibility with all state-of-the-art recycling processes simultaneously.

Several guidelines generally recommend the **minimisation of applied adhesive**. The reduction of non-target materials to the possible minimum whilst assuring their functionality is a general principle in design-for-recycling.

Most guidelines assume that laminating adhesives will not be removed before extrusion and therefore enter the recycling process. Guidelines which specifically cover laminating adhesives consequently focus on the compatibility of the adhesive with that process and their impact on the quality of the recyclate.

The **CEFLEX guidelines[3]** (Phase 1, 2020) consider up to 5 weight% of polyurethane- and acrylic-based (laminating) adhesives as fully compatible and above 5 weight% to be of limited compatibility. At the time of writing, a testing campaign is ongoing to provide supporting data and refine thresholds.

The **RecyClass guidelines for coloured LDPE films[8]** (Version January 2024) also recognise polyurethane and (water-based) acrylic laminating adhesives as compatible, but with different limits (up to 3 wt% for full and up to 5 wt% for limited compatibility). For natural LDPE films[9], only aliphatic polyurethane laminating adhesives up to 2.5 wt% are considered as having limited compatibility. All other adhesives are required to be tested specifically.

Aside from the general specifications of compatible adhesive types in these design guidelines, **specific approvals** have been generated by RecyClass and APR for several laminating adhesives, [7,8] demonstrating that they can, when suitably designed and applied within certain conditions, be **fully compatible** with recycling of flexible plastic packaging.

Assessment of flexible plastic packaging recyclability

Several **test methods** have been established to assess the sortability and recyclability of flexible plastic packaging (Table 2) and generate product-specific confirmation (and approvals) of technical recyclability. These methods typically seek to mirror and simulate the process steps in waste sorting centres and mechanical plastic recycling[9] facilities (as described in the chapter 'Recycling of flexible plastic packaging'). In particular, test methods typically seek to assess the following:

1. Sortability
2. Processability
3. Mechanical performance and visual appearance of the recycled plastic

[7] For Europe, for example: https://recyclass.eu/wp-content/uploads/2022/12/2022-PO-005-Dow-technology-approval.pdf, https://recyclass.eu/wp-content/uploads/2022/12/2022-PO-006-Dow-technology-approval.pdf, https://recyclass.eu/wp-content/uploads/2021/11/2021-PO-012-Henkel-technology-approval-letter.pdf, https://recyclass.eu/wp-content/uploads/2021/11/2021-PO-011-Henkel-technology-approval-letter.pdf, https://recyclass.eu/wp-content/uploads/2021/09/2020-PO-004-Bostik-technology-approval-letter.pdf, https://recyclass.eu/wp-content/uploads/2023/07/2022-PO-001-Polysack-technology-approval-VF.pdf, https://recyclass.eu/wp-content/uploads/2023/09/2023-PO-007-COIM-technology-approval-v1.pdf and https://recyclass.eu/wp-content/uploads/2023/07/Technical-Review-Laminating-Adhesives-v2.pdf

[8] For North America, for example: https://plasticsrecycling.org/images/Critical-Guidance-Letters/APR-CGR-PEFILM-additive-dow-2021-2.pdf, https://plasticsrecycling.org/images/Critical-Guidance-Letters/APR-CGR-PEFILM-adhesive-henkel-2021.pdf

[9] At the time of writing, no specific test method for determining the compatibility of plastic packaging designs with recycling technologies other than mechanical recycling is available publicly. Novel technologies such as physical (dissolution) recycling and especially chemical recycling differ strongly in their processes from mechanical recycling and thus cannot reasonably be approximated by applying a test method that simulates mechanical recycling.

To assess sortability and recyclability, in addition to a **test method**, which provides the procedures and defines what numerical results are to be reported, an **assessment scheme** is required, which provides threshold values (pass/fail criteria) to apply to the data coming from testing. The assessment may also take the form of a committee decision rather than a written procedure or decision tree with fixed thresholds.

Table 2: Test methods for determining the sortability and recyclability for flexible plastic packaging (non-exhaustive list).

	Europe	Global
Sorting	RecyClass[19] cyclos-HTP[10]	APR[11]
LDPE film recycling	RecyClass[18] COTREP[19],[20] cyclos-HTP[21]	APR[22]
PP film recycling	RecyClass[23] cyclos-HTP[24]	

Besides the general 'Recyclabilty Evaluation Protocol for PE Films' [18] mentioned in Table 2, RecyClass has recently also published a 'Recyclability Evaluation Protocol for Laminating Adhesives applied on PE Films'.[12] According to this, the compatibility of laminating adhesives is measured by their impact on specific parameters related to both processing behaviour and quality of the recyclate. Cyclos-HTP has published a requirements and assessment catalogue for the verification and examination of packaging recyclability.[13] Depending on the packaging type and examination focus, different testing methods and paths are described.[14]

Adhesives in the (flexible) plastic recycling process

Laminating adhesives, just like other non-target materials, are required to be compatible with recycling processes for flexible plastic packaging, so as to not disturb the process itself or the quality of its output.

In the **preparatory steps** of mechanical recycling, i.e., sorting, shredding and washing, laminating adhesives are not known to have any impact on the behaviour of packaging waste.

> No cases of laminating adhesives affecting the **sensor-based sorting** of plastic waste have been reported in relevant studies.[15] Laminating adhesives are applied in two thin layers to influence near-infrared (NIR) based sorting. As their applications are generally colourless and transparent, no impact on colour sorting is expected.[16]

[10] CHI-C2-NIR, NIR Test for the Detection and Sorting Performance of Packaging, Version 3.0
[11] Several documents from the APR-SORT series
[12] RecyClass website testing protocols: https://recyclass.eu/recyclability/test-methods/
[13] Cyclos-HTP(2021): Anforderungs- und Bewertungskatalog - Institut cyclos-HTP
[14] Cyclos-HTP(2024): CHI test methods - Institut cyclos-HTP
[15] 'Near-infrared classification and sorting test programme' (Testing: Results - CEFLEX D4ACE). Paragraph 4.13, Table 18
[16] Nor could they be expected to be picked out in manual sorting operations or steps, as they are not visible to the naked eye.

As laminating adhesives are generally not pressure-sensitive ('sticky') adhesives, no issues with the **shredding** of flexible packaging waste into flakes have been reported in relevant studies[25].

No cases of laminating adhesives affecting **density-based sorting** of plastic waste have been reported in relevant studies. The weight share that laminating adhesives represent in a flexible packaging is low, often in the range of less than 5 weight%. Therefore, even if the density of a laminating adhesive were to differ substantially from that of the plastic material, the adhesive's impact on the overall density of the packaging item would be negligible.

Any material in the recycling input which is not target material should either be **removed** during the process or be sufficiently **compatible with the recycling process and the target material.**

A **removal** of adhesives during mechanical recycling may, in principle, occur by removing the adhesive with the process water during **preparatory steps** (in the case of water-soluble or water-dispersible adhesive applications) or by mechanical separation in the **filter of the extruder**.

Washing processes for flexible packaging waste today are generally mild (cold wash or up to 40 °C), with no added caustic soda or detergents. However, the application requirements placed on flexible packaging typically require laminating adhesives to be highly resistant against liquids (such as the filling goods), and the adhesive is located in between water-impermeable plastic layers. Therefore, it is technically contradictory to ask for laminating adhesives to be dissolved or dispersed in washing processes for flexible packaging waste. **A removal of the laminating adhesives with wash water is therefore generally not to be expected.** Likewise, a contamination of the wash water with laminating adhesives is not to be expected.

As the conditions of **density-based separation (flotation)** are even milder than those of washing, no effects on laminating adhesives are expected or have been reported.

Although laminating adhesives do not melt, they partly **pass melt filtration** and become part of the recycled plastic. [25]

Materials which are not removed before extrusion are required to not negatively impact the **extrusion process**. The key criteria for the acceptability of the presence of laminating adhesives passing into the recyclate are impacts on the **quality of the recyclate.**[17]

Many laminating adhesives are designed for high thermal resistance, for example, to allow packaging to be hot filled or sterilised, and to ensure resistance to hot climates and sunlight. According to current knowledge, most **laminating adhesives are not expected to undergo substantial decomposition** under the conditions of PE and PP extrusion. The absence of strong discoloration or formation of gases during extrusion has been demonstrated for a number of laminating adhesives.[18] These studies have also shown the absence of odour or strong impacts on mechanical performance.

[17] Mechanical performance, visual appearance and odour.

[18] For example, see [25] and https://recyclass.eu/wp-content/uploads/2022/12/2022-PO-005-Dow-technology-approval.pdf, https://recyclass.eu/wp-content/uploads/2022/12/2022-PO-006-Dow-technology-approval.pdf, https://recyclass.eu/wp-content/uploads/2021/11/2021-PO-012-Henkel-technology-approval-letter.pdf, https://recyclass.eu/wp-content/uploads/2021/11/2021-PO-011-Henkel-technology-approval-letter.pdf, https://recyclass.eu/wp-content/uploads/2021/09/2020-PO-004-Bostik-technology-approval-letter.pdf, https://recyclass.eu/wp-

Laminating adhesives have in some publications and statements been associated with the **formation of gels** (localised defects) in films made from recycled plastics. However, this is not true for all laminating adhesives as was shown in a wealth of approvals and studies.[19] Therefore, the proper selection of adhesives with focus on laminate production, use phase and end-of-life should prevent the formation of gels in the extrusion process.

While laminating adhesives are generally found to pass extrusion without large changes to their chemical composition on a trace level, the formation of chemical **degradation products** from laminating adhesives cannot be ruled out.[20] Such traces can be of relevance for the use of recycled plastics in contact-sensitive applications, such as food contact.[21]

Recommendations

To develop **design guidelines for flexible plastic packaging** further in terms of clarity, applicability and benefit to the quality of recycling, while recognising the importance of laminating adhesives in packaging design and production, the following aspects should be considered:

- **Acknowledge the minimisation approach for adhesive applications but ensure the approach is followed uniformly for all non-target material**, i.e., any non-target material. This would recognise universally valid principles while ensuring that adhesives are not held against a higher standard than other materials.

- Express specifications for adhesives in the form of **required recyclability assessment properties** (for example: maintenance of the colour and optical aspect of the recyclate)[22] or by specifying their **chemistry**, rather than specifying their function (e.g., 'laminating adhesives for the lamination of PET films'), reactivity (e.g., 'reactive adhesives', 'two-component adhesives') or delivery form (e.g., 'solvent-based', 'water-based').

- **Distinguish laminating adhesives from labelling adhesives** as they differ in their use cases, differ in their chemistry, and are subject to different functionalities.

- **Do not require laminating adhesive to show thermoplastic behaviour**, as the application and food contact safety requirements placed on flexible plastic packaging typically require laminating adhesives to be reactive chemistry, and as full compatibility with recycling has already been demonstrated for numerous non-thermoplastic laminating adhesives. [18]

- **Do not require laminating adhesives to be water-soluble or water-releasable**, as the application requirements placed on flexible packaging typically require laminating adhesives to be highly resistant against liquids (such as the filling goods) and as full compatibility with recycling has already been demonstrated for numerous non-water-soluble or releasable laminating adhesives. [18]

content/uploads/2023/07/2022-PO-001-Polysack-technology-approval-VF.pdf, https://recyclass.eu/wp-content/uploads/2023/09/2023-PO-007-COIM-technology-approval-v1.pdf and https://recyclass.eu/wp-content/uploads/2023/07/Technical-Review-Laminating-Adhesives-v2.pdf

[19] See footnotes 7 and 8.

[20] In particular, the formation of primary aromatic amines (PAAs) from aromatic polyurethane laminating adhesives at high temperatures is well known[26], and analytical methods to determine their presence are defined[27].

[21] The use of plastic recyclates in food contact articles and materials is governed by Regulation (EU) No 2022/1616.

[22] As is the case in some existing recyclability protocols in Table 2 and the upcoming CEN standard under mandate 584 of 1 August 2022: https://ec.europa.eu/growth/tools-databases/enorm/?fuseaction=search.detail&id=610

- Ensure that the **technical data sheets or safety data sheets of a laminating adhesive** - which describe its delivery form - **are not used as the source of information on the (water-) solubility, solvent content, melting behaviour or any other property of the final adhesive application.** The properties of an adhesive may change substantially between its delivery form and its final applied form in the packaging material, and it is the latter which enters recycling. Differences arise, for example, due to removal of water and solvents from adhesives during application and drying, as well as due to curing and setting processes.

- **As a general principle, allow for testing to override guidelines**. If a specific laminating adhesive or product design can be shown to meet all criteria of an accepted test method and assessment scheme, then this finding should be allowed to override the more generic statements in a design guideline.[23]

- Ensure that **effects are attributed to adhesives only where a clear causal relationship can be established** (e.g., residues on melt filters, pressure increases and gas formation during extrusion). They may all result also from other components of flexible plastic packaging, unless the sample under investigation contains, aside from the adhesive, only materials of known behaviour during recycling.

Next steps – Outlook

Due to its benefits – especially in terms of material use, light weight and appealing design, fast processing, and logistics – flexible plastic packaging is enjoying great popularity with brand owners, retailers and consumers. It is one of the most versatile packaging formats enabled by laminating adhesives that bond different thin materials with unique functions and protection properties. Adhesives play a key role enabling low packaging to product ratios while keeping packed goods protected and preventing food waste. Considering the whole life cycle, flexible packaging often contributes, on the one hand, to minimise environmental impact by lower carbon footprints compared to other packaging formats.[24] On the other hand, it contributes to environmental pollution when littered and where no suitable recycling infrastructure exists. In addition, its low material utilisation benefit and its composite structure mean that flexible packaging is more unattractive in its end-of-life treatment than heavy weight target materials. To resolve this trade-off and to follow circularity objectives set by the European Commission, the contribution of all levers, from compatible packaging designs over intelligent sorting to suitable recycling technologies, is required.

Several design guidelines have been already published, and harmonisation among associations is ongoing while packaging design implications on recycling are still evolving. To date, mechanical recycling is efficient for well sortable thermoplastic waste streams going into end-applications not always requiring recycled plastics of virgin-like quality. Addressing the possibility to mechanically recycle flexible packaging, the entire value chain has worked to replace, where possible, traditional multi-layer, multi-material flexibles with multi-layer, mono-material flexibles.[25] In this context, laminating adhesives are still essential to provide, through bonding together substrates with different

[23] For example, if polyurethane laminating adhesive applications overall are to be recognised as having only 'limited compatibility' in a guideline, give consideration to recognising adhesive applications that pass relevant testing as 'fully compatible'. As a second example, according to RecyClass guidelines for PE Films and PP Films, 'Laminating adhesives specially developed for high thermal applications above boiling and/or high chemical resistance ' are required to be tested. However, also these kinds of adhesives could be classified as fully compatible if tested with positive results.

[24] Food Lifecycle Studies - Flexible Packaging Europe (flexpack-europe.org)

Flexible Packaging Association (flexpack.org)

FPE-ifeu_study_FMCG_pack_waste_EU (flexpack-europe.org)

[25] CEFLEX Position statement: Accelerating the circular economy for flexible packaging – a recommendation for recyclable mono-materials

functionalities, the required properties for the final packaging (as mentioned in the paragraph on laminating adhesives on pages 2-3). The behaviour of laminating adhesives in standard mechanical recycling processes is still under active investigation, and **knowledge is evolving**. This is evidenced by the large number of studies and approvals occurring.

Chemical recycling should be considered as complementary to mechanical recycling. Heavy investigations into chemical recycling techniques, such as gasification, pyrolysis, hydro-cracking or depolymerisation, are currently carried out, as they would be suitable for applications requiring recycled plastics of virgin-like quality. Those can be regulated applications (e.g., food-contact, medical), technically demanding or safety-critical applications (e.g., automotive structural parts).[26] Likewise with mechanical recycling, depending on the chemical recycling technique, a certain number of hetero-materials are tolerable. Due to the small quantities and their chemical composition, adhesives are not expected to cause issues based on residue requirements.[27]

Other advanced recycling technologies, like selective dissolution, are also under development. However, in most cases, the supporting infrastructures for these forms of advanced recycling are still missing. To further improve the quality of recyclates, pioneer projects focus on the subject of deinking and debonding of multi-layer laminates. In the case of laminated mono-materials, delamination technologies could ease subsequent deinking. In the case of multi-layer, multi-material packaging, delamination technologies could offer the possibility to separate materials and to send them to different recycling streams, thus increasing recyclate values.

Overall, with all initiatives ongoing, further improvements in recyclability of flexible packaging laminates are expected. Therefore, it is important to keep the openness to evolving technologies in legislative and guiding frameworks allowing further innovation work.

[26] Plastics Europe 2022: Chemical Recycling in Brief • Plastics Europe and 1689304_ChemicalRecyclingOne-pagerCopy_082223 (plasticseurope.org)
[27] IVK 2023: IVK_Adhesives-in-the-Circular-Economy.pdf (klebstoffe.com)

References

[1] 'Comparative Life Cycle Assessment of different pouches and alternative packaging systems for food (Pasta Sauce and Olives) on the European market'.
[2] 'Terminology and Definitions to Be Used in the Context of Adhesives in the Recycling of Packaging'. FEICA, 2021.
[3] 'Designing for a Circular Economy - Recyclability of Polyolefin-Based Flexible Packaging'. CEFLEX, 2020.
[4] 'The Guidelines - Films and PE flexible (January 2023)'. COTREP, 2023.
[5] 'Design for recycling'. DSD Der Grüne Punkt, 2018.
[6] 'Circular Packaging Design Guideline - Empfehlungen für recyclinggerechte Verpackungen (Version 5)'. FH Campus Wien, 2022.
[7] 'Plastic Packaging Recyclability by Design 2021'. RECOUP, 2021.
[8] 'Design for recycling guidelines: Coloured PE Flexible Films for Household and Commercial Packaging'. RecyClass, January 2024.
[9] 'Design for recycling guidelines: Natural PE Flexible Films for Household and Commercial Packaging'. RecyClass, January 2024.
[10] 'The Suez.circpack Design for Recycling Guidelines for Packaging'. suez, 2019.
[11] 'Mindeststandard für die Bemessung der Recyclingfähigkeit von systembeteiligungspflichtigen Verpackungen gemäß § 21 Abs. 3 VerpackG'. Stiftung Zentrale Stelle Verpackungsregister, 2022.
[12] 'Design guide: PE film'. APR. [Online]. Available: https://plasticsrecycling.org/pe-film-design-guidance.
[13] 'Golden Design Rules for Optimal Plastic Design, Production and Recycling'. Consumer Goods Forum, 2021.
[14] 'Design for Recycling for Packaging and Paper in South Africa'. PackagingSA, 2017.
[15] 'Packaging Design for Recycling'. World Packaging Organisation (WPO), 2021.
[16] 'Design for recycling guidelines: Coloured PP Flexible Films for Household and Commercial Packaging'. RecyClass, January 2024.
[17] 'Design for recycling guidelines: Natural PP Flexible Films for Household and Commercial Packaging'. RecyClass, January 2024.
[18] 'Recyclability Evaluation Protocol for PE Films (Version 5.0)'. RecyClass, January 2024.
[19] 'Test protocol Flexible PE-1: Regeneration of flexible PE household packaging'. COTREP, 2022.
[20] 'Test protocol Flexible PE-2: Production of recycled PE films by blow extrusion'. COTREP, 2021.
[21] 'CHI-C8-PEF-1 Recycling Application Compatibility Test for PE-based Flexible Packaging (Version 4.0)'. Institut cyclos-HTP, 2023.
[22] 'FPE-CG-01 Critical Guidance Protocol for PE Film and Flexible Packaging'.
[23] 'Recyclability Evaluation Protocol for PP Films (Version 4.0)'. RecyClass, January 2024.
[24] 'CHI-C8-PPF-1 Recycling Application Compatibility Test for PP-based Flexible Packaging (Version 3.0)'. Institut cyclos-HTP, 2021.
[25] 'Laminating adhesives', presented at the RecyClass webinar series 'Science behind recyclability', 2023.
[26] R. Pela, 'Primary Aromatic Amines in Relation to EU Regulations'. Henkel, 2021.
[27] 'FEICA recommendation to adhesive suppliers and users on the assessment of PAAs in polyurethane adhesives intended to be used in food packaging'. FEICA, 2022.

Annex I. Laminating adhesive-related statements made in design guidelines

Table 3: Laminating adhesive-related statements found in design guidelines (excerpts).

Entity and material	Full compatibility	Limited compatibility	Low or no compatibility
RecyClass – natural LDPE films*	'Laminating adhesives approved as fully compatible by RecyClass; To be tested if in combination with a barrier material'	'Aliphatic polyurethanes ≤ 2.5%; Laminating adhesives approved as limited compatible by RecyClass; To be tested if in combination with a barrier material'	'Aliphatic polyurethanes >2.5%; Aromatic polyurethanes & Water-based acrylics; Laminating adhesive specially developed for high thermal applications above boiling and/or for high chemical resistance (to be tested); Any other laminating adhesives (Epoxy, etc.)'
RecyClass – coloured LDPE films*	'Polyurethanes and water-based acrylics ≤ 3%; Laminating adhesives approved as fully compatible by RecyClass; To be tested if in combination with a barrier material'	'Polyurethanes and water-based acrylics 3-5%; Laminating adhesives approved as limited compatible by RecyClass; To be tested if in combination with a barrier material'	'Polyurethanes and water-based acrylics >5%; Laminating adhesive specially developed for high thermal applications above boiling and/or for high chemical resistance (to be tested); Any other laminating adhesives (Epoxy, etc.)'
RecyClass – natural PP films*	Aliphatic polyurethanes <= 2.3%; Laminating adhesives approved as fully compatible by RecyClass; To be tested if in combination with a barrier material	Aliphatic polyurethanes between 2.3% and 4.5%; Laminating adhesives approved as limited compatible by RecyClass; To be tested if in combination with a barrier material	Aliphatic polyurethanes > 4.5%; Aromatic polyurethanes; To be tested: Acrylics; Laminating adhesives specially developed for high thermal applications above boiling and/or for high chemical resistance; Any other laminating adhesives
RecyClass – coloured PP films*	Polyurethanes <= 3%; Laminating adhesives approved as fully compatible by RecyClass; To be tested if in combination with a barrier material	Polyurethanes between 3 and 4.5%; Laminating adhesives approved as limited compatible by RecyClass; To be tested if in combination with a barrier material	Polyurethanes > 4.5%; To be tested: Acrylics; Laminating adhesives specially developed for high thermal applications above boiling and/or for high chemical resistance; Any other laminating adhesives
CEFLEX – PE and PP films	'Polyurethane, acrylic or natural rubber latex adhesives, as well as non-PE or non-PP based tie-layers, are permitted to a maximum of 5% by weight of the total packaging structure'	'Above 5% of total packaging structure weight'	'To be determined'
APR – LDPE films		'Laminating adhesives: detrimental'	

* As of January 2024

Contact

This document was developed by the FEICA expert group on Sustainability & Recycling of Adhesives in P&P Applications

FEICA Regulatory Affairs:
Jana Cohrs (j.cohrs@feica.eu)
FEICA is registered in the **EU Transparency Register** with ID no. **51642763262-89**

FEICA - Association of the European Adhesive & Sealant Industry
Rue Belliard 40 box 10, 1040 Brussels, Belgium
Tel: +32 (0)2 896 96 00
info@feica.eu | www.feica.eu

Publication ref.: RAM-EX-N03-005

This document has been designed using the best knowledge currently available, and is to be relied upon at the user's own risk. The information is provided in good faith and no representations or warranties are made with regards to the accuracy or completeness, and no liability will be accepted for damages of any nature whatsoever resulting from the use or reliance on this paper. This document does not necessarily represent the views of all member companies of FEICA.

Copyright © FEICA, 2024 - This document contains confidential information and is intended for FEICA members, for working i.e. internal use only. No other use may be made without the prior written permission of FEICA. If you are not the intended recipient you are notified that disclosing, copying, distributing or taking any action in reliance on the contents of this information is strictly prohibited.