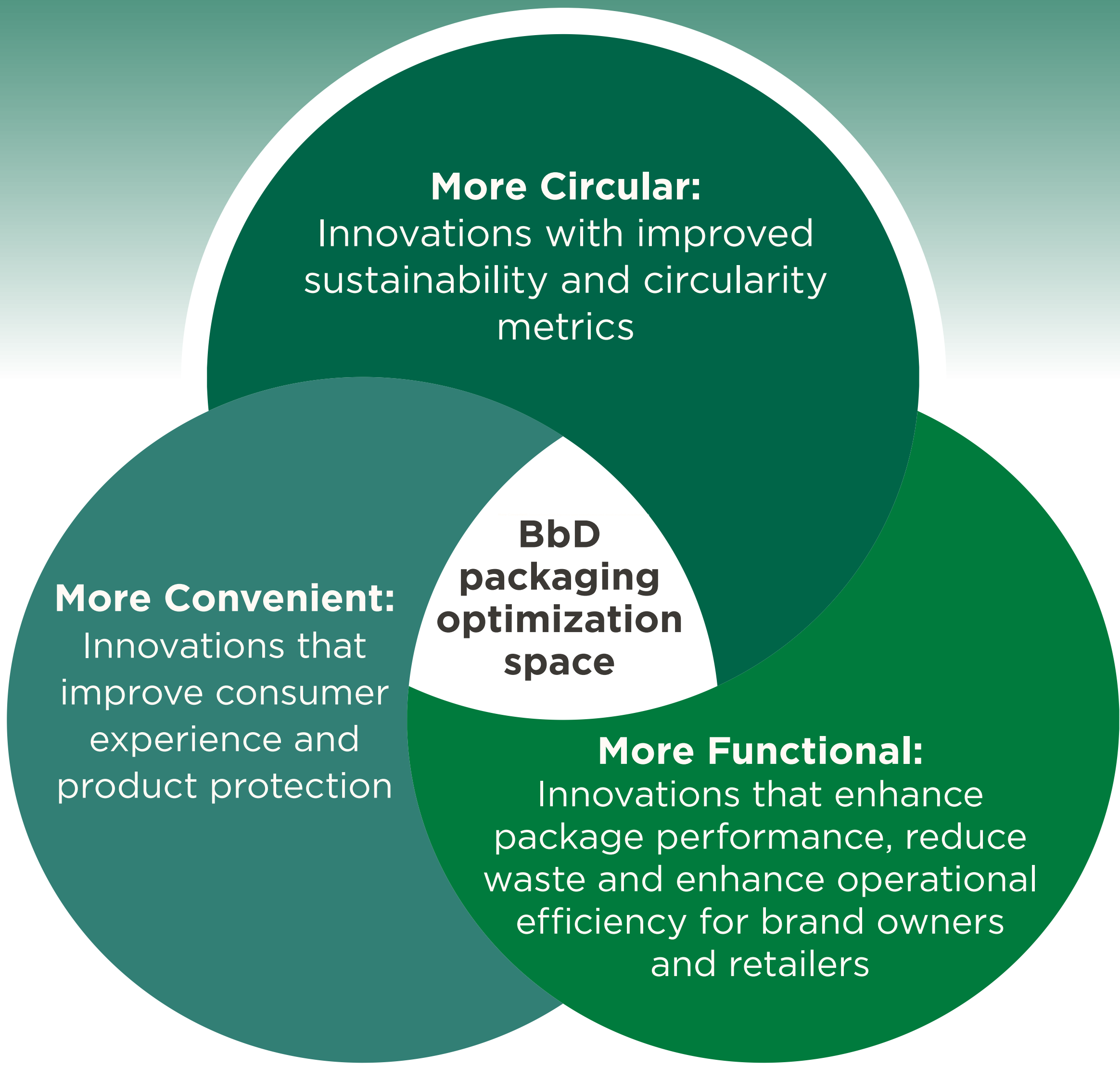
Better by Design Framework to Support Packaging Circularity, Functionality and Convenience



Graphic Packaging INTERNATIONAL

Introduction

The Ellen MacArthur Foundation's first principle — design out waste and pollution — notes that ~80% of a product's environmental impact and its fitness for the circular economy are primarily determined during the design phase.

In our previous eBook, "Unwrapping Circularity: The Power of Design for Environment in Paperboard Packaging Design", we discussed how integrating Design for Environment (DfE) principles into product design can reduce packaging's lifecycle environmental impacts and improve circularity.

We have now named the framework we developed to support our Better Packaging goals, "Better by Design" (BbD), as it covers more than the external DfE methodology. In this latest eBook, we present how our BbD framework ensures our design decisions support our Driving Circularity goal, which requires each new product innovation to be more circular and demonstrate at least one functionality and convenience positive differentiator compared to the incumbent packaging.

We consider the functionality of the packaging from the perspective of the brand owners and retailers, where the right packaging meets the operational requirements, improves performance, reduces waste and the impact across the value chain.

We consider packaging convenience to improve the user experience and product protection, driven by consumer insights. The acceptance of the pack on the market is key to making sure it has a more beneficial impact for the planet vs. the current solutions at scale.

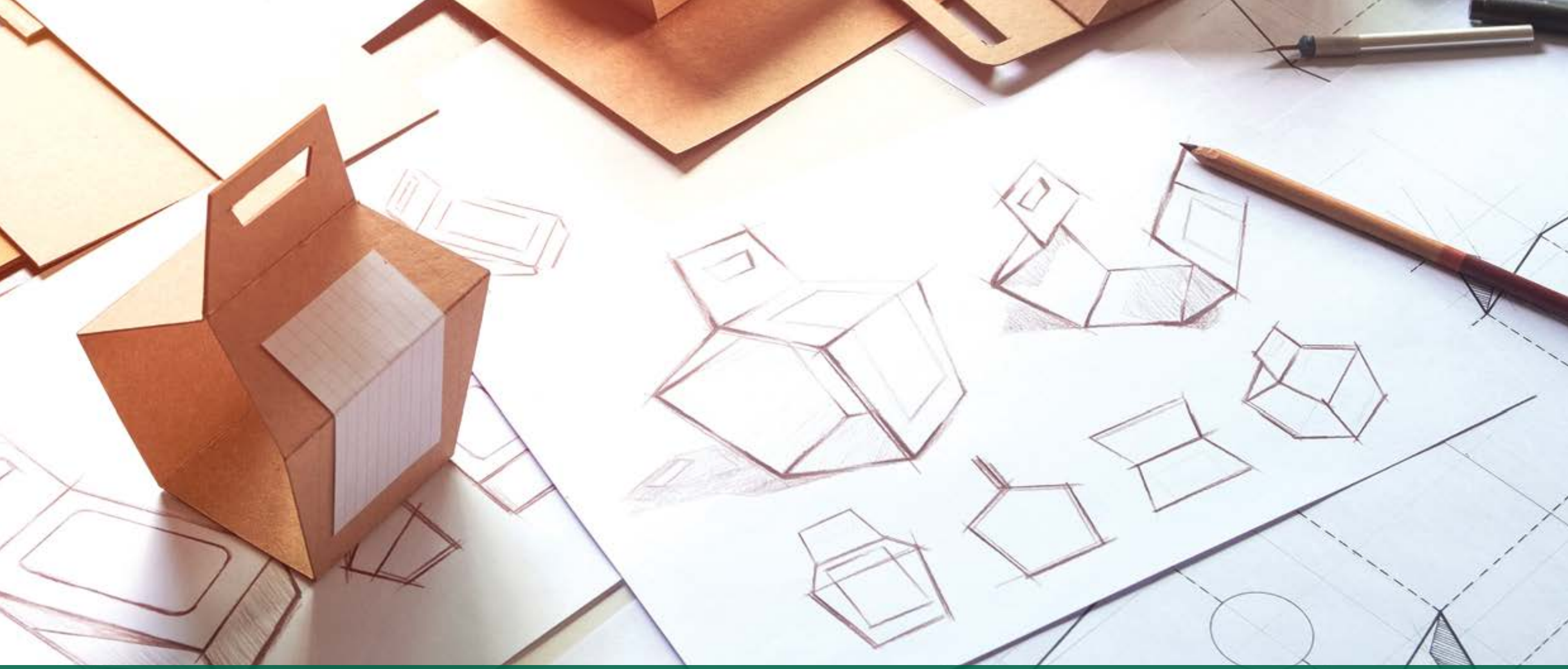
Among the options that meet the above requirements, we consider options that lead to maximized circularity, carefully choosing their composition and design, as well as maximizing their compatibility with circular end of life.

Trade-offs between different metrics and a customer's sustainability priority must also be considered to achieve a lower carbon footprint. This framework also helps us comply with current and known emerging regulatory requirements.

In addition to reviewing the framework, this document also provides a case study, illustrating how we apply BbD to our ProducePack™ Punnet solution.

We will expand the use of the BbD framework and underlying circularity and carbon footprint calculation tools in addition to functionality and convenience measurements as part of our innovation process. We are keen to support our customers' sustainable packaging goals with a third-party reviewed approach, and we will continue improving the approach as new standards and requirements become available.

*We are proud to report that our framework has been critically reviewed by **Ramboll**, a global consultancy company with more than 18,000 experts that create sustainable solutions for governments and companies all over the world, and has a great expertise on circularity applied in other studies for our sector. Ramboll's review concluded that the BbD framework and underlying circularity assessment methodology and calculation tools developed by Graphic Packaging are solid and transparent in providing a science-based comparison of the developed innovation and the applicable market benchmark.*



Better by Design

This is the second eBook on our Better by Design (BbD) methodology. The first[1] introduced the BbD concept, giving background on its importance and an overview of some of the key sustainability and circularity metrics embedded within. This second eBook describes Graphic Packaging's BbD methodology in more detail, reviewing the circularity metrics we consider, as well as introducing our approach to assessing functionality and convenience. We then demonstrate BbD as applied to one of our innovation platforms from 2024. The methodology described here represents our current version of BbD, where the initial packaging circularity aspects have now been complemented with those related to functionality and convenience, to help drive and support the tracking of our Better by 2030 Driving Circularity goal, that states that by 2030, every new product innovation will be more circular, more functional, and more convenient than existing alternatives. We acknowledge that the methodology will continue to evolve into the future, for example, to reflect the evolving regulatory landscape.

In an era where the call for environmental responsibility echoes louder than ever, the packaging industry stands at the forefront of change. As consumers become increasingly aware of the environmental impact of their choices as well as of waste, and as climate change climbs higher on the global agenda, the need for circular solutions has never been more pressing. Regulatory shifts and evolving customer demands are reshaping the landscape, urging companies to reevaluate their approach to packaging design and production.

Design plays a pivotal role in minimizing the environmental impact of packaging and maximizing its compatibility with a circular economy. In response to this, we have developed our BbD methodology, which also serves as a foundation for meeting our Better by 2030 Driving Circularity goal stated above. As a follow-up to our previous eBook, this guide deep-dives into the BbD methodology, including a case study from one of our innovation platforms.

1. **https://www.graphicpkg.com/resources/unwrapping-circularity-the-power-of-design-for-environment-in-paper-board-packaging-design/**

BbD Methodology

The BbD optimization space lies at the intersection of packaging circularity, functionality, and convenience (Figure 1). The packaging must be more circular to meet the exponentially growing expectations to reduce packaging waste and the environmental impact of packaging; it must be more functional, to help improve efficiency and reduce the environmental impact along the value chain; and it must be more convenient, so that the consumer chooses the packaging, thereby unlocking its circular and functional benefits.

The current and known emerging regulatory requirements are also considered for each dimension to inform the need to evolve our designs.

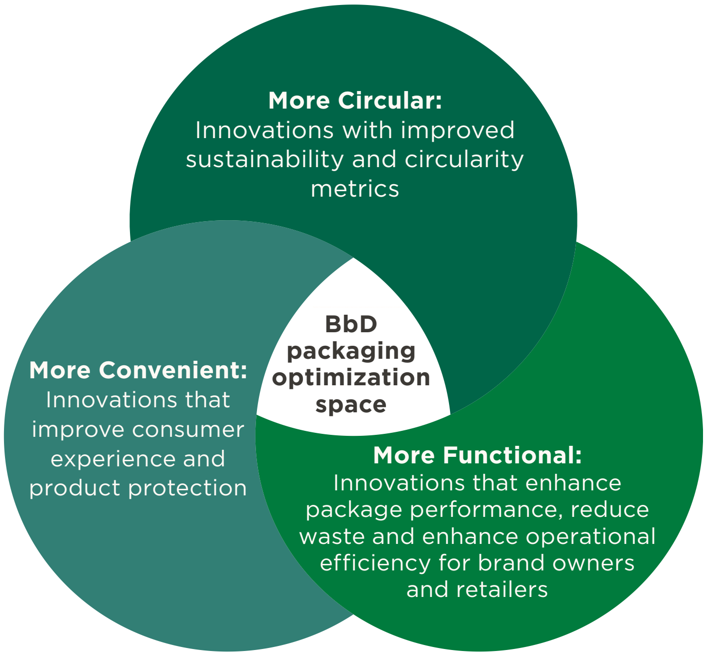


Figure 1: Schematic overview of Better by Design

BbD supports a continuous improvement journey that requires measuring performance and progress, generating the facts and proof points about a package's performance that matter most. By integrating more standardized metrics for circular, functional, and convenience dimensions, we can demonstrate transparently and objectively the benefits of selected packaging options. We outline in more detail our approach to each dimension, more circular, functional, and convenient, on the following pages.

More Circular

We are committed to making our packaging more circular by integrating more renewable, recycled, and sustainably sourced raw materials into our products; designing products so they are resource efficient and can be recycled, composted, or reused at end-of-life; and updating our packaging manufacturing facilities to use more renewable energy, reduce waste, and embrace circular principles. Together with intentional material selection and combination, these actions also ensure the carbon footprint of the packaging we design is as low as possible. We also consider current and known emerging safety and sustainability-related regulatory requirements, among others, to ensure our solutions are safe and sustainable
by design.

As such, we have defined a set of measures, assessments, and scoring criteria to quantitatively assess improvements in packaging circularity, see Table 1 on the following pages.

The circular economy is a system where materials never become waste and nature is regenerated. In a circular economy, products and materials are kept in circulation through processes like maintenance, reuse, refurbishment, remanufacture, recycling, and composting. The circular economy tackles climate change and other global challenges, like biodiversity loss, waste, and pollution, by decoupling economic activity from the consumption of finite resources.

Ellen MacArthur Foundation

Table 1. Overview of the Circularity metrics used in the BbD methodology

	Metric	Assessment Criteria	Scores (compared to benchmark)	Relevance of Metric for Sustainability: Graphic Packaging Solutions
Material Composition	**Weight/ minimization**	Packaging weight, volume, wall thickness and empty space ratio. Assessment method currently under development in the international standardization bodies.	Positive (+), Neutral (=), Negative (-)	Many impacts will be reduced along the value chain. Weight may also need to be minimized to match new regulatory requirements in a way that fulfills the packaging functional criteria and is specific to the packaging material used, e.g. in the Packaging and Packaging Waste Regulation (PPWR)[1].
	Recyclable content % (paper content % for fiber-based packaging)	The weight fraction (%) of the packaging as a whole that is available to be recovered as recyclate through the respective material-specific recycling process. **Paper content** is the weight fraction (%) of the total pack comprising the sum of fiber, filling material, starch, coating color including binder, as well as additives typically used in the paper industry, such as wet-strength agents, glue and bound water, specifically in the paper fraction of the pack (ISO 4046 Paper, board, pulps and related terms — vocabulary). Excludes any of the above-listed materials that may be present in the barrier coating/lamination or other non-paper components.	Positive (+), Neutral (=), Negative (-)	In some countries, recyclable content is relevant to recyclability criteria and/or collection thresholds. In addition, increasing paper content often leads to maximized yield in recycling.
	Renewable content %	Material composed of biomass from a living source that can be continually replenished (ISO 14021). Excludes recycled content to avoid double-counting and difficulties in proving material origin.	Positive (+), Neutral (=), Negative (-)	Supports the transition away from fossil-based materials to renewable ones. Can come from the paperboard or barrier fraction, e.g., bio-based coatings, inks, varnishes or adhesives, among others. Relevant for innovations aimed at replacing fossil-based materials with renewable ones or where we replace plastic packaging with paperboard solutions. Often an enabler for reducing the CO_2 footprint and improving the circularity of the product. Many of our paperboards additionally use widely available minerals such as clay in coatings, which are naturally occurring, as opposed to fossil-based materials, but are not considered as renewable content.
	Plastic content %	Includes plastic coatings, films, or other components such as lidding, sealing film, etc. Excludes natural non-modified polymers as well as polymers used in adhesives and varnishes (following the Single-Use Plastics Directive definition[2])	Positive (+), Neutral (=), Negative (-)	In some countries relevant to recyclability or collection criteria. Often an enabler for reducing CO_2 footprint and leading to improvement in circularity, as well as being linked with voluntary pledges on plastic reduction targets across the value chain.
	Recycled content %	The proportion of recycled material by mass, considering only pre- and post-consumer recovered materials, following definitions of ISO 14021 in general (or for recycled content in Graphic Packaging paperboard, the US Environmental Protection Agency).	Positive (+), Neutral (=), Negative (-)	Can come from the paperboard or other materials such as barrier, inks, varnish, and adhesive. May be linked to value chain targets to use more recycled material, or to avoid specific plastic taxes, or reduce extended producer responsibility (EPR) fees. Generally leads to improvement in circularity.
	Excludes toxic/ persistent chemicals	Aligns with regulatory requirements confirmed via a document of compliance in terms of the safety of materials used and the cradle to cradle list of raw materials, among others.	Yes, No	Basic requirement as an enabler for the usability of the packaging and circular economy in terms of use of secondary raw materials. Criteria especially relevant when substituting problematic compounds like PFAS.

1 **Regulation (EU) 2025/40**
2 **Directive (EU) 2019/904**

	Metric	Assessment Criteria	Scores (compared to benchmark)	Relevance of Metric for Sustainability: Graphic Packaging Solutions
Environment	**Carbon footprint**	CO_2e estimated directionally on a cradle-to-gate or cradle-to-grave basis using primary data wherever possible or representative industry average dataset available from commercial LCA software. Approach disclosed on a case-by-case basis and consistent with international standards ISO 14040 and ISO 14044	Positive (+), Neutral (=), Negative (-)	Relevant to climate goals in terms of reducing value chain scope 3 emissions. In case the functionality of the packaging may vary or potentially the product wastes, it may be relevant to consider the carbon footprint for the packed product together with the packaging given the environmental impact of a product is generally much greater than that of its packaging.
Environment	**Additional LCA parameters (optional)**	Added in the case a specific metric from an LCA study that would be relevant for the specific case study beyond CO_2e, e.g., land use, water consumption, etc.	Positive (+), Neutral (=), Negative (-)	Provides a more holistic view of the environmental impact of the packaging designs, following recommendations for Green Claims.
End of Life	**Design for Recyclability**	For paperboard packaging, based on industry design guidelines such as 4evergreen for the EU and AF&PA for the USA. Recyclability is assessed based on the presence of any design elements classified as not recyclable, conditionally recyclable, or otherwise classified as widely recyclable. In cases where the packaging is technically recyclable, but collection is limited, e.g., in the foodservice sector, or requires a take-back program, the packaging may be classified as locally recyclable. For flexibles, based on CEFLEX Design for Recyclability guidelines.	Widely Recyclable, Conditionally Recyclable, Locally Recyclable, Not Recyclable (see **page 21** for definitions)	Aligned with many value chain commitments, plastic pacts & pledges, and our own goal for all our packaging innovations to be more circular than the replaced alternative. Will become mandatory in Europe via the PPWR in 2030. Particularly relevant when replacing a non-optimally recyclable packaging, removal of any component disrupting recycling, e.g., two-sided coating, wax dipping, or full metallization of the outside surface of the packaging.
End of Life	**Actual current recycling rate %**	Based on the material category and region (e.g., EU Eurostat 2023[1] for standard packs or US EPA[2] : 2018. Where possible, recycling rates specific to certain pack formats should be used, e.g., fiber-based composites, PET trays, or end-use applications, e.g., food service.	Positive (+), Neutral (=), Negative (-)	Especially meaningful to show the "actual" improvement in recyclability when comparing different materials. Also relevant for demonstrating recyclability at scale and in practice, which will also be part of PPWR compliance in the EU.
End of Life	**Reusability by Design**	Packaging which has been conceived, designed, and placed on the market with the objective to be re-used multiple times within a system of reuse and to accomplish as many rotations as possible in a system for reuse (ISO 13429).	Yes (number of achievable rotations), No	In some cases, it may be seen as a more circular strategy than recycling. Secondary packaging reuse may complement refillable primary packs or those part of deposit and return schemes. Could become increasingly mandatory by law in some sectors. Advantages should be proven by LCA.
End of Life	**Biodegradability/ compostability**	Specify environments (industrial compost, home compost, soil or marine biodegradability). Based on testing meeting the requirements of international standards such as ISO 13432, ASTM 6400 or ASTM 6868. For industrial composting, there must be a system or infrastructure in place to support this claim.	Yes, Unknown, No	An alternative circular approach if recyclability is not possible. The reason for considering it may be product/ food residues that may prevent recyclability, or in some regions, the absence of sufficient recycling infrastructure. Minimizing environmental persistence in case of littering may only be a secondary reason, but should never be encouraged.
Circularity	**Material Circularity Indicator (MCI)[3]**	Based on the methodology developed by the Ellen MacArthur Foundation giving a value in the range 0 (perfectly linear) to 1 (perfectly circular).	Positive (+), Neutral (=), Negative (-)	Provides a holistic measure of circularity, including not only recyclability but also considers material origin (recycled, renewable, reused or virgin), recycling efficiency and production waste.

1 **Eurostat Packaging waste by waste management operations**
2 **Containers and Packaging: Product-Specific Data | US EPA**
3 **Material Circularity Indicator | Ellen Macarthur Foundation**

Wherever possible, the circularity assessments are based on international standards, detailed compositional analysis, or regulatory requirements. Recyclability scoring criteria considers legal requirements on a national or regional level and in the future, will include requirements set forth by the Packaging & Packaging Waste Regulation (PPWR) in the EU, the proposed California Senate Bill 54: reporting, packaging and plastic food service ware in the USA, or specific other rules in other regions we operate, e.g., UK or ANZ. In the BbD process, all circularity metrics are evaluated for transparency; however, metrics not applicable to a given assessment may be removed e.g., where two single-use packages are compared, Reusability by Design may not be relevant for the comparison.

By using a robust set of circularity metrics, we can capture the key sustainability-related impacts of packaging design but also highlight any trade-offs which may arise. For example, the higher package weight for paperboard compared to its plastic equivalent may be offset by a lower carbon footprint, better recyclability and a higher Material Circularity Indicator (MCI). Specific sustainability-related priorities and metrics may vary between different companies and their products, where improving even only some of the circularity metrics may result in a meaningful improvement. However, when considering circularity holistically, MCI is the only parameter that encompasses all aspects related to composition and end of life at a material level within a single measurement value. Due to the importance of mitigating climate change and our value chain's ambitious related goals, CO_2e impact is also a critical parameter that depends on several other inputs. When taken together, these two parameters alone can provide a meaningful assessment of the overall sustainability of a packaging or product.

While the Circularity dimension consists of 13 individual metrics, there is no single, cumulative score to evaluate circularity, which can make overall comparisons challenging when results per metric are mixed or very close between the packaging being compared. Such situations can easily arise when replacing a traditional, fossil-based barrier coating with a novel, renewable one, where MCI, carbon footprint and weight may be similar; however, small improvements in renewable content or recycled content may represent a significant improvement in circularity for paperboard packaging. In these cases, the decision rules for making a claim of more circular are based on assigning a metric hierarchy, where the highest-ranking metric shall be used first to make a final decision if more circular. If no improvement is observed within the highest-ranking metric, the next highest-ranking metric shall be used, and so forth. The Circularity Metric hierarchy is as follows:

MCI → Carbon footprint → Weight → Recyclable content → Recycled content → Renewable content

For cases where results per metric are mixed or very close and no clear improvement can be demonstrated according to the metric hierarchy, the innovation is not be deemed to be more circular.

Data inputs used to evaluate each circularity metric may come from different sources, e.g., primary data, secondary data/industry averages, or, at times, assumptions must be made. In order to quantify the quality of the input data used for each analysis, we define a data hierarchy as shown below:

(1) Primary data → **(2) Secondary data/ industry average** → **(3) Assumption**

By assigning a numeric value to each data source (1–3), we can determine an average data quality rating of the circularity assessment of a given packaging, where lower values indicate the assessment is based mainly on primary data. When replacing plastic packaging, industry average data is typically used in order to generalize across all potential plastic replacements unless a comparison is made with a very specific benchmark. However, when using average data, extreme values are also considered, e.g., incorporating a minimum recycled plastic content vs 100% virgin plastic, depending on application or local conditions. This allows a general comparison but also helps determine the sensitivity of data, which may vary case by case.

Reducing the carbon footprint in products and manufacturing processes is essential to mitigating climate change and global warming. This is why nearly every country has joined the Paris Agreement on climate change. Limiting global warming to 1.5°C globally and achieving net zero greenhouse gas emissions by 2050 are considered the science-based requirements to avoid the worst impacts of climate change according to the Intergovernmental Panel on Climate Change (see more details in IPCC, 2019).

More Functional

Functionality is a core dimension of BbD, to ensure our packaging is fit for purpose, meets all relevant customer requirements, and improves the packaging operational efficiency in the value chain.

Functionality is assessed from our customers' point of view, i.e., the brand owner, retailer, packer, or filler. Depending on the respective function each of our packaging platforms must fulfill, we assess functionality through performance assessments, such as: packing and filling operations, shelf-life trials, storage performance (stackability and sealability), transport efficiency, containment, and integrity testing, among other relevant approaches — to ensure the design improves process and operational efficiency and provides optimal protection to minimize product damage and waste from factory to consumer.

Additionally, we consider applicable legal functionality requirements, for example, information or safety requirements.

In Table 2 on page 11, we provide a list of current functionality metrics we consider; however, we leave the possibility open to our designers to identify and use new metrics as this assessment space evolves or for new packaging case scenarios.

Table 2: Overview of select Functionality metrics used in the BbD methodology

	Metric	Assessment Criteria	Scores (compared to benchmark)	Relevance of Metric for the Brand Owner, Retailer, or Packer
Containment	**Sealing integrity**	Resistance to tampering and/ or durability of the seal. Required equipment, time taken to seal, and consistency of the seal.	Positive (+), Neutral (=), Negative (-)	Ensures product safety, shelf-life (where applicable), filling efficiency and machine speed during packing/filling.
Protection	**Drop and impact resistance**	Cushioning properties, deformation under impact, and protection of contents. Resistance to cracking, tearing, or breaking.	Positive (+), Neutral (=), Negative (-)	Packaging must protect the product from the point of packaging or filling until the product's end use, with a view to preventing significant product damage, loss, deterioration, or waste damage to the product during different transport and use stages.
	Compression resistance	Load-bearing capacity: maximum weight supported, deformation under load, and structural integrity under compression.	Positive (+), Neutral (=), Negative (-)	
	Puncture resistance	Maximum force applied before puncture, material thickness, and resistance to sharp objects.	Positive (+), Neutral (=), Negative (-)	
	Barrier properties: Decreased speed of product loss	Oxygen/moisture transmission, grease resistance, light/UV protection.	Positive (+), Neutral (=), Negative (-)	Improves product safety, shelf-life (where applicable), and product protection against chemical or environmental damage and reduces product loss.
	Resilience in different environmental conditions	The packaging should have the required protection mechanisms for the given environment.	Positive (+), Neutral (=), Negative (-)	
Branding & Information	**Space available for branding, labelling & information**	Printable surface.	Positive (+), Neutral (=), Negative(-)	Enables the customer's branded product to clearly be identified on the shelf. Also ensures the packaging can provide information on the product itself, legal or safety requirements or bar codes, without the need for additional materials or components, e.g., stickers, labels or wraps.
	Quality of printing	Print quality, missing dots, mottle	Positive (+), Neutral (=), Negative (-)	
Manufacturing & Filling	**Filling speed & efficiency**	Packaging/filling cadence	Positive (+), Neutral (=), Negative (-)	The packaging must be compatible with the packaging manufacturing and filling process. Packaging should maintain (or improve) line speed, stability and efficiency, without the need for tool changes, thereby enabling reductions in energy and waste.
	Impact & stress resistance	Relevant mechanical properties	Positive (+), Neutral (=), Negative (-)	
	Size, shape & thickness	Compatible with existing packing and filling lines	Positive (+), Neutral (=), Negative (-)	
Storage & Transportation	**Stackability**	Number of packs per unit height	Positive (+), Neutral (=), Negative (-)	The packaging and packed product shall ensure safe and efficient distribution, transport, handling and warehousing of the packaged product. Optimization can include transport of the packaging to the packer. This can lead to optimal space utilization, improved operational efficiency, while minimizing the need for secondary or tertiary packaging.
	Pallet density	Number of packs per pallet	Positive (+), Neutral (=), Negative (-)	
	Pallet stability	Can include static, dynamic and driving stability as given in ISO 17321 – Transport stability of packages	Positive (+), Neutral (=), Negative (-)	

Assessment of packaging functionality metrics is, wherever possible, based on standardized quantitative measurements, e.g., given in ISO, ASTM, and TAPPI standards. In general, we consider a score to be positive, negative, or neutral wherever this can be demonstrated quantitatively. With our Better by 2030 Packaging goal, we require one or more relevant functionality metrics to demonstrate improvement; however, we always strive to improve as many as possible among those relevant to the specific use case.

More Convenient

Packaging convenience is also an essential design dimension, as we evaluate whether new, more circular and functional packaging innovations will be accepted and preferred at scale by consumers.

Convenience is therefore assessed from the consumer's point of view. We conduct trials to understand package convenience in terms of usability, including re-sealability, ease of carrying, hygiene and food safety, visual appeal to the consumer, and fitness for special occasions, among others. We also conduct practical consumer tests to evaluate preferences and acceptance of different design materials and features, guiding final packaging design. Convenience can even include the ability to provide information to the consumer, such as product composition, instructions for storage and use, best-before dates, or even more practical information, such as cooking instructions.

In Table 3, we provide a list of current metrics we consider, however, we leave the possibility open to our designers to identify and use new metrics as this assessment space evolves.

Table 3: Overview of select Convenience metrics used in the BbD methodology

	Metric	Assessment Criteria	Scores (compared to benchmark)	Relevance of Metric (Consumer)
Ease of Use	**Opening force**	Opening and reclosing of the packaging shall be easily understood and manipulated for intended actions such as grasping, pinching, rotating, twisting, tearing, pushing, and pulling. May be based on force or torque measurements or consumer studies. (ISO 17480)	Positive (+), Neutral (=), Negative (-)	The force to open the package is achievable by the intended users and is as low as possible (unless childproofing or similar is required). Minimizes/ avoids consumer frustration. Avoids spilling and product waste.
	No spills after opening	The packaging should be designed to assist users by preventing splashing and minimizing waste.	Positive (+), Neutral (=), Negative (-)	Avoids product waste, inconvenience or need for cleaning spills.
	Resealability	There is a reclosing mechanism to confirm the packaging is closed, providing visual markings, tactile markings, auditory information such as a click sound, or strength limits (see ISO 17480). The packaging should also be easy to re-open after re-closing.	Positive (+), Neutral (=), Negative (-)	Offers enhanced product protection and reduces product waste. A well-functioning re-closing/sealing mechanism will also avoid consumer confusion or frustration.
	Ease of taking a portion (multipack)	The packaging allows for measured product dispensing or removal when useful and/or required (ISO 22015).	Positive (+), Neutral (=), Negative (-)	Minimizes product waste and/or overconsumption.
	Ease of disposal	The packaging can be easily folded or crushed after use and components can be easily separated according to guidance printed on the pack, for easier disposal, even for users with weak muscle strength (ISO 22015).	Positive (+), Neutral (=), Negative (-)	Encourages consumers to recycle their packaging and correctly separate different components, thereby increasing the overall circularity of the packaging.

Table 3: Overview of select Convenience metrics used in the BbD methodology

	Metric	Assessment Criteria	Scores (compared to benchmark)	Relevance of Metric (Consumer)
Portability	**Weight**	The packaging is light enough to be held and lifted, whether it is intended to be handled by both hands or by one hand. If the packaging and content are too heavy, mechanical assistance should be provided for ease of holding, lifting, and carrying, e.g., by including a handle.	Positive (+), Neutral (=), Negative (-)	Allows users in general or users with physical disabilities ease with holding, lifting, and carrying the packaging. Avoids unintended dropping and potential damage to product.
	Volume/size	The package volume is optimized to the minimum necessary to ensure its functionality, taking account of the shape and material from which the packaging is made.	Positive (+), Neutral (=), Negative (-)	Enables easier handling but also aligns with evolving regulatory on packaging minimization requirements.
	Handling/ ergonomics	The shape of the packaging enables ease of handling and manipulation in accordance with different types of holding, lifting, and grasping (ISO 22015). The shape of the packaging should be designed so that it accommodates users and situations where only one hand is available.	Positive (+), Neutral (=), Negative (-)	Packaging can be held and lifted even with one hand and finely controlled, e.g., for accessing the product.
Durability	**Barrier properties: Decreased speed of product waste**	Oxygen/gas/moisture transmission, grease resistance	Positive (+), Neutral (=), Negative (-)	Ensures protection of the product against deterioration from the point it is purchased, with a view to preventing significant product damage, deterioration, or waste for the consumer.
	Integrity: Content protected during use life	Mechanical and shock absorption properties	Positive (+), Neutral (=), Negative (-)	Minimizes product damage during handling by the consumer.
Safety & Security	**Tamper-evidence**	The packaging provides visible indication of unauthorized access. Tested according to ISO 8317.	Positive (+), Neutral (=), Negative (-)	Promotes consumer safety, enhances product quality and can increase consumer trust and sense of security.
	Child/elderly proof	Packaging prevents any misuse or wrong operation during handling, manipulation or opening.	Positive (+), Neutral (=), Negative (-)	Avoids the of risk accidental ingesting harmful substances such as medications or chemicals and may be a legal requirement in certain applications.
	Avoidance of sharp edges	The packaging shall not have sharp points or harmful edges on the surface.	Positive (+), Neutral (=), Negative(-)	Children or people with visual disabilities have a higher risk for being injured by sharp point or edges.
Fit for occasion	**Incremental consumption occasion**	The packaging is aligned with specific consumption occasions, such as celebrations, gifting or TV dinners.	Positive (+), Neutral (=), Negative (-)	Enhances overall experience and considers the overall customer journey.
	Space for display of information	% printable surface, or absolute space mm^2/cm^2	Positive (+), Neutral (=), Negative (-)	Gives the consumer additional information on the product, instructions or suggestions for its use and provides space for legal information requirements.

Where possible, standardized measurements are used to assess a given convenience metric, e.g., shelf-life, opening force or printable surface area. In some cases, standardized measurement methods do not exist, and qualitative assessments must be made. Here, consumer studies may be required to measure relative convenience. In cases where a new packaging innovation offers a convenience metric not available in the alternative being replaced, for example, our PaperSeal® Cook with in-pack cooking functionality, the convenience analysis may be based on a simple “yes/no” assessment.

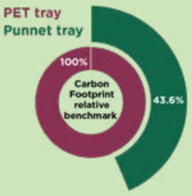
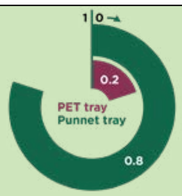
Case Study: ProducePack™ Punnet Tray

Table 4 illustrates the results from the BbD analysis comparing the ProducePack™ Punnet tray to a virgin polyethylene terephthalate (PET) tray in representative EU markets.

The paperboard punnet tray outperforms its plastic counterpart for the key metrics to be considered more circular, while simultaneously demonstrating improved functionality and convenience. However, there are some tradeoffs.

The footnotes provide details on the specific metrics and assumptions made where not otherwise self-explanatory. We then discuss the most important aspects of the analysis.

Table 4: Better by Design metrics applied to the ProducePack™ Punnet tray. The data quality rating (see definition on p. 9) for the analysis is 1.87 for the ProducePack Punnet tray and 2.18 for the PET tray.

Better Packaging Dimension	Metric	PET Tray (Virgin)	ProducePack™ Punnet Tray	Score ProducePack Punnet vs. Benchmark
Circularity	**Weight/minimization**[1]	6.9 g	11.5 g	(-)
	Recyclable/paper content[2]	95%	95%	(=)
	Renewable content	0%	85%[3]	(+)
	Plastic content[4]	95% (excluding lid)	0% (excluding lid)	(+)
	Recycled content	0%	0%	(=)
	 **Carbon footprint cradle-gate (gCO_2eq)**[5]	23.29	10.03	(+)
	Design for Recyclability[6]	Conditionally Recyclable	Widely Recyclable	(+)
	Actual recycling rate[7]	25%	83%	(+)
	Biodegradability/compostability	(0)	(0)	(=)
	 **Material Circularity Indicator**[8]	0.204	0.798	(+)
Functionality	**Increased shelf-life**[9]	Mold growth +60% (fridge) to 320% (room temperature) for cherry tomatoes	Reduced product loss across the value chain	(+)
	Sealing efficiency	PET sealing temperature 140-180°C	Lower sealing temperature with PE than PET lidding film (120-140°C)	(+)
Convenience	**Shelf-life (total at store + at home)**[4]	Baseline	+5 days (room temperature), +1day (fridge) for cherry tomatoes	(+)
	Ability to see the product	> 80%	Transparent lid (≈ 30% transparent viewing)	(-)
	Ability to provide information to the consumer	Uses added label	≈ 70% printable surface	(+)

1 Includes only main packaging body (tray) and excludes lidding film in both cases. Higher weight is penalized as it can lead to increased transport emissions across the value chain. However, since we are comparing different packaging materials, the higher weight paperboard punnet should not be penalized for packaging minimization requirements in the PPWR.
2 For PET trays, assumes 5% non-recyclable content due to paper label used for information purposes and small amounts of filler. For Punnet Tray, based on based on the mass fraction of fiber, filler material, starch, coating color including binder, as well as additives typically used in the paper industry.
3 Based on supplier certification according to FSC® Chain of Custody and PEFC™ and excludes additives typically used in the paper industry such as process aids, strength and sizing agents.
4 Follows the SUPD definition excluding varnish, inks, adhesives as well as natural non-chemically modified polymers
5 Directional cradle to gate carbon footprint. for Punnet tray, it includes: board type and weight with emission factors based on supplier primary data following CEPI 10 toes methodology (valid until 2028-10-13), data for conversion based on average scope 1 and 2 emissions from all GPI converting sites in the region 2024 (calculated by limited independent third-party assurance in accordance with ISAE 3000 and 3410), data for ink and varnish from industry averages. Sheet waste generated during conversion is included. It would be later recycled leading to credits in a cradle to grave analysis. Inbound and outbound transport is symmetrically assumed to be 500 km by truck for the two compared cases. In the case of the PET tray, Gabi LCA Packaging Calculator (2024 Sphera database) was used and excludes any converting waste and any additional materials used in the PET packaging, e.g. labels, sealing layer etc. The model uses industry average data and is consistent with international standards ISO 14040 and ISO 14044.
6 Considers an internal methodology to assess DfR readiness (widely recyclable, conditionally recyclable, locally recyclable or limited recyclability with standard recycling mills using background such as 4evergreen circularity by design guidelines **https://4evergreenforum.eu/about/industry-tools-and-guidelines/**. PET tray conditionally recyclable due to the need for a paper label for informational requirements.
7 2023 data from Eurostat for Paper and Board category (EU-27) and PETcore data on PET tray sorted for recycling **https://www.petcore-europe.org/images/pet/PET_report_V3.pdf**
8 **Material Circularity Indicator | Ellen Macarthur Foundation** MCI ranges from 0 (linear material flows) to 1 (fully circular material flows)
9 Resulting in improved breathability and reduced condensation. More details can be found in: A Comparative Assessment of the Shelf-Life of Tomatoes in Paperboard and Plastic Punnet Trays, Graphic Packaging International **https://www.graphicpkg.com/resources/a-comparative-assessment-of-the-shelf-life-of-tomatoes-in-paperboard-and-plastic-punnet-trays/**

Table 4 presents several independent aspects of circularity, including the origin of raw materials used in the packaging, their fate at end of life, as well as the resulting MCI of the packaging, most of which show an advantage for the punnet tray. It also shows the lower packaging carbon footprint for the punnet tray in a cradle-to-gate scenario. For cradle-to-grave, incineration of plastic in greater proportion at end of life would further reinforce the advantages of the paperboard alternative. Depending on the regions, landfill may also be the predominant end of life for plastic.

Fresh produce has a much higher carbon and resource footprint than its packaging. Our externally published studies confirm that the global warming potential and resources embedded in the packed products are far greater than those related to packaging (in the range of 3-5% in general[1]). than those related to the produce itself. It is therefore vital that packaging protects and minimizes waste and damage. We performed several studies supported by external parties to understand how our paperboard punnet would compare to a plastic alternative in terms of protecting produce.

In 2023-2024, Graphic Packaging collaborated with researchers from Ghent University's Sustainable Food Packaging program to further investigate how changes in fresh produce loss and waste patterns affect environmental impact when considering different types of packaging. This work provided an approach to support packaging decisions that enable a lower environmental burden from a systems point of view, taking into account produce waste rather than focusing solely on packaging materials, which is crucial when comparing packaging that can have different functionality. In particular, it revealed that paperboard punnet trays reduce climate impact compared to virgin plastic counterparts, provided that grape waste in the paperboard punnet does not exceed that in the plastic punnet by more than 9%[2].

Independent testing conducted by Washington State University showed that both grape and cherry tomatoes had a longer shelf-life in paperboard punnets than those packed in plastic trays[3]. The paperboard's permeability, combined with the punnet tray's ventilation holes, allows moisture and gases to escape, resulting in lower relative humidity. Condensation did not form on the tomatoes in these punnets, which likely explains why mold growth was slower and significantly less on these tomatoes than on the ones packed in plastic. This is an essential aspect of the functionality of the packaging that has the potential to limit waste at retail and at the consumer level.

1 **Stop Waste- Save Food project**
2 Food Science and Technology journal, Volume 38, Issue 4, Dec 2024, Pages 48-51:
Thinking Outside the Box https://ifst.onlinelibrary.wiley.com/doi/epdf/10.1002/fsat.3804_12.x
3 **A Comparative Assessment of the Shelf-Life of Tomatoes in Paperboard and Plastic Punnet Trays, Graphic Packaging International**

To ensure the ProducePack Punnet tray is fit for purpose and would be successful with consumers, we iterated our innovation, e.g., in terms of paperboard and varnish (where applicable) combinations, until we achieved several core requirements. Other aspects of the improved value chain performance of our paperboard solution include its ability to be sealed with a mono-PE film, which requires lower sealing temperatures compared with a PET film, thereby opening up the possibility of faster filling speeds even when accommodating the use of existing filling equipment with minimal CAPEX investment. In addition, the ability to print directly on our packs and provide a more impactful aesthetic also avoids the need for labels as required on the plastic counterpart. In terms of consumer experience, the ability to see the produce is recognized as a key aspect when purchasing[1] and this is met to a sufficient extent by using a transparent lidding film.

This ProducePack Punnet tray example also considers current and known emerging regulations in Europe. The use of paperboard packaging can lead to lower Extended Producer Responsibility (EPR) fees in most countries, as well as avoidance of the plastic tax (where applicable). Additionally, by using a regenerated cellulose lid instead of PE film, it is possible to design the entire packaging unit to be compatible with the restriction of single-use plastic packaging for unprocessed fresh fruit and vegetables < 1.5 kg upcoming in the PPWR (details pending) and with restrictions under the Single-Use Plastics Directive (SUPD) for prewashed individual portions. We have, for example, launched a “plastic-free” version with a Spanish grower using a regenerated cellulose lid[2].

1 Mintel, Food Packaging Trends US, 2024
2 “Plastic-free” in accordance with the SUPD definition of plastic, excluding varnish, inks, adhesives as well as natural non chemically modified polymers

BbD & Innovation

To ensure the BbD methodology is a part of all new product innovations, we are systematically integrating its use into our internal innovation process. We include it in the earliest framing stage of the new innovation, where a hypothesis is made on how the innovation will be more circular, more functional, and more convenient than the existing alternative.

At each subsequent stage of the innovation process, and as more details of the new packaging innovation are defined, we begin incorporating more detailed metrics and assessments into the BbD analysis. For example, in the prototyping stage, we can align material selection with Design for Recyclability tables, ensure documents of compliance are available, and perform initial calculations of circularity metrics.

When the innovation moves on to piloting, recyclability assessments are conducted on relevant samples where needed (e.g., for conditionally recyclable package designs), regulatory compliance is confirmed, and we perform testing as necessary to validate our initial hypotheses for more circular, more functional, and more convenient improvements. Once the innovation reaches the production stage, we embed the circularity, functionality, and convenience differentiators into the value proposition for the new innovation.

At each stage-gate, BbD metrics are reviewed and used as a decision point to proceed with the innovation, or to iterate the design stage to further improve the circularity, and/or the functionality, and/or the convenience of our packaging.

Conclusions

The BbD methodology encompasses a comprehensive approach that gives designers the tools and measurement metrics to make informed choices that will reduce the environmental impacts of packaging across the value chain. It also considers current regulations and known future requirements.

By integrating BbD into the design process, packaging solutions can be delivered that are more convenient, more functional, and more circular than their replaced alternatives. It enables us to make the right decisions early in the design and innovation process, helping us achieve our Better by 2030 Driving Circularity goal, but also our customers to meet their packaging sustainability goals. It also gives us the possibility to clearly identify areas for further improvement and identify trade-offs that may be required when approaching sustainability from a holistic perspective.

When used together with our customers, it allows us to design packaging for their most important needs as well as to provide benefits for the environment.

BbD is also a continuous journey, and as our collective knowledge, know-how, and tools relating to sustainability evolve, so too will our BbD methodology.

Glossary of Terms

Carbon footprint: A common term used in the provision of information relating to greenhouse gas (GHG) emissions of both processes and products.

Compostable: A characteristic of a product, packaging or associated component that allows it to biodegrade, generating a relatively homogeneous and stable humus-like substance.

Environmental impact: Change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's activities or products (ISO 14021).

Life cycle: Consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal (ISO 14040).

Life cycle assessment: Life cycle assessment, also known as life cycle analysis, (LCA) is a process for evaluating the environmental impacts of a product or service over the course of its entire life. It is often used to determine the best performing product, service, or other solution, at a given point in time, in terms of specific environmental impacts, such as carbon emissions.

Packaging: Material that is used to protect or contain a product during transportation, storage, marketing or use (ISO 14021).

Paperboard: Generic term applied to certain types of paper frequently characterized by their relative high rigidity (ISO 4046-3:2016). The primary distinction between paper and board is normally based upon thickness or grammage, though in some instances the distinction will be based on the characteristics and/or end-use.

Plastic: A material consisting of a polymer within the meaning of Article 3, point (5), of Regulation (EC) No 1907/2006, to which additives or other substances may have been added, and which is capable of functioning as a main structural component of packaging, with the exception of natural polymers that have not been chemically modified.

Recyclable: A characteristic of a product, packaging or associated component that can be diverted from the waste stream through available processes and programmes and can be collected, processed and returned to use in the form of raw materials or products (ISO 14021).

Recycling: Any recovery operation by which waste materials are reprocessed into materials or substances, whether for the original or other purposes, except for biological treatment of waste, reprocessing of organic material, energy recovery and reprocessing into materials that are to be used as fuels or for backfilling operations.

Waste: Anything for which the generator or holder has not further use and which is discarded or is released to the environment (ISO 14021).

Graphic Packaging Recyclability Terms

Widely recyclable: Packaging products that are widely collected for recycling and meet criteria for technical recyclability, as well as criteria to demonstrate recycling in practice and at scale — according to either the expected Recycled at Scale requirement in PPWR, or FTC requirements for wide recyclability. Technical recyclability is evaluated through recyclability testing, or by following well-recognized circularity-by-design guidelines — such as those developed for paperboard packaging by AF&PA and 4evergreen, or those developed for flexible packaging by Circular Economy for Flexible Packaging (CEFLEX).

Conditionally recyclable: Packaging products that have well-established collection systems and are technically recyclable but contain a higher share of non-recyclable material which may exceed some country thresholds for collection, or products that may require specialized recycling technologies that are not widely implemented. Also included in this category are certain packaging products that require further analysis or validation testing to confirm broader product recyclability claims.

Locally recyclable: Packaging products that meet criteria for technical recyclability, but for which collection and access to recycling is often limited. This can be due to a lack of local infrastructure to properly collect or recycle the packaging materials, or due to the nature of their application (for example, foodservice packaging used in the informal dining sector).

Not recyclable: Packaging products lacking a dedicated recycling stream and infrastructure, or that do not meet technical recyclability criteria such as contamination at the point of disposal due to their applications (e.g. non-packaging products), such as window filter frames.

Acronyms

AF&PA: American Forest and Paper Association

ASTM: American Society for Testing and Materials

CEFLEX: Circular Economy for Flexible packaging

CEPI: Confederation for European Paper Industries

CO_2: Carbon dioxide

CO_2e: Carbon dioxide equivalent

BbD: Better by Design

DfR: Design for Recyclability

EPA: Environmental Protection Agency

EPR: Extended Producer Responsibility

EU: European Union

HORECA: Hotel, Restaurant and Catering sector

ISO: International Organization for Standards

LCA: Life Cycle Assessment

MCI: Material Circularity Indicator

PE: Polyethylene

PET: Polyethylene terephthalate

PFAS: Per- and polyfluoroalkyl substances

PPWR: Packaging and Packaging Waste Regulation

SUPD: Single-use Plastics Directive

TAPPI: Technical Association of the Pulp and Paper Industries

USA: United States of America

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