ELLEN MACARTHUR FOUNDATION

PAPER-BASED FLEXIBLE PACKAGING

The role it could play in tackling small-format flexible plastic pollution in markets with high leakage rates

CONTENTS

ABOUT THIS REPORT

WHY THIS REPORT

Tackling flexible plastic packaging waste and pollution is essential to solving plastic pollution. The Ellen MacArthur Foundation's decade of work on this challenge, culminating in the 2030 Plastics Agenda for Business, identifies it as one of three key systemic barriers to realising a circular economy and curbing plastic pollution. Addressing this is a top priority for many industry players.

As interest in paper-based flexible packaging as a solution pathway is increasing, important questions are also emerging about its benefits, risks, and limitations, as well as which interventions can accelerate the development and deployment of such solutions in a way that is beneficial.

HOW THIS REPORT AIMS TO CONTRIBUTE

This report provides a vision and guardrails for the role paper-based packaging could play in tackling small-format flexible plastic pollution in markets with high leakage rates. It brings alignment on when, and under what conditions, paper can contribute — alongside other approaches.

It also lays out what is needed to realise the vision and guardrails in practice, including pathways to accelerate innovation in responsible design, production and sourcing, and actions from business and policymakers to put safeguarding systems in place.

The findings draw on extensive input and expertise from a wide range of stakeholders. More than 60 experts from across NGOs, brands, manufacturers of paper and plastic packaging, and academics contributed insights. Research from the Consumer Goods Forum's Plastic Waste Coalition of Action informed this work, supported by a dedicated technical review of compostability and biodegradability content conducted by Normec OWS. These inputs were synthesised by the Ellen MacArthur Foundation alongside its own field research and analysis. This extensive engagement has helped ensure the conclusions reflect a wide base of industrial and scientific perspectives, bringing together knowledge across deforestation, waste management, hazardous chemicals, the informal waste sector, biodegradability, and packaging innovation across the world.

THE SCOPE OF THIS REPORT

This report focuses on small-format flexible packaging in markets with high leakage rates, where the impacts of flexible plastic packaging are most acute and the opportunity most significant. By paper-based flexible packaging, we mean flexible packaging mainly made from a cellulosic substrate, whether derived from wood or non-wood fibres, and often combined with performance features such as coatings, laminates, additives, adhesives, and inks.

Flexible plastic waste is a global problem, but the nature of the challenge — and the solutions required — varies widely by context. In some countries, flexible packaging is largely collected, but typically ends up incinerated, landfilled, or exported;[1] in others, low collection rates and widespread waste mismanagement lead to high levels of leakage into the environment. In markets with high leakage rates, where informal waste pickers play a critical role in waste recovery systems, the low value of small-format packaging means that it is rarely collected and often pollutes the environment. Many of these markets are lower-middle to upper-middle income countries where demand for flexible packaging is rising rapidly.[2] Sachets in particular are popular in these markets, valued by consumers for their convenience, low cost, and ease of storage.

Markets with formal collection systems and lower leakage rates are not part of the scope of this report. Any use of alternative materials in these markets should be considered with equivalent scrutiny and high standards.

The analysis centres on small-format flexible packaging sized A5 or smaller, such as sachets, wrappers, pouches, and small pillow bags. It examines primary, business-to-consumer (B2C) packaging,[3] which makes up a large share of packaging pollution.[4] These formats are commonly used for everyday products such as snacks, confectionery, shampoo, cooking oil, coffee, and milk.

The report does not prescribe any individual business, product, consumer segment, or country-level choices. Instead, it offers guiding principles to support case-by-case decision-making that should be made with considerable local stakeholder engagement, recognising that outcomes depend heavily on packaging design, local waste management systems, and social and economic context. Evidence is still emerging in several areas. As such, the report is intended as a starting point rather than a definitive guide, and we welcome further, context-specific research.

All packaging materials should be subject to an equivalent level of scrutiny and high standards. While this report is focused on paper-based flexibles, any other material should be assessed against comparably high standards to ensure its potential benefits are realised and associated risks are actively mitigated.

EXECUTIVE SUMMARY

Paper-based flexible packaging has the potential to help tackle one of the most challenging sources of plastic packaging pollution: small-format flexible packaging in markets with high leakage rates.

Tackling this challenge requires multiple tools. Paper can be an important one of these — but only if it is 'responsibly designed', to avoid replacing one set of problems with another.

Promising innovations are emerging, but paper packaging that meets these requirements does not yet exist at the scale, cost, and performance needed. This report therefore calls for urgent, systematic investment in innovation, guided by six critical criteria that define 'responsibly designed', to develop paper-based solutions that deliver real benefits.

More progress is urgently needed to tackle small-format flexible plastic packaging pollution. Lightweight, functional, convenient, and cost effective, flexible plastic packaging has become ubiquitous and is the fastest growing category of plastic packaging[5] — yet it is also the hardest to manage after use. Because of its small size and low value, small-format flexible packaging is rarely collected in practice, particularly in markets with informal waste collection. Flexible plastic packaging accounts for 80% of plastic packaging entering the oceans and has some of the lowest recycling rates globally.[6]

Tackling this challenge requires multiple tools, with no single solution. Since their size is the main barrier to collection, opportunities to reduce reliance on small-format flexibles should be prioritised wherever feasible. Where flexible formats continue to be used, any material substitution should be paired with efforts to help scale effective collection and recycling systems, including support for waste pickers who play a critical role in many high-leakage contexts. Packaging should never be intended to end up in the environment.

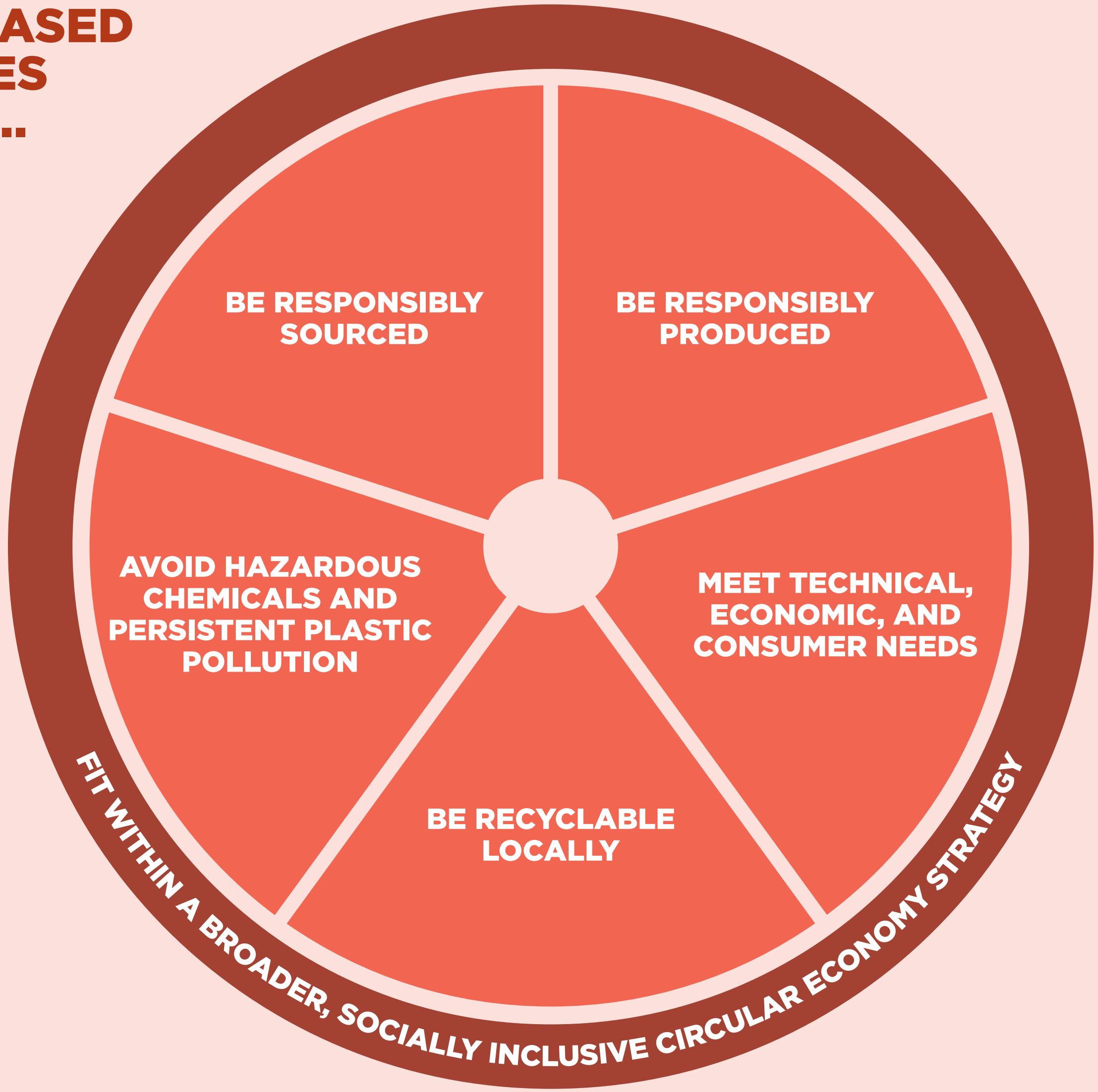
Responsibly designed paper-based flexible packaging has the potential to offer a valuable additional tool. Its fundamental advantage over plastic-based flexible packaging is that it could be more easily designed to be recyclable and biodegradable across different environments.[7] In geographies with high leakage rates, this could reduce persistent plastic pollution in the undesired case it does end up in the environment, while also enabling a future recycling pathway if significant improvements to collection and sorting systems are made. As all solutions to tackle flexible plastic packaging pollution are challenging and have their limitations, having one more tool in the toolbox would be useful.

It is crucial for paper-based flexible packaging to be responsibly designed and sourced to avoid introducing substantial new environmental and social risks. A shift to paper can carry its own risks, including contributing to forest degradation and biodiversity loss,[8] high water use, and methane emissions when landfilled in unmanaged sites. Designs that incorporate polymer coatings or chemical components that fail to biodegrade, or that contain chemicals of concern, can still drive persistent pollution and introduce avoidable chemical risks. Given the large volume of packaging in question, proactively assessing and mitigating these risks is central to ensuring paper-based flexible packaging delivers genuine benefits.

Six critical criteria define responsibly designed small-format paper-based flexible packaging. Together, they provide clear guardrails and guidance for innovators, businesses, and investors, showing how paper can play a valuable role while mitigating risks. These criteria help to ensure that paper-based substitution:

- does not contribute to forest degradation
- minimises environmental impacts during production
- meets technical, economic, and consumer needs
- is compatible with recycling in local systems when collected
- does not lead to hazardous chemical releases or persistent plastic pollution
- does not undermine efforts to reduce reliance on small-format flexibles.

PAPER-BASED FLEXIBLES SHOULD...



To unlock the opportunity, significant innovation and scale are required. Today, packaging that meets all six criteria is not available for the vast majority of applications. Early progress signals real momentum, but significantly more innovation and economies of scale are needed to expand the range of applications[9] where responsibly designed paper becomes a technically and economically viable tool. In particular, combining biodegradability with performance and recyclability requirements remains an innovation challenge.

The current gap between ambition and market-ready packaging should reinforce, not deter, the case for innovating, investing, and piloting now. Developing and deploying responsibly designed paper-based packaging will not happen overnight. There will be interim steps.[10] These steps should be deliberately designed and intended to progress towards meeting all six criteria.

Action will be required across four key areas to accelerate the development of responsibly designed small-format paper-based flexible packaging and establish the safeguards needed to guide their responsible use:

Accelerate innovation towards paper-based solutions that meet all critical criteria

Ensure sustainable fibre supply chains and protect forests at company and system levels

Establish effective and socially inclusive collection and recycling systems for paper-based flexibles as part of holistic waste management

Advance and prioritise other solution pathways (elimination, reuse) wherever viable

Ending small-format flexible plastic pollution and creating a circular economy will require long-term collaboration and sustained commitment from both industry and policymakers. Done well, responsibly designed paper-based packaging can contribute to addressing plastic pollution and creating a circular economy, benefiting people and the planet.

IN SUPPORT

The Ellen MacArthur Foundation would like to thank the organisations and individuals who have significantly contributed to developing this agenda over the past six months through multiple review rounds, working group sessions, and expert interviews.

STRATEGIC THOUGHT PARTNERS

Canopy

Nandini Kumar
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Professor Gaurav Goel
Indian Institute of Technology Delhi

Professor M. Reza Cordova
National Research and Innovation Agency (BRIN) of Indonesia and Alpha Association

WIEGO

WRAP

WWF

WORKING GROUP AND OTHER EXPERTS CONSULTED

More than 60 experts from across NGOs, brands, manufacturers of paper and plastic packaging, and academics contributed insights. Technical review of relevant sections was provided by the Carbon Trust, the Food Packaging Forum, and Normec OWS.

ENDORSING ORGANISATIONS

PRIVATE ENDORSERS

Professor Gaurav Goel and Dr John Williams

Endorsers support the overall vision and recommendations of this publication. The report reflects areas of broad alignment, but does not necessarily represent the detailed views of every endorsing organisation on all aspects of the analysis or conclusions, and does not reflect any agreement by any endorsing organisations to take any individual or collaborative actions.

“I welcome this report, which recognises that paper-based alternatives could help meaningfully reduce persistent plastic pollution, but only when they are responsibly designed and aligned with local infrastructure and regional realities. It rightly underscores that material substitution alone is not a shortcut to sustainability, and that real environmental benefits depend on these considerations.”

M. Reza Cordova, Research Professor

NATIONAL RESEARCH AND INNOVATION AGENCY (BRIN) OF INDONESIA

“This report, backed by evidence and stakeholder input, sets the initial canvas on challenges and critical conditions to turn the promise of paper flexibles into a scalable reality. It strongly emphasizes the need to combine judicious material choice and radical material innovation with deep collaboration and data-driven assessment for engineering packaging solutions that protect the product and the planet.”

Gaurav Goel, Professor

INDIAN INSTITUTE OF TECHNOLOGY DELHI

“In Indonesia, where small-format flexible packaging frequently escapes collection systems and contributes to environmental leakage, we urgently need solutions that work in the real world. Responsibly designed paper-based alternatives — developed with robust safeguards and scaled through innovation — can be an important complement to reduction, reuse, recycling, and investment in inclusive waste systems. This report provides clear guardrails for when and how paper solutions can deliver environmental benefits without creating unintended risks. Now is the time for coordinated action from industry, policymakers and communities to accelerate innovation, protect forests, strengthen collection systems, and drive the transition toward truly circular materials systems that work for people, the economy, and the planet.”

Widharmika Agung, Partner and Head of Indonesia Office

SYSTEMIQ

“This report makes clear that paper-based flexibles can be a valuable tool, but only when designed responsibly and deployed as part of a broader circular economy strategy. It should be viewed not as a material swap, but as a system transformation challenge requiring innovation, supply-chain collaboration, and strong policy alignment to meaningfully reduce flexible packaging pollution in high-leakage markets.”

Anthony Perrotta, Partner, Sustainability & the Regenerative Economy

PA CONSULTING

“Well-designed, responsibly-sourced paper, as laid out in this report, is one of the viable solutions against plastic pollution. However, we need more innovation to broaden the scale and applications of paper-based packaging, including coating and adhesive technologies. We hope this report highlights the need for additional investments and innovation into this space, as well as the necessary guardrails.”

Allison Lin, Global VP Healthy Planet

MARS

“Nestlé believes paper-based flexible packaging can play a valuable role in addressing virgin plastic reduction and minimizing flexible packaging waste and pollution. This report provides stakeholders with a much-needed common vision and a clear set of criteria to ensure that paper-based flexible packaging solutions are developed and deployed responsibly. We call on the entire value chain and policymakers to join us in taking action to accelerate innovation aligned with these criteria, while prioritizing collection and recycling systems for all packaging.”

Gilles Demaurex, Head of Global Packaging Development

NESTLÉ

“Business, governments, financial institutions and civil society all have a role to play to continue to drive packaging circularity. We hope this report helps align all stakeholders behind a common vision and set of critical criteria to responsibly advance paper-based flexibles as one of the possible levers to support circularity.”

David V Allen, Vice President Sustainable Packaging

PEPSICO

“Next-generation paper-based flexible packaging is a key focus for Unilever and an industry-wide priority. This report is clear on the important role paper will play and what it will take to scale solutions that are desirable for consumers, better for the environment, and viable for businesses.”

Pablo Costa - Global Head of Packaging, Digital & Transformation

UNILEVER

“Companies seeking to have more sustainable flexible packaging need to avoid jumping from the plastics “frying pan” into the paper “fire.” This report provides a good view into the options and pitfalls, so essential when supplies of sustainable wood fibre are increasingly constrained and so much virgin paper contains high-risk forest fibre.”

Nicole Rycroft, Executive Director

CANOPY

“Plastic sachets and other small-format flexible plastics are produced and sold in the billions globally and are among the most leakage-prone single-use packaging formats, contributing to persistent environmental pollution and risks to ecosystems and human health. This report sets out a clear, evidence-based pathway to mitigate these impacts, including reducing reliance on conventional plastics and advancing responsibly designed fibre and paper-based alternatives that can support greater circularity.”

Dr. Manuel Brunner, Senior Manager, Sustainable Material Innovation & Investments

MINDEROO FOUNDATION

“Given the crucial role played by waste pickers in the recycling chain any intervention on the value chain must be carefully designed by interrogating what can the impacts be on the livelihoods of these circular economy stewards. Therefore, I welcome the careful thinking behind the report ‘Paper-Based Flexible Packaging: The role it could play in tackling small-format flexible plastic pollution in markets with high leakage rates’. As we push towards greater circularity we cannot leave the goal of greater inclusivity behind.”

Sonia Dias, Waste Specialist

WIEGO

“Small-format flexible packaging is a significant contributor to plastic pollution, particularly in high leakage markets, making it one of the most pressing challenges we face. Material substitution has an important role to play in addressing this crisis, but it must be applied thoughtfully — alongside elimination and reuse solutions — to avoid unintended trade-offs. This report provides the much-needed guardrails and practical guidance to ensure that any transition to paper-based packaging is pursued responsibly and delivers real environmental and social benefits.”

Erin Simon, Vice President and Head, Plastic Waste and Business

WWF

01

RESPONSIBLY DESIGNED PAPER-BASED PACKAGING: ONE TOOL IN A BROADER CIRCULAR ECONOMY STRATEGY

A number of complementary approaches will be needed to tackle small-format flexible plastic waste and pollution in markets with high leakage rates. These can be broadly grouped into two main approaches:

- **Reduce reliance on small-format flexible packaging** through alternative delivery models and packaging formats that avoid the need for small-format flexible packaging, including packaging-free systems, reuse models, or widely-recycled formats.
- **Design any remaining flexibles to fit within a circular economy,** thereby reducing environmental impacts. Material choice is a key part of this, including biodegradable paper-based packaging for recycling, biodegradable plastic-based packaging for composting, and recyclable plastic flexibles.

Responsibly designed paper-based flexible packaging has the potential to be a valuable tool in such a broader circular economy strategy. This is particularly true when the likelihood of leakage is high and reducing reliance on small-format flexibles is not immediately feasible.

Determining the most appropriate pathway is complex. It requires considerable research and local stakeholder engagement, and this section provides high-level guidance to support those deeper, context-specific assessments.

In all cases, scaling effective collection, sorting, and recycling infrastructure is essential. This is critical to reduce leakage and ensure that all packaging is kept out of the environment and circulated within the economy.

REDUCE RELIANCE ON SMALL-FORMAT FLEXIBLE PACKAGING

Alternative delivery models, such as reuse and packaging-free models, should be prioritised where feasible and beneficial.[11] Small-format flexible packaging is hard to manage once it becomes waste, regardless of the material. Avoiding the generation of packaging waste in the first place is the most direct way to address waste and pollution.

Where alternative delivery models are not viable, shifting away from small, single-portion flexible packaging towards larger, widely-recycled formats can reduce pollution. Packaging that is larger with higher material value to waste pickers can incentivise collection. Life-cycle assessments — that include end-of-life outcomes — are needed to understand trade-offs between material use and likelihood of pollution.

Evidence suggests that reducing reliance on small-format flexibles through alternative delivery models and formats is feasible in the near term. Many products sold in small-portion sachets — such as home or personal care products or milk — are already available in reuse or larger, widely recycled formats in the same markets. Several studies also indicate that inability to afford larger portions is not a barrier to shifting to other formats for many consumers.[12] In the Philippines, for instance, half of consumers in the top 10% of households by income use personal care sachets, while a third of those in the lowest income bracket do not;[13] larger pack sizes are often preferred for some products, even among low-income consumers.[14] This suggests near-term opportunities to promote alternative formats to a larger share of consumers for certain product categories.

Collaboration, policy, and broader economic development could further reduce small-format use over time. Scaling reuse business models can accelerate this shift while bringing significant business benefits.[15] While small-scale reuse pilots have demonstrated promise, they remain limited in scope.[16] Larger, industry-wide initiatives, combined with policy interventions, could help scale these solutions by overcoming the barriers individual companies cannot tackle alone. In parallel, continued economic development in markets with high leakage rates is expected to further reduce segments of consumers who depend on single-portions to access products.

FURTHER READING

WWF and Ellen MacArthur Foundation, Reuse in the Global South (2025)

DESIGN REMAINING FLEXIBLE PACKAGING FOR A CIRCULAR ECONOMY, REDUCING ENVIRONMENTAL IMPACT

Since not all flexible packaging can be avoided, any we do use should be designed to enable material recycling, avoid hazardous chemicals, and reduce the likelihood of persistent plastic pollution. Avoiding persistent plastic pollution is particularly relevant in regions where waste collection and management systems for small-format waste are not expected to scale in the near future, and where leakage is therefore highly likely.

Where alternatives to small-format flexible packaging are unlikely, improving flexible formats is the main route to reducing environmental impact. In some product categories, viable alternative formats to flexible packaging are hard to identify in the foreseeable future, particularly where larger portions are not desirable and refill models are challenging, such as for certain ‘on-the-go’ foods.

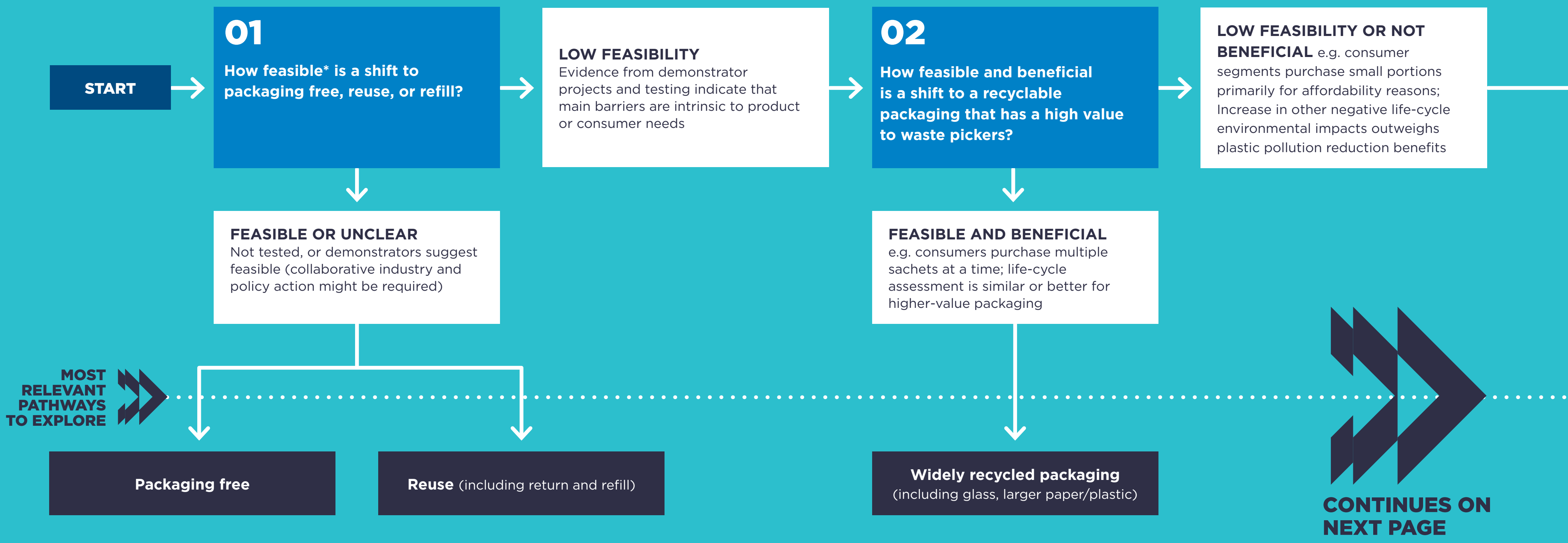
Material choice is a key element of designing flexible packaging, and the most appropriate option will vary by context. Key considerations include whether sourcing and production could aggravate regional environmental or social risks, the technical and commercial feasibility of packaging, and the environmental impact of the packaging given local waste-management infrastructure and likely end-of-life outcomes.

There is rarely an objectively ‘right’ answer when choosing materials: trade-offs and judgement calls are often needed. The benefits, limitations, and risks of each option should be assessed, taking into account local conditions and priorities. As a result, the relative importance of different impacts — such as persistent plastic pollution, greenhouse gas (GHG) emissions, or water use — can vary by context. Furthermore, these assessments may have to rely on incomplete data or forward-looking assumptions, such as when and how waste-management systems will scale in a certain geography.

Responsibly designed paper-based flexible packaging may be a valuable option when the likelihood of leakage is high. In such contexts, it can help avoid persistent plastic pollution in the undesired case it does end up in the environment, while enabling recycling as local collection and sorting systems improve over time.

Innovations in flexible packaging design should sit alongside continued investment in alternative delivery models. In many cases, reuse and other delivery models could play a significant role over time but their success depends on factors beyond the control of any single company. Such factors could include cross-industry shared infrastructure, policy interventions, and changes in consumer habits, supply chains, and retail environments. In these cases — where alternatives are the long-term goal — improving the design of small-format flexible packaging can help manage near-term risks, but should sit alongside industry collaboration and advocacy to overcome the barriers to scaling other delivery models over time.

REDUCE RELIANCE ON SMALL-FORMAT FLEXIBLES WHEREVER POSSIBLE



*Feasibility depends on factors such as logistics, regulations, and technical and commercial viability.

DESIGN ANY REMAINING FLEXIBLE PACKAGING FOR A CIRCULAR ECONOMY

CONTINUED FROM PREVIOUS PAGE

03
Which flexible packaging options are feasible without aggravating environmental or social risks?

- Is it currently available, functional, and commercially viable?
- Can it be developed before small-format flexible plastic packaging is expected to be recycled at scale?
- Can it be developed in a way that does not aggravate environmental and social problems? (i.e. forestry or water pressures in regions where ecological boundaries are endangered)

04
Which have lower environmental impacts given near-term end-of-life outcomes?

- How likely is the packaging to leak in the environment? (depending on size, recyclability, material value)
- How likely is mismanaged landfilling and burning?

05
Which have more promising expected future end-of-life outcomes?

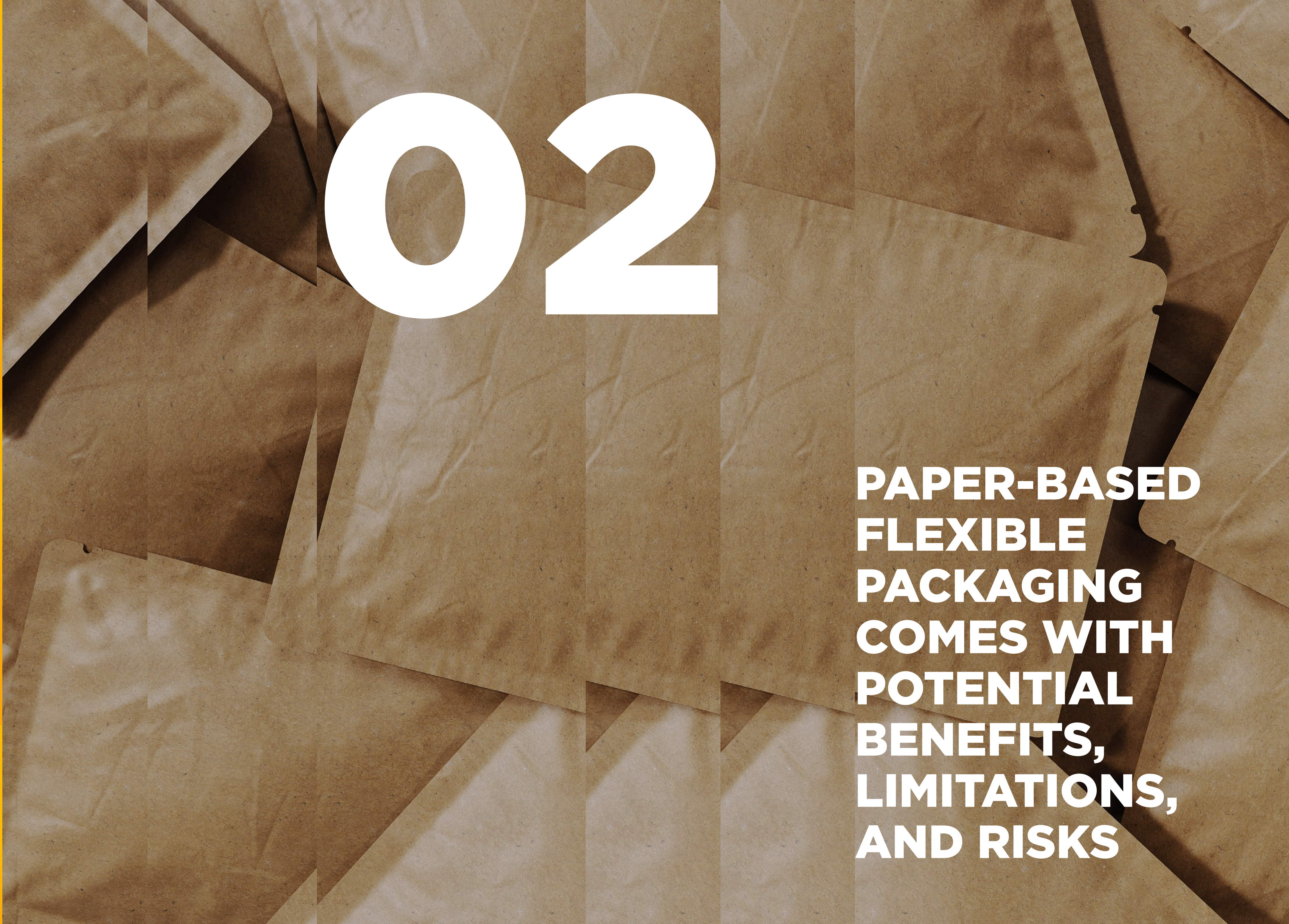
- How likely and quickly are paper recycling, flexible plastic recycling, and composting expected to scale locally?
- Is the packaging designed to be compatible with these expected local recycling or composting systems?

MOST RELEVANT PATHWAYS TO EXPLORE

CONSIDERATIONS INFORMING MATERIAL CHOICE:

	03	04	05
Recyclable and biodegradable paper-based	If technically feasible, and forestry and water risks are manageable in the focus market	If high pollution rates likely to persist and mismanaged landfill is less likely	If collection and recycling rates expected to be higher for paper than plastic
Biodegradable, not paper-based	If environmental impact lower than paper, and technically more feasible	If high pollution rates likely to persist and mismanaged landfill is less likely	If composting infrastructure is expected to scale, and it would not contaminate local recycling
Recyclable, non-biodegradable plastic	If environmental impact lower than biodegradable alternatives, or alternatives are not technically feasible	If pollution rates for plastic are significantly lower than paper and burning is less likely	If collection and recycling rates expected to be higher for plastic than paper

Notes:
- This assessment is relevant for regions where risk of leakage is high. Other regions, with very different contexts, have not been studied at depth for this report.
- Assessments should be specific to product, consumer segment, channel, and market, since answers may vary significantly by these contexts. Given this, considerable evidence and local stakeholder engagement is required to answer these questions accurately. Evidence and resulting answers may evolve over time.
- Assessments are not meant to be deterministic and will often be along a spectrum. Rather, the assessment intends to surface and prioritise key considerations.
- Multiple approaches may be relevant and pursued in parallel
- Whilst this is designed primarily to support decision-making for brands, policymakers may use these questions to target cases for which different approaches should be incentivised and enabled



02

PAPER-BASED FLEXIBLE PACKAGING COMES WITH POTENTIAL BENEFITS, LIMITATIONS, AND RISKS

BENEFITS: A MEANS TO AVOID PERSISTENT PLASTIC POLLUTION

In markets with high leakage rates, the main potential benefit of paper-based flexibles is not contributing to persistent plastic pollution in the undesired case they end up in the environment. Longer-term, they could also be recycled in these geographies, if collection and sorting challenges — that small flexible plastic packaging also face — are overcome.

At the same time, paper-based packaging introduces other risks such as forest degradation and high water use that must be carefully managed to avoid addressing one problem while creating another. If not developed and deployed responsibly, it can bring substantial new environmental and social risks and may offer little or no improvement over the plastic it replaces.

Understanding these potential benefits, limitations, and risks is essential to ensure that paper-based flexible packaging is developed and deployed responsibly. This section examines the most pressing impacts, drawing on independent research and expertise from industry, NGOs, and academia, with a focus on factors most relevant to decision-making for small-format flexibles. These findings underpin the six critical criteria for responsibly designed paper-based packaging set out in the following section.

Responsibly designed alternatives that are biodegradable in different environments could substantially reduce persistent plastic pollution. Although the long-term goal is to stop leakage altogether, scaling comprehensive collection, sorting, and recycling systems often takes significant time, funding, and policy interventions. Until then, designing packaging to fully biodegrade in the undesired case that it ends up in the environment can minimise persistent plastic pollution and limit the accumulation of waste in the environment over time.[17,18] This can reduce many of the physical impacts related to such pollution — such as animal ingestion, smothered habitats, and flood damage from blocked drains.[19] While there is no way to guarantee packaging will fully biodegrade in a certain timeframe or in any environmental condition,[20] meeting existing standard specifications for home compostability[21] and biodegradation across marine, freshwater, and soil environments is currently the best available proxy.[22] These standard specifications can help ensure that packaging that passes all criteria is likely to be much less persistent and cause significantly less harm than conventional, non-biodegradable flexible plastic packaging in the vast majority of real-world environments.

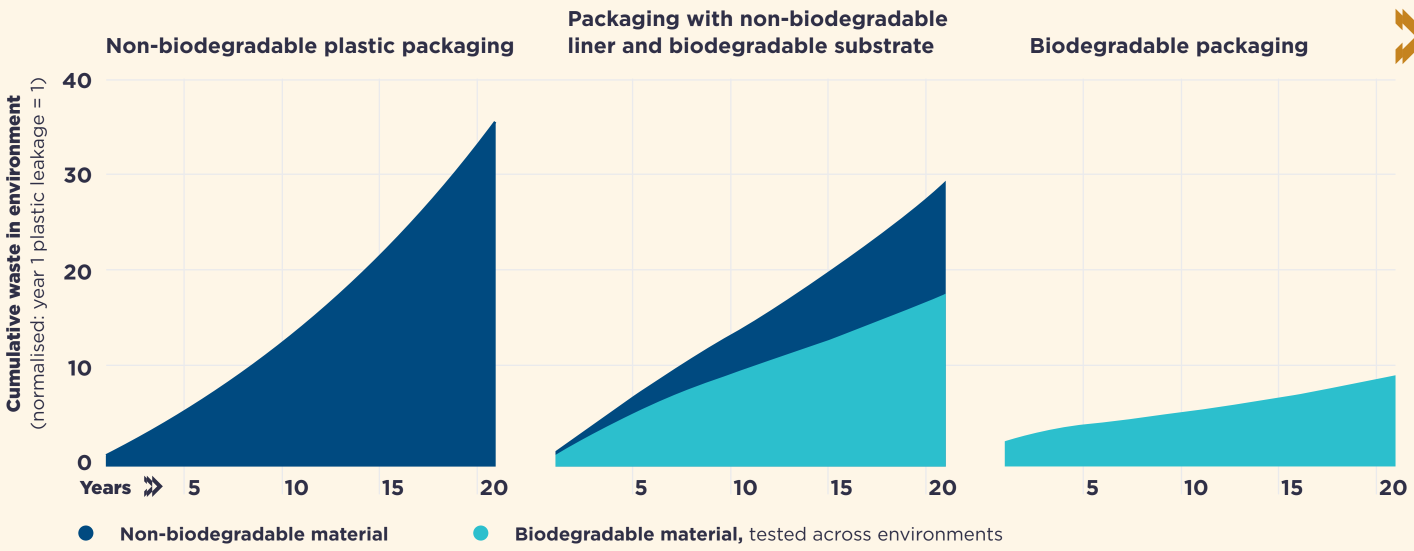
However, as meeting biodegradation standard specifications does not guarantee no harm, stopping leakage altogether remains the long-term goal. Real-world conditions differ from lab tests: biodegradation in real-world conditions is typically slower, may not occur in all environments (e.g. on a road), and varies with climate, humidity, and microbial conditions. Further research is needed to better understand these dynamics. Projections (see Figure 1) show that, even where packaging is designed to biodegrade, total pollution continues to rise over time if sales grow and collection rates do not improve, underlining that improving collection remains essential to stopping pollution altogether.

Clear consumer communication is important to reduce risk of increased littering. Early studies also suggest some consumers may be more likely to discard packaging in the open environment if they believe it will biodegrade.[23,24] Even accounting for increased littering, overall waste accumulation in the environment is most likely still substantially lower for biodegradable packaging (see Figure 1).[25] However, packaging should never be intended to end up in the environment. For this reason, it is recommended to not communicate biodegradability on packaging. Instead, consumer communication should focus on clear, context-specific disposal guidance, aligned with local collection, recycling, or composting infrastructure.

FIGURE 1 PROJECTED ENVIRONMENTAL ACCUMULATION OF DIFFERENT FLEXIBLE PACKAGING MATERIALS

Biodegradable packaging could lead to significantly less waste building up in the environment year-on-year — but total leakage would continue to increase without collection intervention

Simplified analysis for illustrative purposes



ASSUMPTIONS

Three types of packaging are introduced to an area with no existing waste in the environment:

- Conventional non-biodegradable plastic-based flexible packaging
- Packaging with a non-biodegradable liner on one side and a biodegradable substrate
- Packaging that meets home-compostability and biodegradability standard specifications across marine, freshwater, and soil environments.

Packaging sales rise 5% each year in line with expected market growth rates for flexible packaging.

Biodegradable packaging is 1.5 times the weight of equivalent plastic item; non-biodegradable liner is 20% of packaging weight.

The rate of leakage into the environment is kept constant over time, with no changes in collection and littering rates. Littering rates are 10% higher for packaging with biodegradable components than for non-biodegradable plastic packaging, reflecting potential differences in disposal behaviour.[26] To enable comparison, the weight of non-biodegradable packaging littered into the environment in the first year is set at 1.

Biodegradation rates in the environment:

- Once leaked, non- biodegradable materials persist and accumulate in the environment over time (shown in dark blue).
- Packaging that is biodegradable across marine, freshwater, soil, and home-composting environments slowly break down (light blue). This analysis assumes 60% of the original packaging biodegrades after one year, 80% after two, 90% after three, 95% after four. After four years, the remaining packaging biodegrades at a rate of 50% per year. This is significantly slower than under lab conditions.
- For packaging with a non-biodegradable liner and a biodegradable substrate, the substrate biodegrades 60% more slowly than fully biodegradable packaging as the liner reduces the surface area available for biodegradation to take place. If the substrate had a non-biodegradable liner on both sides (not assumed here), the biodegradation process would again be significantly slower.

INTERPRETING THE RESULTS

Over time, packaging that meets home-compostability and biodegradability standard specifications across environments leads to a much lower cumulative load. Because paper-based items are heavier and more likely to leak than plastic, leaked paper initially contributes a larger mass of material. However, over time, non-biodegradable plastic continues to accumulate year after year, while packaging that meets home-compostability and biodegradability standard specifications across environments biodegrades.

Packaging with a non-biodegradable liner and biodegradable substrate results in similar levels of waste as non-biodegradable packaging, due to the significantly slower biodegradation caused by the liner and the greater packaging weight relative to non-biodegradable packaging.

Across all scenarios, annual leakage and total waste build up continues to rise if sales rise and collection rates do not improve, stressing the importance of ultimately stopping leakage altogether.

This is a simplified conceptual model. More detailed modelling of microplastic accumulation and CO_2 production of selected non-biodegradable and biodegradable materials when littered, accounting for differences in littering rates, can be found in research by Brouwer, M. T., et al. (2024).[27] This model focuses on waste build up in the environment and does not look at impacts from material sourcing, production, landfill, and burning.

LIMITATIONS: COLLECTION AND RECYCLING CHALLENGES REMAIN

Small-format flexible packaging has very low collection rates, regardless of material. Its small size and low value mean they are rarely collected in practice — typically below 5% in India, and under 1% for multimaterial plastic flexibles in Indonesia.[28,29] A worker would need to collect over 60 small paper sachets to match the value of one PET bottle.[30] This is fundamentally a challenge of economics and packaging size, not material choice.

If collection rates do not increase, pollution is likely to remain significant. The total mass of leakage into the environment is projected to rise regardless of whether packaging is made of biodegradable plastic or biodegradable paper (see Figure 1). As such, material substitution should not detract from efforts to scale reuse, refill, or packaging-free models, nor from the need to build effective collection and recycling systems for all packaging.

Although both materials can be designed for recycling, this doesn't always translate into recycling in practice. For example, coated paper-based flexible packaging that meet recyclability standards such as 4Evergreen can be processed by duplex paper mills, which make up a quarter of paper mill capacity in India.[31] Likewise, plastic flexibles that meet relevant design-for-recycling guidelines could be recycled. However, as long as the systems for collection, sorting, and recycling are not in place and economically viable, packaging is unlikely to be recycled in practice.

Paper has the advantage of more established recycling capacity than plastic flexibles, if the collection challenge is overcome. In many regions, cardboard and uncoated paper have historically been sufficiently economically viable to collect and recycle at low levels. And in several countries, the existing recycling capacity is able to absorb additional volumes of domestic waste paper: paper mills in both India[32] and Indonesia,[33] for example, are currently reliant on imported waste. In India, duplex mill capacity could likely absorb a shift of up to 15% of flexible plastics to paper-based packaging by 2040.[34]

Both paper and plastic flexible packaging recycling have inherent material limits. In paper recycling and mechanical plastic recycling, fibres and polymers degrade with each cycle, meaning there is a finite number of technically viable recycling loops before they can no longer be used for packaging applications. Certain uses — including those requiring high mechanical performance, barrier properties, or food-contact safety — depend on higher-quality fibres, strict hygiene controls, and traceability that post-consumer paper and plastics often cannot provide today. Chemical recycling has the potential to recycle flexible packaging back into high-quality plastics. However, the material yields are typically low, environmental impacts are typically higher than mechanical recycling, and existing chemical recycling capacity is very limited.[35] As a result, while significantly reducing virgin material use, any paper or plastic flexible recycling system relies on input of virgin material, especially for more challenging applications such as flexible packaging.

Across both paper and plastic flexibles, small format size, contamination, and low material quality can undermine recycling economics. These characteristics make it both technically and economically challenging to collect, sort, and recycle flexible packaging into high quality secondary materials. Even where comprehensive waste collection exists, small sizes can be uneconomical to sort and recycle. Oil, shampoo, powders, and other residues can cause sorting facilities to reject incoming materials. Evidence from India shows that plastic rejection rates can reach 25%,[36] illustrating how contamination can undermine recycling yields and economics more broadly. Moisture sensitivity can disrupt paper collection and recycling particularly during monsoon seasons.[37]

Industrial and home composting are potential alternative end-of-life options for responsibly designed paper-based packaging — however, these require systems to be built. Successful initiatives include Delhi's zero-waste residential areas[38] and closed-loop systems such as college campuses. Yet despite relatively low capital requirements, composting infrastructure remains scarce in most regions. Where any such composting infrastructure exists, it does not remove the need for effective collection systems.

Ultimately, improving collection and recycling or composting for small-format flexibles will require system-wide change. Large-scale initiatives to improve collection and sorting rates and designing packaging in consultation with local recyclers will be critical. These should be designed to ensure a just transition for all workers. Policy interventions are crucial. Measures such as effective Extended Producer Responsibility (EPR) schemes, mandatory recyclability standards, and minimum levels of recycled content could all help improve collection and recycling economics. However, for small-format flexibles, there are few, if any, examples to date where such measures have been sufficient to close the gap between the cost of collecting, sorting, and recycling and the market value of the resulting recycled materials. Without collaborative investment and policy action, collection and recycling challenges will persist, regardless of whether small-format flexible packaging is made from paper or plastic.

RISKS: KEY ISSUES TO ADDRESS

Shifting from plastic to paper-based flexible packaging introduces a set of risks that need to be actively managed. Some of these risks are specifically associated with the sourcing and production of paper. Others are material agnostic impacts that apply to plastics, paper, and other materials. These are shaped by how a specific packaging is designed, sourced, and managed at end of life, rather than by material choice alone.

RISKS SPECIFIC TO PAPER

INCREASED PRESSURE ON FORESTS

The world is facing large-scale deforestation and forest degradation, impacting biodiversity, carbon storage, and local communities, with knock-on effects that can exacerbate natural disasters. In several forested regions, including parts of Canada,[39,40] managed forest landscapes have turned from carbon sinks to net carbon emission sources. Forest degradation can weaken soil stability and watershed function, leading to erosion, landslides, and increased flooding risk, exacerbating impacts of extreme weather events on local communities. This has been cited as a driver of the recent flash flooding in Sumatra.[41] Land conversion associated with unsustainable forest management can also negatively impact local communities by displacing indigenous and rural populations, disrupting livelihoods and compromising labour rights. As demand for paper-based packaging increases, these pressures risk being amplified if sourcing is not carefully managed.[42]

The nature of these risks, and appropriate interventions, vary by region, depending on governance, forest conditions, and sourcing practices. In some regions, weaker governance, regulatory oversight, and condition of existing forests are linked to higher risks of forest degradation and deforestation, land tenure issues, and associated social impacts. In other cases, carefully managed plantations on previously degraded land along with regenerative practices[43] — operating under robust legal, environmental, and social safeguards — can help improve biodiversity and livelihoods for neighbouring communities.[44]

Globally, wood demand already exceeds responsible supply[45] and the projected growth in pulp and paper demand would add to the pressure on forests. Logging is the third largest driver for tree cover loss, accounting for about a quarter of global loss after permanent agriculture and wildfire,[46] and is estimated to contribute around a tenth of global annual emissions.[47] Paper production and other short-lived fibre products already account for nearly a fifth of total logging — approximately 5 billion trees every year[48] — and demand is forecast to rise.[49]

Without ambitious mitigation measures, a large shift from plastic to paper-based flexible packaging could significantly add to global paper demand. While such a shift would be one of many drivers of global wood demand, it is not insignificant. Shifting just 10% of global plastic flexible volumes to virgin paper-based alternatives equates to a fifth of today's total global supply of certified wood pulp.[50]

Current sourcing practices can be problematic for climate, biodiversity, and livelihoods, and even where certification is in place, environmental impacts can remain. Up to half of all virgin wood pulp used for paper may come from Ancient and Endangered Forests,[51] while only 23% of industrial roundwood is Forest Stewardship Council (FSC) certified.[52,53] Certified fibre helps, does not guarantee low impact: harvesting in managed forests can reduce carbon stocks by 30-50% compared to natural landscapes, with recovery taking centuries.[54] Irresponsible forest management practices can lead to the degradation of forest ecosystems and the depletion of natural forest resources, affecting not only endangered or old-growth forests but all forest types, and driving biodiversity loss.[55,56,57] Furthermore, limited visibility into fibre origin constrains the effectiveness of certification and policy enforcement, and undermines the ability to distinguish responsible sourcing from high-risk practices.

Compounding this, responsibly certified supply is not keeping pace with demand. The volume of credibly certified supply has nearly stagnated over the past decade[58] and is projected to grow 50% slower than pulp demand to 2040,[59] meaning that greater demand for responsibly sourced paper by some businesses would likely displace certified supply from other market segments rather than expand overall supply. Robust certification remains a critical tool for improving sourcing transparency and forest management, but improvements are needed to prevent further climate change and ecological damage.

At an individual business level, applying best practice reduction, sourcing, recycling, and certification is vital, yet should be matched by broader interventions at a system level to address structural supply constraints and encourage consistent application of best practices across the sector. The 2025 Forest 500 report highlights this gap, showing that while a small number of influential companies have demonstrated leadership in protecting forests, nearly half of the 500 largest companies involved in forest-related supply chains do not have a deforestation commitment for pulp and paper.[60] Business-level and system-level actions required are detailed in the next section under 'Critical condition 1: Responsibly sourced'.

Sourcing risks and impacts should be considered for all materials, not only wood. While sourcing virgin wood-based paper packaging draws directly on forests and land, other feedstock comes with other impacts and risks. For example, bio-based plastics and alternative fibres can raise land-use and food-system concerns and should be sourced using robust standards.[61] Whilst this report is focused on paper-based packaging, fossil-based feedstock for plastics production can have its own substantial impacts on biodiversity[62] and local communities, and should be subject to an equivalent level of scrutiny and high standards.

WATER USE IS HIGHER FOR PAPER PRODUCTION THAN PLASTICS

Paper production is often significantly more water-intensive than plastic. While water use varies widely across different production facilities for both materials, paper production typically consumes several times more water compared to the same amount of plastic, by weight.[63,64] This reflects fundamental differences in production processes: pulping and fibre processing rely heavily on water as a carrier, unlike plastics which rely on heat and chemical reactions. Water use differences could be amplified further, as paper-based packaging typically uses more material — by weight — compared to a plastic alternative. The water footprint of the other packaging components (barrier layers, adhesives, inks) should also be taken into account when assessing overall impacts.

Even with best-practice measures in place, paper production still carries a higher water footprint. Some manufacturers are working to reduce water use through closed-loop systems and water stewardship initiatives.[65] These help minimise withdrawals and pollution and are important steps, but even with such improvements, paper production typically remains more water-intensive than plastic production.

The impact of water use is highly dependent on the local context. Especially in water-scarce regions, high water demand can exacerbate water stress and can put direct pressure on local communities and ecosystems.

RISKS FOR ANY FLEXIBLE PACKAGING

GHG EMISSIONS ARE HIGHLY CONTEXT-DEPENDENT

For both paper and plastics, GHG footprints vary widely depending on packaging design, supply chains, and local energy mixes. On a per-kilogram basis, emissions from production, converting, and forming are generally lower for paper than for fossil-based plastic.[66] However, paper-based flexibles typically require more material by weight to achieve the same performance, which can offset these advantages. As a rough rule of thumb, paper-based packaging may have lower emissions when the packaging is less than 1.5 times the weight of the plastic it replaces.[67] This does not take into account end-of-life pathways and other packaging components such as barrier layers, additives, and inks which may significantly contribute to the overall GHG emissions.

Sourcing practices are fundamental to overall carbon impacts. How carbon is accounted for in fibre sourcing has a major influence on GHG results. Some studies treat biogenic carbon as carbon-neutral, assuming that emissions released during harvesting, processing, or disposal are balanced by forest regrowth, however this assumption can be misleading. Robust life-cycle assessments show that omitting carbon losses from sourcing can understate net GHG emissions by 75-92%.[68] When accounting for carbon, the full product life cycle should be considered from cradle-to-grave. Emissions released during activities in harvesting (such as use of chainsaws) and processing of wood to make paper should always be included. The end-of-life emissions associated with disposal should be adequately accounted for.

End-of-life treatment is one of the most important drivers of overall GHG emissions for both paper and plastic in regions with high rates of waste mismanagement. In these areas, disposal in unmanaged landfill or burning can contribute up to 50% of overall packaging-related emissions.[69]

In regions where waste is primarily burned, paper flexibles may have a lower carbon footprint than plastic equivalents. When burned, both materials release carbon, but burning fossil plastic — including paper-based packaging with fossil polymers — adds new carbon to the atmosphere whereas paper releases biogenic carbon that was absorbed from the atmosphere during tree growth.

When unmanaged landfill is the primary disposal pathway, paper-based flexibles may have a higher carbon footprint than plastic equivalents. This is because paper can decompose anaerobically in landfill, releasing methane,[70] whereas plastic is largely inert. Even where landfill remediation is underway, capturing methane from old, unlined sites is difficult and often not a priority.[71]
As an approximation, paper tends to have a lower GHG impact than plastic when landfilling is less than 1.5 times as likely as burning.[72]

GHG driver	Approximate 'rule of thumb'[73] Paper-based flexibles may be less carbon intensive than their plastic equivalent if...
Weight	...they are less than ~**1.5 times** the weight of the plastic equivalent[74]
End-of-life treatment	**...landfilling is less than ~1.5 times as likely than burning[75]**

Note: Rule of thumb should not replace case-by-case assessment

EUTROPHICATION IMPACTS REMAIN POORLY UNDERSTOOD

Both paper and plastic waste may contribute to eutrophication if they leak into the environment. Eutrophication is the nutrient enrichment of water systems that can trigger algal blooms and oxygen depletion. Paper may release nitrogen-containing additives more rapidly as it breaks down, while plastics can indirectly affect nutrient cycles by adsorbing pollutants and altering aquatic feeding behaviour.[76,77]

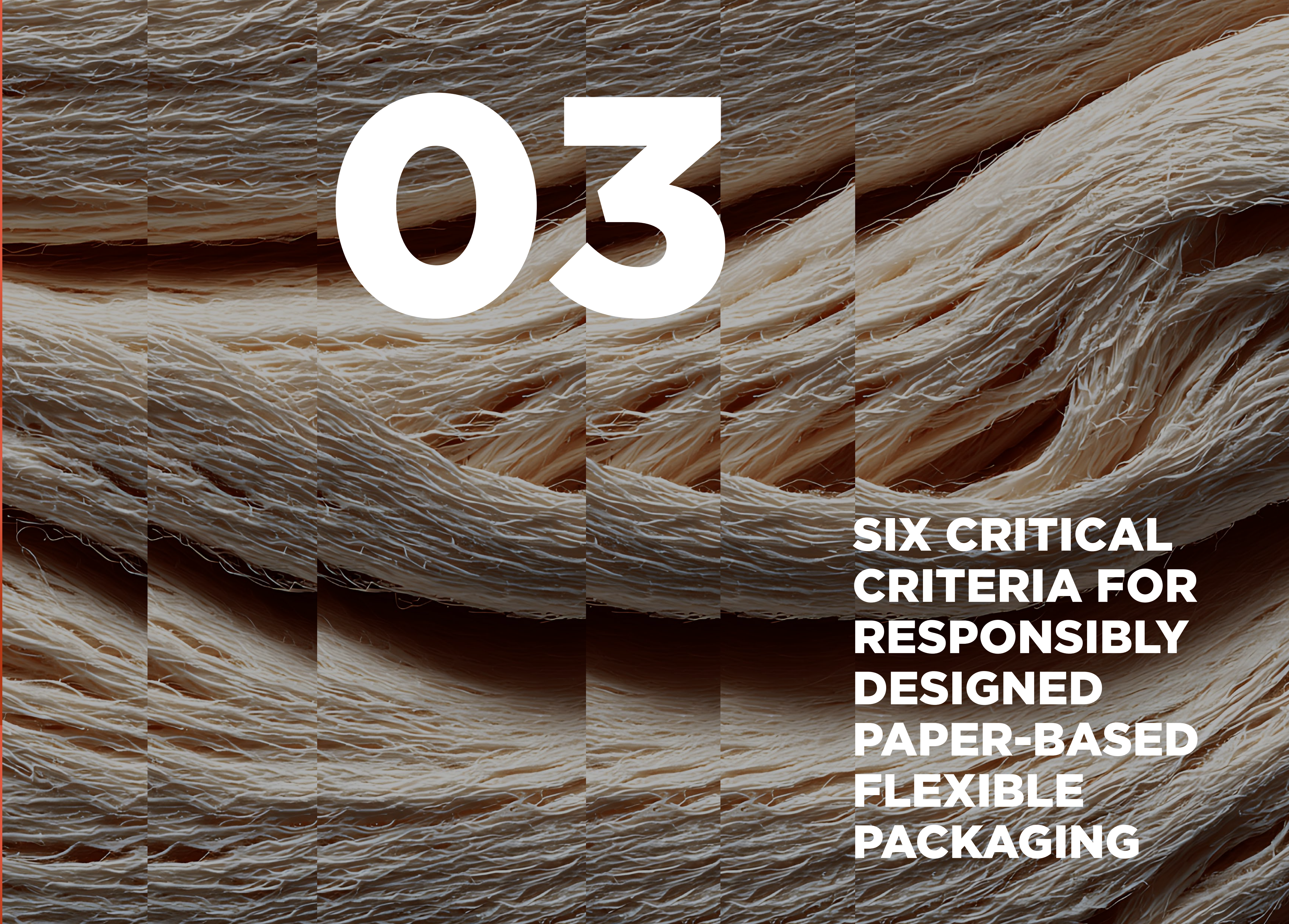
The scale of impact is uncertain, and further research is required. European life-cycle assessments generally do not identify eutrophication as a major impact category for paper;[78] however, these studies tend to exclude impacts from environmental leakage. Experts suggest that the eutrophication risk from leaked packaging is likely smaller than those associated with leaked residual food,[79] but evidence on eutrophication impacts of both paper and plastic packaging is limited.

CHEMICAL RISKS ARE MAINLY DETERMINED BY PACKAGING DESIGN, NOT MATERIAL CHOICE

Both paper and plastic packaging can introduce potentially harmful substances into the environment and human health systems. Scientific studies have detected nearly 1,900 different chemicals in paper and board and nearly 3,700 in plastics. Both include per- and polyfluoroalkyl substances (PFAS) and other chemicals of concern.[80] Risks stem primarily from additives, stabilisers, residual monomers, inks, adhesives, coatings, and barrier layers, rather than from the base material itself. These substances can migrate into food from the packaging, persist in ecosystems, and enter food chains, with wide-ranging potential human health impacts including on reproductive, immune, and cardiovascular systems.[81,82]

Impacts are largely defined by packaging design. While there are always risks of non-intentionally added substances entering the material, the overall chemical footprint also depends heavily on chemical ingredients intentionally used. Designing packaging with chemical safety front of mind is therefore essential to reducing potential risks.

Current safeguards require harmonisation. Ecotoxicity tests, such as those required for home compostability certification, are not consistently enforced worldwide: some require ecotoxicity testing with plants only, while others also require ecotoxicity testing with earthworms and bacteria. In addition, the intentional use of constituents that appear on the list of Substances of Very High Concern and organic fluorinated chemicals is increasingly being banned by certification organisations worldwide, but requires further alignment and significant regulatory gaps could remain.



03

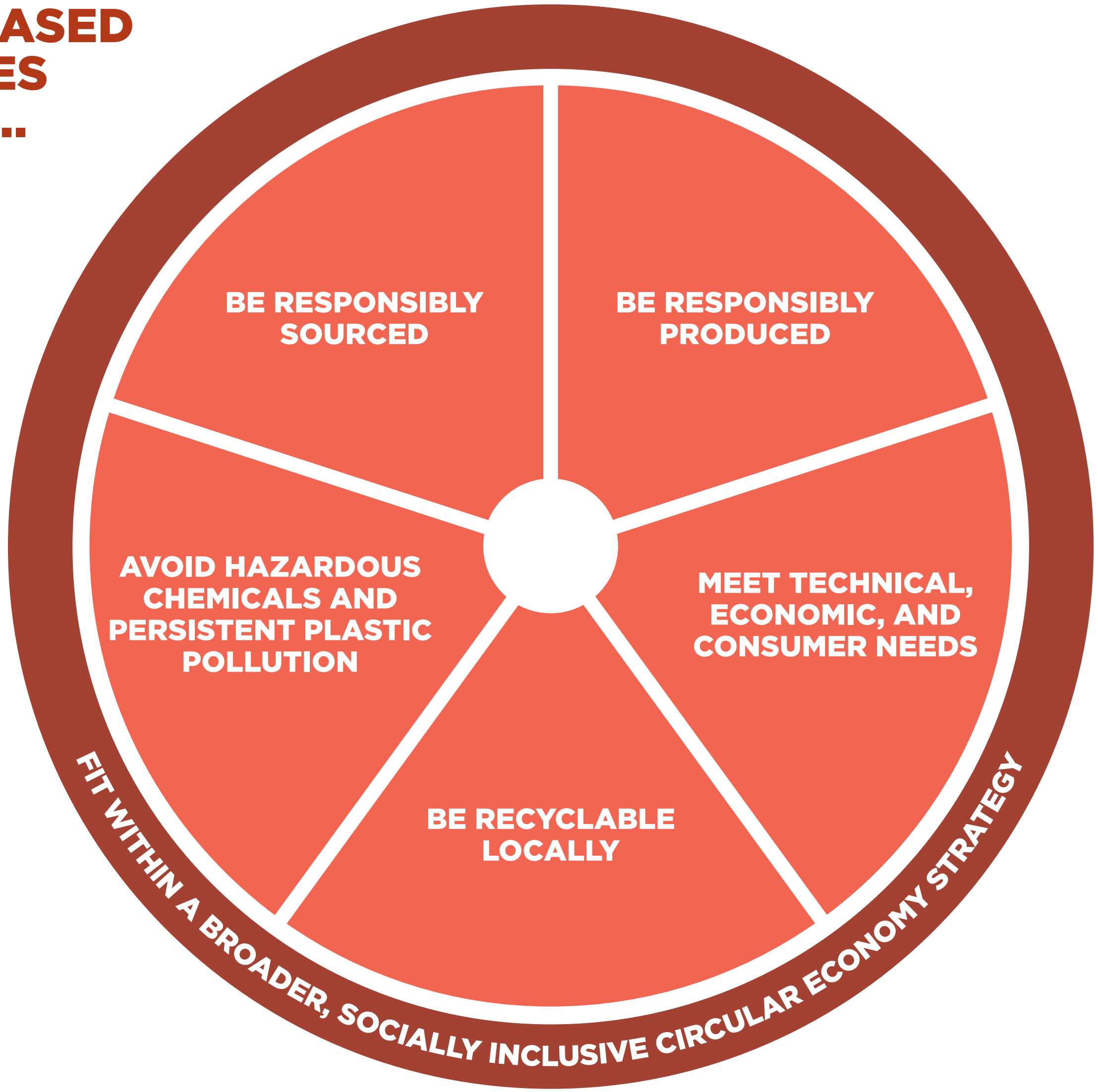
SIX CRITICAL CRITERIA FOR RESPONSIBLY DESIGNED PAPER-BASED FLEXIBLE PACKAGING

Six critical criteria set a clear framework for small-format paper-based flexible packaging in markets with high leakage rates. Together, they provide clear guardrails and guidance for innovators, businesses, investors, and policymakers to help deliver the potential benefits of paper-based solutions while minimising the risks. They apply to the entire packaging structure, including the base paper, barrier layers, adhesives, inks, varnishes, and other components. Falling short on any one can undermine environmental outcomes and confidence in paper-based alternatives.

Today, packaging that satisfies all criteria is not available for the vast majority of applications. Early progress signals real momentum, but significantly more innovation is needed to expand the range of applications where responsibly designed paper becomes a technically and economically viable tool. In particular, combining biodegradability with performance and recyclability requirements remains an innovation challenge. The pace and feasibility of progress will differ depending on product[83] and packaging type, geography, and supply chain maturity.

The current gap between this ambition and market-ready packaging should reinforce, not deter, the case for innovating, investing, and piloting now. Developing and deploying responsibly designed paper-based packaging will not happen overnight. There will be interim steps.[84] These should be deliberately designed and intended to progress towards addressing all six criteria.

PAPER-BASED FLEXIBLES SHOULD...



RESPONSIBLY SOURCED

AIM

To ensure paper-based flexibles do not contribute to pushing demand for wood beyond ecological limits and that the rights and livelihoods of local and indigenous communities are respected.

HOW

Implement a holistic strategy that combines individual business-level action — to reduce overall fibre use, prioritise environmentally preferable fibres, and ensure best practice sourcing practices — with collaborative, system-level efforts to maximise best practice sourcing across the industry and scale responsible, non-wood fibres.

In addition to recycled content, responsibly sourced non-wood fibres — in particular from agricultural waste — can play an important role in expanding responsible fibre supply for packaging, where environmentally and socially beneficial. Responsibly sourced agricultural waste fibres can have 80-100% lower land use impacts and much lower biodiversity and carbon impacts than conventional wood.[88] Scaling these feedstocks requires targeted investment and collaboration.

WHAT THIS MEANS IN PRACTICE

INDIVIDUAL COMPANY ACTIONS:

- **Take a portfolio-wide approach to fibre sourcing with the objective of reducing overall virgin fibre use and prioritising environmentally preferable fibres where feasible for each application.** Any increase in virgin fibre use resulting from shifting to paper-based flexible packaging should ideally be offset by reductions in other parts of the portfolio — for example, secondary and tertiary packaging — through improving resource efficiency (including eliminating unnecessary packaging, optimising design, and prioritising reuse where feasible) and prioritising recycled fibres and responsibly sourced non-wood fibres where feasible[85] and environmentally beneficial.[86]
- **Responsibly source all feedstock by following best practices** that protect biodiversity, respect the rights of Indigenous Peoples and local communities, and improve transparency and accountability across supply chains. This includes aiming to avoid sourcing from areas linked to deforestation and forest degradation, maintain carbon stocks, and apply robust safeguards for land and people. Sourcing practices that support the Global Biodiversity Framework — such as those defined by The Consumer Goods Forum's (CGF) Forest Positive Coalition — along with credible certification — with FSC recognised as the most robust and credible standard[87] — are essential tools for improving transparency and reducing risks of deforestation, forest degradation, and social harm. In cases where certification may not be strong enough to provide assurances to local communities, companies should strengthen their own internal policies such as grievance mechanisms.

COLLABORATIVE COMPANY ACTIONS:

- **Advocate for regulation** that supports deforestation-free and degradation-free fibre supply and forest conservation across the global supply chain.
- **Scale responsible, non-wood-based fibres** across the packaging portfolio where environmentally beneficial, recognising that scaling these innovations and supply chains will take time and early investment. These fibres should be recyclable, responsibly sourced, and verified through credible schemes.
- **Engage with credible certification schemes** to strengthen traceability of origin, chain of custody, regenerative practices, and implementation to the extent required to prevent further climate change and ecological damage. This would require increased investment in traceability systems and increased data sharing across the value chain.

LIMITATIONS

Regardless of certification, there is a global limit to the amount of wood that can be responsibly produced. Reducing the need for packaging in the first place should therefore be prioritised, for example, through reuse, refill, and eliminating packaging where feasible.

RESPONSIBLY PRODUCED

AIM

To ensure paper-based flexibles do not increase pressures on climate and water resources, particularly given the higher water intensity of paper production and the wide variability in GHG emissions.

HOW

Procure, produce, and/or deploy paper-based packaging with minimal environmental impacts. This section focuses on water use and GHG emissions — two of the most pronounced environmental impacts — from cradle-to-grave.

WHAT THIS MEANS IN PRACTICE

Assess, track, and minimise water use and GHG emissions of all packaging components, including substrates, liners, coatings, and additives, with particular attention to water use in water-scarce regions. This will require case-by-case credible life-cycle assessments that reflect producer-specific data, local supply chains, and waste management realities.

Design packaging with life-cycle emissions in mind, including likely end-of-life treatment. Minimising packaging weight can significantly reduce GHG emissions. Local waste management conditions also heavily influence overall climate impact. As waste systems evolve, these dynamics may shift, reinforcing the need for ongoing, context-specific assessment when determining whether paper is the most appropriate option. These downstream outcomes also need to be considered alongside upstream constraints, including biogenic and fossil-based emissions from sourcing, which can be a key driver of GHG emissions.[89]

Improve energy efficiency and transition to renewable energy across the supply chain. This requires upgrades to paper mills, such as converting fossil-fuelled boilers.

Apply best-practice water management in paper production. Large variations in water use across producers indicate significant potential for improvement. This is particularly important given that the pulp and paper industry is among the largest industrial consumers of water globally,[90] while half of the world's population live under highly water-stressed conditions for at least one month of the year.[91] Countries such as India and Chile face both significant water stress and rapidly growing demand for flexible packaging, heightening the importance of water-efficient production and sourcing for any use of paper-based packaging. Steps to reduce water footprints include minimising the weight of paper used, investing in closed-loop water systems, and aligning supply chains with water stewardship initiatives. Water consumption during recycling should also be considered when choosing fibres and additives.

LIMITATIONS

Even with continuous improvement, water use for paper production will likely be high as the pulping process fundamentally depends on water. Avoiding the production or recycling of paper in water scarce areas will minimise impact.

MEETS TECHNICAL, ECONOMIC, AND CONSUMER NEEDS

AIM

To enable packaging to be brought to market without creating unintended consequences such as increased food waste, product damage, or consumer rejection, which can undermine both environmental outcomes and commercial viability.

HOW

Ensure packaging delivers the product protection, shelf life, and consumer usability needed in the specific context where they are used, in a way that is economically viable for both businesses and consumers.

WHAT THIS MEANS IN PRACTICE

Define packaging specification based on the actual product needs, rather than relying on benchmarking against existing, default plastic flexible packaging formats, which often exceed what is truly needed. Technical needs vary significantly by product and geography so specifications should be set based on the conditions in which packaging is used. Benchmarking against default plastic flexible formats can result in over-specification without delivering additional value. Product reformulation can also enable more sustainable packaging. Key considerations include mechanical properties, barrier properties, format, machinability in filling, sealing, and labelling processes, performance in the supply chain and retail environments, consumer convenience, and commercial viability.

Invest in innovation to deliver paper-based packaging solutions that meet technical, economic, and consumer needs, while simultaneously addressing all other critical criteria. Paper alone rarely delivers the functionality needed for most applications; coatings, additives, or polymer layers are typically necessary to achieve essential barriers and performance properties. These components should be designed and combined in a way that meets performance and consumer needs, without compromising on the other critical criteria, while remaining cost-effective at commercial scale. For most applications, viable options that meet all these requirements do not yet exist. In particular, combining biodegradability with performance and recyclability requirements remains an innovation challenge. Machinability and suitability of machines to process paper-based packaging at competitive run times is also critical. Innovations needed are detailed in the next section under 'Closing the gap: The innovations needed'.

Expanding the range of applications where responsibly designed paper-based solutions are technically and economically viable will require industry-wide collaboration across brands, suppliers, and policymakers to share knowledge, spread costs and risks, and enable economies of scale.

Engage with consumers to encourage adoption. Success also depends on customer acceptance and packaging solutions that perform well from a technical perspective may still conflict with consumer expectations. Brands can play an influential role in addressing this by shaping consumer understanding and expectations — for example, through shelf-ready designs and merchandising toolkits to support retailers.

RECYCLABLE LOCALLY

AIM

To ensure that, when coupled with significant efforts to scale collection infrastructure, packaging has a high chance of being recycled in practice, keeping materials in the economy and reducing the need for virgin material inputs.

HOW

Design paper-based packaging to be clearly recognisable as paper and practical to handle post-use to consumers, waste pickers, sorters, and formal waste collectors and in alignment with widely recognised recycling guidelines — ideally local recyclability guidelines where these exist.

In parallel, help scale infrastructure through collaboration and industry-wide policies to ensure paper-based packaging is collected and recycled in practice.

WHAT THIS MEANS IN PRACTICE

Design packaging to meet local recyclability guidelines wherever they exist. Design criteria that determine whether paper-based packaging is likely to be collected, sorted, and recycled successfully differ by geography. Local recyclability guidelines should therefore be applied where available. Where they are not, guidance should be developed in consultation with local recyclers, taking into account local processing conditions and constraints, including water scarcity.

Use international guidance as a reference where local guidelines are absent. In regions without established design guidelines, widely recognised international guidelines can provide a useful starting point, but should be adapted to local processing realities[92] rather than applied wholesale. For example, the 4Evergreen guidelines for 'recycling mills with conventional process' or 'standard mills' provide a strong reference point.[93] Although developed for a European context, they are one of the most comprehensive and widely supported guidelines available. While meeting this standard does not guarantee that packaging will be accepted or successfully processed in local mills in every geography, the majority of its design criteria will help improve the technical feasibility of recycling.

Scale collection and recycling infrastructure through collaboration and industry-wide policies. See the sixth critical condition, 'Part of a broader, socially inclusive circular economy strategy' for details.

LIMITATIONS

Closed-loop recycling remains limited for some applications. For example, food-grade paper that is often 'downcycled' into other paper formats rather than returned to equivalent applications.

AVOID HAZARDOUS CHEMICALS AND PERSISTENT PLASTIC POLLUTION

AIM

To ensure packaging does not introduce hazardous substances — during or after use — and does not lead to persistent plastic pollution in the undesired case that it escapes managed waste streams. As scaling comprehensive collection, sorting, and recycling systems will take significant time, funding, and policy interventions, designing packaging that avoids hazardous substances or persistent plastic pollution provides an interim safety net, particularly in markets with low collection rates. The long-term goal is to stop leakage altogether.

HOW

Design packaging so that it meets robust, recognised standard specifications for home composting and biodegradability in soil, freshwater, and marine environments. Designing packaging with chemical safety at the front of mind is essential, and consideration of widely recognised restricted lists of chemicals can be a support. Packaging should provide clear disposal guidance to avoid littering.

WHAT THIS MEANS IN PRACTICE

Design packaging so that the entire structure — including substrate, liners, and additives — meets robust, recognised standard specifications for home composting and biodegradability in soil, freshwater, and marine environments. In the absence of a universal method to measure all real-world environmental impacts of packaging leakage, meeting existing robust standard for home-composting[94] and biodegradation across marine, freshwater, and soil environments is the best available proxy.[95] The most stringent and scientifically up-to-date certification schemes provide useful reference points for this assessment (see Appendix II for more detail). Examples of reference certification schemes include:

- OK compost HOME (TÜV Austria)
- DIN-Geprüft Home Compostable (DIN CERTCO)
- Commercial & Home Compostable (BPI)
- Home Compostable Verification (ABA)
- OK Biodegradable SOIL (TÜV Austria)
- DIN-Geprüft Biodegradable in Soil (DIN CERTCO)
- Soil Biodegradable Verification (ABA)
- OK Biodegradable Water (TÜV Austria)
- OK Biodegradable Marine (TÜV Austria)
- DIN-Geprüft Biodegradable in marine environment (DIN CERTCO).

Adhere to widely recognised restricted chemical lists. Chemical safety and persistence should be addressed with the same urgency as physical pollution. As a minimum, packaging should adhere to widely recognised restricted chemical lists, such as that under the EU REACH and POP regulations, and should not contain PFAS chemicals.

Provide clear, accurate disposal guidance and avoid misleading environmental claims. Packaging should focus on labels with clear disposal information, rather than claims of biodegradability.[96] 'Home compostable' labelling may be misleading when not certified against a recognised standard, supported by evidence that home or industrial compostability is achievable and likely in practice within the local context.

LIMITATIONS

While meeting these standard specifications is the best available indicator of significantly reduced impact,[97] it may not fully eliminate risks as it does not guarantee full biodegradation within a certain timeframe, or in all real-world conditions. No packaging, be it paper-based or plastic-based, can be guaranteed to have zero impact when leaked.

Biodegradability tests are conducted under controlled laboratory conditions, which differ from the wide range of environments where packaging may end up. For this reason, standard test methods for biodegradability should continue to evolve and be globally harmonised to demonstrate the inherent biodegradation potential of materials under defined and reproducible conditions, while complementary field-based and disintegration testing is needed to better reflect real-world variation in factors such as sunlight, temperature, and oxygen availability.

Current restricted chemical lists and ecotoxicity tests required for home-compostability and biodegradability certification only address part of the risk from chemical exposure. They capture a limited subset of the chemicals in use, and do not assess the full spectrum of potential impacts on human health and ecosystems. This underscores the need for precautionary design and transparency across the supply chain. Ongoing innovation in safer barrier coatings, adhesives, and inks will be critical to ensure that paper-based flexibles do not introduce new or poorly understood risks while addressing plastic pollution.

Minimising harm when ending up in the environment is not a long-term solution and does not lessen the urgency of stopping leakage altogether.

PART OF A BROADER, SOCIALLY INCLUSIVE CIRCULAR ECONOMY STRATEGY

AIM

To ensure that any material substitution contributes meaningfully to reducing flexible plastic packaging waste and pollution, enables the transition to a circular economy, and supports the livelihoods of workers in the informal waste sector.

HOW

Deploy responsibly designed paper-based flexibles as part of a broader circular economy strategy that prioritises alternative delivery models — such as reuse — and formats that reduce reliance on small-format packaging, supported by comprehensive collection, sorting, and recycling systems. Material substitution alone cannot address the challenges of flexible packaging waste and pollution.

WHAT THIS MEANS IN PRACTICE

Assess flexible packaging portfolios by region, channel, and product to identify the most impactful pathways for each context. In some cases material substitution will be appropriate, but in others, greater impact can be achieved through alternative formats or delivery models. Significant untapped potential remains to reduce reliance on small-format flexible packaging altogether, and a first priority should be identifying and scaling these opportunities.

Join multi-company reuse demonstrators. Reuse demonstrators that are multi-brand, multi-retailer, use shared infrastructure and/or packaging, and operate at a local scale can help overcome cost and consumer behaviour barriers that companies face individually. These initiatives can also inform policy and unlock financing for further scale up.

Advocate for enabling policies. Policies play an important role in incentivising and improving the viability, feasibility, or desirability of alternatives to small-format flexible packaging. This should include harmonising reuse guidelines and regulations, setting clear targets for reuse systems, and financial incentives to improve economics. Time-bound, regulatory phase-outs where appropriate can also accelerate scaling.

Increase efforts to establish inclusive collection and sorting infrastructure for all packaging. Effective collection and sorting systems are fundamental across all packaging strategies. Delivering these systems requires collaboration by industry and governments, including unlocking co-investment from public and private finance and demonstrating viable pathways to national-scale system transformation. Effective EPR schemes and other enabling policies that stimulate design for recycling and recycled content use play a crucial role. Committed advocacy efforts, engagement with the waste sector, and demonstrator projects can help accelerate this.

Ensure circular economy strategies are socially inclusive and support a just transition. Informal waste pickers form the backbone of collection and recycling systems in many countries with high leakage rates, and any changes to packaging systems can directly affect their incomes and working conditions — already under threat from increased temperatures and extreme weather events caused by climate change. A socially inclusive approach means protecting livelihoods, investing in climate adaptation, ensuring fair compensation and safe working environments, and meaningfully engaging waste pickers in system design. It also means enabling affordable access to essential products for low-income consumers as systems and packaging formats evolve. Circular economy transitions should create inclusive economic opportunities for lower-income socioeconomic groups, rather than exacerbate existing vulnerabilities.

04

CLOSING THE GAP: THE INNOVATIONS NEEDED

Delivering paper-based flexible alternatives that address the six critical criteria, while also being economically viable, will take a step change in innovation. For most applications, such packaging is not available today at commercial scale. For some applications, recyclable paper-based flexible packaging exists, but these solutions are typically not home-compostable or biodegradable and often cost significantly more than their plastic alternatives. This section focuses exclusively on the innovations required in packaging design, not on waste management systems.

Breakthroughs are needed in material sourcing, paper production, and packaging technology. Particular challenges include:

- **Non-wood fibre** technical performance, recyclability, and responsible supply
- **Water efficiency and decarbonisation** of paper production and recycling
- **Barrier performance improvements** (including coating materials) that are recyclable, home-compostable, and biodegradable across environments
- **Inks, adhesives, and additives** that are non-toxic, home-compostable, and biodegradable across environments
- **Machinability** and suitability of machines to process paper-based packaging at competitive run times

Interest and investment in this space are growing. In 2025, companies such as Amcor and Kraft Heinz launched open innovation challenges that include a focus on paper-based flexibles and more brands are prioritising these materials in their R&D strategies. Meanwhile innovators such as Pakka and Varden are bringing responsible non-wood fibre to flexible packaging applications. Together, these developments signal clear momentum behind reimagining paper as a high-performance, flexible, and circular packaging material.

While significant progress is still needed, encouraging advances are emerging. Advances in paper surface modification, biopolymer and other coatings, and inks have led to progress in barrier performance and recyclability whilst also meeting home-compostability and biodegradability standard specifications. For example, emerging coating technologies such as atomic layer deposition are enabling ultra-thin barrier layers, which allow high barriers at lower cost with improved recyclability, while innovations in responsible non-wood fibres are expanding the range of potential feedstock sources and applications. Example innovations are listed in Figure 3.

The pace and feasibility of innovation will vary substantially by product types. For example, solutions for applications with lower oxygen or moisture barrier requirements are likely to become viable sooner than those requiring high barrier packaging. Liquid or greasy products can be particularly challenging. In some cases, product reformulation can unlock different packaging options. To date, biodegradable solutions are largely limited to low-barrier applications, their compatibility with recycling still needs to be proven, and most are not available at commercial scale. This highlights a need and opportunity for further investment and development. Figure 2 provides an indicative timeline of technology readiness, challenges, and cost drivers based on expert opinions.

Cost remains one of the biggest barriers to scale. Today, home-compostable paper-based flexible packaging options are typically two to six times more expensive than plastic alternatives. This reflects slower production speeds, higher material costs, and the need for additional barrier layers, as well as potential capital expenditure to adjust or retrofit packaging lines. For small-format products with thin margins even modest packaging cost increases can affect competitiveness — and, in some instances, access to products for low-income consumers.

Economies of scale could reduce costs over time. Larger production runs and improved manufacturing efficiency can all help reduce unit costs. Policy measures such as eco-modulated EPR schemes, regulatory phase-outs of non-recyclable packaging designs, recycled-content mandates, and targeted subsidies could create incentives that enable faster scaling.

Collaboration between brands and across the supply chain can further accelerate cost reduction and scale. By sharing costs, risks, and enabling faster learning and economies of scale, collaboration can help bring viable solutions to market more quickly and at lower cost.

With sufficient innovation and investment, paper-based packaging could become a viable option in a wider range of use cases. Plastic has benefitted from decades of optimisation: in the past 15-20 years, filling lines that once ran on both paper and plastic have been converted and fine-tuned for plastic-only processes. Applying the same creativity, talent, and investment to reimagining paper-based packaging could unlock new potential, making responsibly designed paper-based packaging a technically and commercially viable choice across more markets and packaging types.

FIGURE 2 TECHNOLOGY STATUS PER CRITICAL CRITERIA

Critical criteria	Innovation challenges	Cost drivers	Today	1-5 yrs	5+ yrs	10+ yrs
SOURCING INNOVATION						
Responsibly sourced	**Improve material performance of non-wood fibres** (agri-waste/deforestation-free crops) in packaging applications, including mechanical and barrier properties, and compatibility with coatings and recycling	**Infrastructure required** to build localised hub supply models and retrofit mills for alternative fibres	**Partial use of non-wood fibres** (non-wood fibres make up around 3% of the fibre market)	**Expand pulping capacity for non-wood fibres,** as well as fibre diversity and product applications	**Certified non-wood fibre supply chains available to satisfy significant demand**	
PAPER PRODUCTION INNOVATION						
Responsibly produced	**Advance water efficiency and decarbonisation technologies** including for water reuse systems, wastewater treatment, boilers fueled by renewables, and process efficiency	**High capital outlay required to retrofit mills,** in particular to convert fossil boiler. Plus higher operational costs of responsible water disposal.	**Wide variation in emissions and water use,** with best practices not widely rolled out	**Optimise and retrofit existing systems**	**Roll out fully renewable and cleaner production and treatment technologies,** with capital outlay enabled through external funding or policy incentives	
PACKAGING INNOVATION						
Technically and economically viable **Recyclable in local streams** **Avoids hazardous chemicals and persistent plastic pollution**	**Improve barrier properties for recyclable and biodegradable packaging** ('dual end of life') **Develop inks, adhesives, and additives** that are home-compostable, non-toxic, and biodegradable **Improve machinability of packaging and suitability of machines** to enable competitive run times, including sealing	**Home-compostable/biodegradable coatings and liners are expensive and not yet available at scale** e.g. PHA, starch-based polymers, PBS **Cost of paper substrate** may be higher than the replaced virgin plastic film substrate **Longer run times** due to longer time to seal, additional step of applying coating, and risk of tearing **Capital outlay required to retrofit existing machinery and build novel equipment** to accommodate and produce paper-based packaging at scale	**Lack of scale, with dual end of life not yet available for majority of applications** Recyclable paper with plastic coating (PE/PP) with medium barriers available at high cost. High moisture barrier requires metallisation, which is costly and can be rejected by mills even if proven to be repulpable. Compostable paper substrates available at low scale. Coatings for medium barrier properties available for rigid applications at high cost.	**Scale material and coating supply, and invest in R&D to realise dual end of life** At scale dual end-of-life coatings for rigid formats and recyclable-only coating for flexible packaging in markets with low leakage. Biodegradable coatings emerging that enabe high barrier requirements (e.g. liquids, grease) in hot and humid climatic conditions. Machines retrofitted and installed based on tests with early launches.	**Dual end of life emerging on the market for flexibles** Seal strength improving and costs lowered through industry maturity. Biodegradable coatings for high barrier requirements launching on market. Greater availability of coating and substrate materials.	**Bring commercially viable dual end-of-life flexibles to market** Dual end of life widely scaled for low- and medium-barrier requirements, and emerging for higher barrier requirements. Minimise thickness of non-fibre components to further improve recyclability and cost.

Innovation timelines cannot be predicted with certainty. This timeline is highly indicative based on expert interviews.

FIGURE 3 EXAMPLES OF EMERGING INNOVATIONS

Innovation challenge	Example innovations
SOURCING INNOVATION	
Improve material performance of non-wood fibres	• enzymatic refining of agricultural residues • pulping innovations • proven applications across paperboard and corrugate with grade-specific fibre blends
PAPER PRODUCTION INNOVATION	
Advance water efficiency and decarbonisation technologies	• closed-loop water systems • biomass boiler conversions • carbon capture
PACKAGING INNOVATION	
Improve barrier properties for recyclable and biodegradable packaging	• modified and composite biopolymers • PHAs • mineral-based coatings • silk-based coatings • chromogenic barriers • foam-formed paper • spatial atomic layer deposition
Develop inks, adhesives, and additives that are home-compostable, non-toxic, and biodegradable	• bio-based plasticizers • water-based inks • vegetable oil-based inks • cellulose-based pigments, aqueous varnishes • bio-polymer based adhesives
Improve machines and machinability of packaging	• cold sealant • multilayer curtain coating • flexographic printing presses • print-applied barrier coatings • 'drop-in' solutions to existing operations

05

WHAT IT WILL TAKE TO SCALE RESPONSIBLY DESIGNED PAPER-BASED FLEXIBLES

Advancing paper-based solutions and scaling them in line with the critical criteria will require significant action in four key areas. In each, both industry and government have a significant role to play. Specific priority actions for business and policymakers are detailed on the next page.

Industry leaders can pioneer the scaling of responsibly designed paper-based packaging through individual business action. But this won't be enough alone. Achieving all six critical criteria at scale will ultimately depend on collaboration and industry-level advocacy to accelerate innovation, investment, and the enabling systems required.

Policymakers also play a vital role in establishing the safeguards and enabling conditions needed to guide the responsible use of paper-based packaging. Through regulation, incentives, and public investment, governments can help create the conditions needed to unlock innovation, improve affordability, and support system-wide change across all four areas.

Accelerate innovation towards paper-based solutions that meet all critical criteria

Establish effective and socially inclusive collection and recycling systems for paper-based flexibles as part of holistic waste management

Ensure sustainable fibre supply chains and protect forests at company and system levels

Advance and prioritise other solution pathways (elimination, reuse) wherever viable

KEY ACTION AREAS

PRIORITY ACTIONS	BUSINESS ACTION individual and collaborative	POLICY encouraged by industry-level advocacy
Accelerate innovation	**Share R&D efforts** to reduce the cost, risk, and timeframe for bringing material innovations that address the six critical criteria to market at scale	**Improve viability of responsibly designed paper-based packaging** e.g. through financial incentives, eco-modulated and effective EPR schemes, blended finance, and regulatory phase-outs of non-recyclable packaging
Ensure sustainable fibre supply chains and protect forests	**Set a portfolio-wide fibre-sourcing strategy** to reduce overall virgin fibre use and prioritise environmentally preferable fibres where feasible. Ensure that all feedstock is responsibly sourced following best practices. **Scale responsible non-wood fibre supply** through investing in innovation and supply infrastructure and creating demand	**Ensure responsible fibre supply** including through enforceable legal safeguards, ending subsidies that support industrial logging of primary forests, and the accounting of forest carbon loss in national inventories. Policies should also prioritise the protection of human rights and conservation of endangered species. This can be complemented by programmes to valorise agricultural residues as feedstocks. Engage with credible certification bodies and paper suppliers to improve transparency, strengthen accountability, and ensure credibility of claims.
Establish effective and socially inclusive collection and recycling systems	**Jointly fund city-scale transformations**[98] of collection and recycling infrastructure for packaging, engaging with and ensuring a just transition for waste pickers, unlocking co-investment from public and private finance, and demonstrating a pathway to national-scale system transformation **Design packaging to be recyclable locally** aligned with local recyclability guidelines developed through engagement with local waste management and paper recycling industries	**Establish effective and socially-inclusive EPR and other policies** that secure ongoing funding for collection and recycling infrastructure. This includes eco-modulated EPR schemes that recognise and reward responsibly designed paper-based packaging. Policies must ensure recognition and protection for waste pickers and support a just transition. Harmonise design-for-recycling guidelines or mandates for paper-based flexibles, supported by local paper industries.
Advance and prioritise other solution pathways	**Join multi-company reuse demonstrators** that are multi-brand and multi-retailer, operate at a city or country scale, and have shared reuse infrastructure and packaging. Such demonstrators can support learning, inform policy, and unlock financing for further scale up. **Identify opportunities to move away from small-format** to larger volumes and to reuse and refill models where appropriate. Many reuse types require collaboration across the value chain and/or policy frameworks to scale.	**Incentivise alternatives** to small-format flexible packaging where beneficial, through policies that improve their viability, feasibility, or desirability, e.g. reuse standards and targets, fiscal or financial incentives, and time-bound reasonable regulatory phase-outs of non-recyclable packaging where appropriate

APPENDIX I: DEFINITIONS

Small-format flexible packaging Refers to primary, business-to-consumer (B2C) flexible packaging sized A5 or smaller, such as sachets, wrappers, pouches, and small pillow bags.

Markets with high leakage rates Regions where waste has a high likelihood of ending up in the environment. This is typically due to low collection rates and high rates of waste mismanagement.

Leakage of waste Flow of waste into the environment, including to water bodies and land. Leakage may be intentional or unintentional and is exacerbated by waste mismanagement. A quarter of all plastic waste is projected to leak into the environment by 2040 under a business-as-usual scenario.[99]

Mismanaged waste Waste that is not collected, treated, or disposed of in controlled facilities, including waste that is openly burned, disposed of in unmanaged landfills, or otherwise not collected. It does not include waste disposed of in managed landfill, waste-to-energy, and recycling. Over half of all plastic waste is projected to be mismanaged by 2040 in a business-as-usual scenario.[100]

Paper-based flexible packaging Flexible packaging mainly made from a cellulosic substrate — derived from wood or non-wood fibres. To be considered recyclable in a standard paper mill this fibre content should be high — typically above 80-90%, depending on the country. On top of that substrate they may include thin coatings or laminates to provide performance features, as well as additives, adhesives, inks, etc. Coatings and laminates are often made from fossil-based plastics. However, they can also be made from carbohydrate polymers, polyesters, and wax-based coatings. While paper-based flexible packaging has the potential to be home-compostable and biodegradable across different environments, most current designs do not meet these standards.

'Responsibly designed' paper-based packaging Paper-based packaging that addresses all six critical criteria laid out in this report.

Biodegradable Able to be broken down by microorganisms into carbon dioxide, water, and mineral salts of any other elements present (mineralization) plus new biomass.[101] Biodegradation depends on the complex biogeochemical conditions at each testing site (e.g. temperature, available nutrients and oxygen, microbial activity, etc.). Therefore, generalised claims about biodegradability can only serve as approximations and need to be confirmed by standardised testing under lab conditions. In-situ behaviour can vary, depending on the conditions, size of the product, type of material, and other factors.[102] Biodegradable is a material-neutral definition: both paper-based and plastic-based products can be completely biodegradable. Applicable standardised test methods and specifications are detailed in Appendix II.

Home-compostable

Able to undergo degradation by biological processes during home composting to yield carbon dioxide, water, inorganic compounds, and biomass at a rate consistent with other known home compostable materials, leaving no visible, distinguishable, or toxic residue.[103] Any home-compostable claim should be supported by standardised testing under lab conditions, typically addressing four aspects: characterisation, biodegradation in well-managed home composting, disintegration in well-managed home composting, and home compost quality.[104] Home-compostable is a material neutral definition: both paper-based and plastic-based products can be home-compostable. Applicable standardised test methods and specifications are detailed in Appendix II.

Plastic

Used here to describe materials made primarily from synthetic or semi-synthetic polymers, including both fossil-based and bio-based plastics, and biodegradable, industrial compostable, home-compostable, and non-biodegradable plastics. Not all plastics cause persistent pollution: the critical condition ‘Avoid hazardous chemicals and persistent plastic pollution’ aims to eliminate persistent plastics, rather than pursuing plastic-free solutions.

Responsibly sourced

The sourcing of resources from supply chains that operate within ecological limits,[105] avoid deforestation and forest degradation, maintain carbon stocks and biodiversity, respect the human rights and livelihoods of local and indigenous communities, and ensure forests and land remain resilient and functional for future generations.

APPENDIX II: REVIEW OF AVAILABLE HOME-COMPOSTABLE AND BIODEGRADATION STANDARDS SPECIFICATIONS AND CERTIFICATIONS

As set out under the critical criteria 'Avoid hazardous chemicals and persistent plastic pollution', responsibly designed paper-based flexible packaging should meet robust testing requirements for home compostability and biodegradation across marine, freshwater, and soil environments, as stipulated by standard specifications. These standard specifications define pass/fail criteria and go hand-in-hand with the rules and guidelines defined in certification schemes. Each certification body has its own certification scheme(s), addressing topics that are not addressed by standard specifications, e.g. how flexible packaging needs to be tested, how inks need to be tested, etc. This appendix presents a selection of pass/fail criteria, rules and guidelines laid down in standard specifications and certification schemes, identified by experts as relevant to packaging. Certification schemes are hence based on international, regional, or national standard specifications (i.e. ISO, CEN, etc.); a high level of stringency; and foundation on the most recent scientific knowledge.

It should be noted that certification covering biodegradation across marine, freshwater and soil environments is available only to products intended to be used in these environments (e.g. agricultural mulch films in soil environment, piscicultural aids in marine environment, etc.). As packaging should never end up in soil, marine or freshwater environments, it falls outside the scope of biodegradation certification and such certification is not possible. Packaging is only eligible for compostability certification. However, packaging that has been tested and complies with standard specifications for a particular environment, whether certified or not, is likely to be much less persistent and causes significantly less harm in that environment than packaging which does not.

While meeting standard specifications is the best available indicator of significantly reduced impact,[106] it may not fully eliminate risks as it does not guarantee full biodegradation within a certain timeframe in all real-world conditions. No packaging, be it paper-based or plastic-based, can be guaranteed to have zero impact when leaked, and biodegradability testing conditions differ from the wide range of environments where packaging may end up.

Table developed by Normec OWS in January 2026.

Environment	Issuer	Name	Standard specification	Biodegradation requirements	Disintegration requirements	Requirements on environmental safety
Home composting	TÜV Austria	OK compost HOME	EN 13432, with adaptations to reflect home composting conditions.	≥90% conversion to CO_2 within maximum 12 months at ambient temperature (20-30°C) following ISO 14855. Ingredients below 1% by dry weight are not required to be tested on biodegradability, unless these ingredients sum up to >5% dry mass.	≥90% of material must break down to <2 mm within maximum 180 days at ambient temperature (20-30°C) following ISO 20200. There shall be no visual contamination of the final compost (<2 mm).	≥90% germination and biomass yield compared to blank, for two plant species, following OECD 208. Ingredients below 0.1% by dry weight are not required to be tested on ecotoxicity, unless these ingredients sum up to >0.5% dry mass. Products shall not exceed set limits of certain heavy metals and total Fluorine nor other substances that are toxic to the environment or humans, as defined in EN 13432. A self-declaration on the non-intentional use of per-fluorinated or fluorinated chemicals is needed. Constituents that appear on the (candidate) list of Substances of Very High Concern are not accepted.

Environment	Issuer	Name	Standard specification	Biodegradation requirements	Disintegration requirements	Requirements on environmental safety
Home composting	DIN CERTCO	DIN-Geprüft Home Compostable	NF T 51-800	≥90% conversion to CO_2 within maximum 12 months at ambient temperature (<30°C) following ISO 14855. Ingredients above 1% by dry weight shall be tested individually on biodegradability. Ingredients below 1% by dry weight are not required to be tested on biodegradability, unless these ingredients sum up to >5% dry mass.	≥90% of material must break down to <2 mm within maximum 180 days at ambient temperature (20-30°C) following ISO 20200.	≥90% germination and biomass yield compared to blank, for two plant species, following OECD 208. Ingredients below 0.1% by dry weight are not required to be tested on ecotoxicity, unless these ingredients sum up to >0.5% dry mass. Products shall not exceed set limits of certain heavy metals and total Fluorine nor other substances that are toxic to the environment or humans, as defined in NF T51-800. Packaging cannot include any endocrine disruptor, any of the carcinogenic, mutagenic, or toxic for reproduction (CMR) substances appearing on the candidate list of Substances of Very High Concern of the EU REACH regulation (EC 1907/2006), as well as PFAS.
	BPI	Compostable — Commercial & Home	NF T51-800, with adding more strict rules on biodegradation and considering compliance with ASTM D6400 (industrial composting) a prerequisite.	≥90% conversion to CO_2 within maximum 12 months at ambient temperature (20-30°C) following ISO 14855. Individual organic ingredients present in concentrations between 1%-10% by dry weight shall be tested individually on biodegradability. Ingredients below 1% by dry weight are not required to be tested on biodegradability, unless these ingredients sum up to >5% dry mass.	≥90% of material must break down to <2 mm within maximum 180 days at ambient temperature (20-30°C) following ISO 20200. Visual contamination of compost as evidenced by reduction of aesthetic acceptability should not be significantly increased by any post-composting residues of the introduced packaging material.	≥90% germination and biomass yield compared to blank, for two plant species, following OECD 208. Ingredients below 0.1% by dry weight are not required to be tested on ecotoxicity, unless these ingredients sum up to >0.5% dry mass. Products shall not exceed set limits of certain heavy metals and total Fluorine nor other substances that are toxic to the environment or humans, as defined in NF T51-800. Packaging assessed shall not include any endocrine disruptor, any of the carcinogenic, mutagenic, or toxic for reproduction (CMR) substances appearing on the candidate list of Substances of Very High Concern of the EU REACH regulation (EC 1907/2006).

Environment	Issuer	Name	Standard specification	Biodegradation requirements	Disintegration requirements	Requirements on environmental safety
Home composting	ABA	Home Compostable Verification	AS 5810	≥90% conversion to CO_2 within maximum 12 months at ambient temperature (20-30°C) following ISO 14855. Ingredients below 1% by dry weight are not required to be tested on biodegradability, unless these ingredients sum up to >5% dry mass.	≥90% of material must break down to <2 mm within maximum 180 days at ambient temperature (20-30°C) following ISO 20200.	≥90% germination and biomass yield compared to blank, for two plant species, following OECD 208. ≥90% survival and biomass yield compared to blank for earthworms, following ASTM E1676. Products shall not exceed set limits of certain heavy metals and total Fluorine nor other substances that are toxic to the environment or humans, as defined in AS 5810.
Marine	DIN CERTCO	DIN-Geprüft Biodegradable in Marine Environment	ISO 22403	≥90% conversion to CO_2 within maximum 24 months at ambient temperature (15-25°C) following one of the following test methods: ISO 18830, ISO 19679, ISO 22404, ASTM D6691, ISO 23977-1, or ISO 23997-2. Individual organic ingredients present in concentrations between 1%-15% by dry weight shall be tested individually on biodegradability. Ingredients below 1% by dry weight are not required to be tested on biodegradability, unless these ingredients sum up to >5% dry mass.	No disintegration requirement included. The rate of disintegration is merely determined to give an indication of the lifetime of the final product under optimal conditions in marine environments. Testing is to be performed following ISO 23832 at ambient temperature (15-25°C).	≤10% of inhibition of marine algae compared to blank, following ISO 10253. ≤10% of mortality of Copepods compared to blank, following ISO 14669. ≥90% of bioluminescence of Vibrio fischeri compared to blank, following ISO 11348-3. Products shall not exceed set limits of certain heavy metals and total Fluorine nor other substances that are toxic to the environment or humans, as defined in ISO 22403. Poly- and perfluoroalkyl substances (PFAS) shall not be intentionally added. Constituents that appear on the (candidate) list of Substances of Very High Concern are not accepted.

Environment	Issuer	Name	Standard specification	Biodegradation requirements	Disintegration requirements	Requirements on environmental safety
Marine	TÜV Austria	OK Biodegradable MARINE	This certification scheme is not based on nor derived from an existing standard specification, it is a privately developed scheme.	≥90% conversion to CO_2 within maximum six months at ambient temperature (30°C) following ASTM D6691. Ingredients below 1% by dry weight are not required to be tested on biodegradability, unless these ingredients sum up to >5% dry mass.	≥90% of material must break down to <2 mm within maximum 84 days at ambient temperature (30°C) following a test method developed by TÜV Austria.	No negative effect on the mobility of ≥90% of Daphnia compared to blank, following OECD 202. Products shall not exceed set limits of certain heavy metals and total Fluorine nor other substances that are toxic to the environment or humans, as defined in EN 13432. Ingredients below 0.1% by dry weight are not required to be tested on ecotoxicity, unless these ingredients sum up to >0.5% dry mass. Constituents that appear on the (candidate) list of Substances of Very High Concern are not accepted.
Freshwater	TÜV Austria	OK Biodegradable WATER	EN 13432, with adaptations to reflect freshwater conditions.	≥90% conversion to CO_2 within maximum 56 days at ambient temperature (20-25°C) following ISO 14851 or ISO 14852. Ingredients below 1% by dry weight are not required to be tested on biodegradability, unless these ingredients sum up to >5% dry mass.	No disintegration requirement included.	Products shall not exceed set limits of certain heavy metals and total Fluorine nor other substances that are toxic to the environment or humans, as defined in EN 13432. Substances of Very High Concern (Annex XIV or REACH) are not accepted.

Environment	Issuer	Name	Standard specification	Biodegradation requirements	Disintegration requirements	Requirements on environmental safety
Soil	TÜV Austria	OK Biodegradable SOIL	EN 13432, with adaptations to reflect soil conditions.	≥90% conversion to CO_2 within maximum 24 months at ambient temperature (20-25°C) following ISO 17556.	No disintegration requirements, however, constituents that include an evident risk of visual contamination not accepted.	≥90% germination and biomass yield compared to blank, for two plant species, following OECD 208. Ingredients below 0.1% by dry weight are not required to be tested on ecotoxicity, unless these ingredients sum up to >0.5% dry mass. Products shall not exceed set limits of certain heavy metals and total Fluorine nor other substances that are toxic to the environment or humans, as defined in EN 13432. A self-declaration on the non-intentional use of per-fluorinated or fluorinated chemicals is needed. Constituents that appear on the (candidate) list of Substances of Very High Concern are not accepted.
	DIN CERTCO	DIN-Geprüft Biodegradable in Soil	EN 17033 & ISO 23517	≥90% conversion to CO_2 within maximum 24 months at ambient temperature (20-28°C) following ISO 17556. Individual organic ingredients present in concentrations between 1%-15% by dry weight shall be tested individually on biodegradability (ISO 23517 specific). Ingredients below 1% by dry weight are not required to be tested on biodegradability, unless these ingredients sum up to >5% dry mass (EN 17033) or >3% dry mass (ISO 23517).	No disintegration requirements.	≥90% germination and biomass yield compared to blank, for two plant species, following OECD 208. ≥90% survival and biomass yield compared to blank for earthworms, following ISO 11268-1. Nitrification inhibition ≥80% for bacteria, following ISO 15685. Products shall not exceed set limits of certain heavy metals and total Fluorine nor other substances that are toxic to the environment or humans, as defined in EN 17033 and/or ISO 23517. A self-declaration on the non-intentional use of per-fluorinated or fluorinated chemicals is needed. Constituents that appear on the (candidate) list of Substances of Very High Concern are not accepted.

Environment	Issuer	Name	Standard specification	Biodegradation requirements	Disintegration requirements	Requirements on environmental safety
Soil	ABA	Soil Biodegradable Verification	ISO 23517	≥90% conversion to CO_2 within maximum 24 months at ambient temperature (20-28°C) following ISO 17556. Individual organic ingredients present in concentrations between 1%-15% by dry weight shall be tested individually on biodegradability. Ingredients below 1% by dry weight are not required to be tested on biodegradability, unless these ingredients sum up to >3% dry mass.	No disintegration requirements.	≥90% germination and biomass yield compared to blank, for two plant species, following OECD 208. ≥90% survival and biomass yield compared to blank for earthworms, following ISO 11268-1. Nitrification inhibition ≥80% for bacteria, following ISO 15685. Products shall not exceed set limits of certain heavy metals and total Fluorine nor other substances that are toxic to the environment or humans, as defined in ISO 23517. A self-declaration on the non-intentional use of per-fluorinated or fluorinated chemicals is needed. Constituents that appear on the (candidate) list of Substances of Very High Concern are not accepted.

CORE TEAM

Laura Smith
Programme Manager, Plastics

Sander Defruyt
Strategy Lead, Plastics

Rob Opsomer
Executive Lead, Plastics

Laura Collacott
Editorial Consultant

Nora Pelizzari
Editorial Lead

Matt Barber
Graphic Designer

WIDER TEAM

Veronika Lundberg
Freelancer, Plastics

Leo Nutter
Senior Product Manager, Strategy (AI & Technology)

Isobel Pinckston
Editorial Consultant

Neil Amos
Digital Programme Manager,
Communications (Content & Delivery)

Sofia Voudouroglou
Senior Strategic Communications Executive,
Communications

Gabriella Hewitt
Senior Strategic Communications Manager,
Communications

Molly Jia
Project Manager, China

Guilherme Suertegaray
Senior Project Manager, Latin America

Marianne Kettunen
Biodiversity Lead

Gilonne Traub
Partnerships Manager

ABOUT THE ELLEN MACARTHUR FOUNDATION

The Ellen MacArthur Foundation is an international charity that develops and promotes the circular economy in order to tackle some of the biggest challenges of our time, such as climate change, biodiversity loss, waste, and pollution. We work with our network of private and public sector decision makers, as well as academia, to build capacity, explore collaborative opportunities, and design and develop circular economy initiatives and solutions. Increasingly based on renewable energy, a circular economy is driven by design to eliminate waste, circulate products and materials, and regenerate nature, to create resilience and prosperity for business, the environment, and society.

Further information:
ellenmacarthurfoundation.org

DISCLAIMER

ENDNOTES

1 Total exports are estimated at 3.5 million tonnes per year, of which 5-10% is estimated to be mismanaged. Source: Pew Charitable Trusts, Breaking the Plastic Wave (2020)

2 Asia Pacific is the fastest growing flexible plastic packaging market. Source: Grand View Research, Flexible Packaging Market (2026-2033) (2025)

3 This report does not assess business-to-business, secondary, or tertiary packaging, nor larger, flexible packaging formats, as these follow different end-of-life pathways and face different collection dynamics

4 A5 size is 14.8 cm x 21.0 cm. Packaging sized A5 or smaller made up 92% of total flexible plastic sachet pollution audited by Break Free From Plastic (Source: Break Free From Plastic, Branded: The Sachet Scourge In Asia [2024]); 75% of FMCG units are sold as <50 ml or <50 g in India (Source: India Plastics Pact, Small formats and sachets: exploring challenges, solutions and interventions [2024]); 52% of branded residual plastic waste in the Philippines is sachets (Source: Global Alliance for Incinerator Alternatives, Sachet Economy: Big Problems in Small Packets [2019]); plastic food packaging, which is usually small format, makes up 33% of macro debris in Indonesia (Source: Plastics in Indonesian Societies [PISCES], A System Analytics Approach to Reduce Plastic Pollution [2024])

5 Based on Wood MacKenzie plastic packaging market data

6 80% is by weight. Source: Pew Charitable Trusts, Breaking the Plastic Wave (2020)

7 See section ‘Six critical criteria’ for more detailed definitions and limitations. Note: this should apply to the entire packaging, including all its components (liners, inks, additives, etc.)

8 Paper production and other short-lived fibre products already account for nearly a fifth of total logging. Source: FAOSTAT, Forestry Production and Trade (2025). Up to half of all virgin wood pulp used for paper may come from Ancient and Endangered forests. Source: Forestry Stewardship Council, FSC Support to Respect for Human Rights (2019). Degradation within managed forests also reduces old-growth forest cover and drives biodiversity loss. Source: Mackey, B., et al., Assessing the Cumulative Impacts of Forest Management on Forest Age Structure Development and Woodland Caribou Habitat in Boreal Landscapes: A Case Study from Two Canadian Provinces, Land (2024). See section ‘Paper-based alternatives come with potential benefits, limitations, and risks’ for more details.

9 The pace and feasibility of progress will differ depending on product and packaging type, geography, and supply chain maturity. For example, liquid products have very different technical packaging needs to solids.

10 Interim steps with packaging that does not yet meet all six critical criteria (e.g. packaging that is not yet both recyclable and biodegradable) would enable the testing of how paper-based packaging behaves in large-scale production, throughout the supply chain, and in terms of consumer acceptance. Such steps would also enable investment in adjusting machinery and supply chains, in parallel with advancing packaging innovation.

11 Feasibility depends on factors such as logistics, regulations, and technical and commercial viability. In many cases this will require collaborative industry and policy action.

12 Singh, R., et al., Buying less, more often: An evaluation of sachet marketing strategy in an emerging market, The Marketing Review (2009)

13 According to survey data reported by Social Weather Stations 2018 Survey Report on Plastic Pollution: Third Quarter 2018 Social Weather Survey. Source: Global Alliance for Incinerator Alternatives (GAIA), Sachet Economy: Big Problems in Small Packets (2020)

14 500 g portions of jam and milk powder sell more than their sachet counterparts. Source: Singh, R., et al., Buying less, more often: An evaluation of sachet marketing strategy in an emerging market, The Marketing Review (2009)

15 Ellen MacArthur Foundation, Reuse: rethinking packaging (2019)

16 WWF and Ellen MacArthur Foundation, Reuse in the Global South: Case Studies (2025)

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21 While home composting itself is limited, compliance with home-composting standards provides a proxy to reduce impacts in the case of leakage. For more details, see section ‘Avoids hazardous chemicals and persistent plastic pollution’.

22 The EU Fertilising Products Regulation and EU REACH Regulation establish precedent for applying ISO-recognised biodegradation test methods linked to pass / fail levels as criteria to mitigate environmental risks. Commission Delegated Regulation (EU) 2024/2770 of 15 July 2024 amending Regulation (EU) 2019/1009 of the European Parliament and of the Council as regards biodegradability criteria for coating agents and water retention polymers,

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73 GHG emissions vary significantly between producers and regions with many factors playing a role. This should not replace a detailed case-by-case assessment.

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94 While home composting itself is limited, and not the target end-of-life outcome, compliance with home-composting standards, alongside the other standards listed, provides a proxy to reduce impacts in the case of leakage

95 The EU Fertilising Products Regulation and EU REACH Regulation establish precedent for applying ISO-recognised biodegradation test methods linked to pass / fail levels as criteria to mitigate environmental risks. Commission Delegated Regulation (EU) 2024/2770 of 15 July 2024 amending Regulation (EU) 2019/1009 of the European Parliament and of the Council as regards biodegradability criteria for coating agents and water retention polymers,

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96 Early studies also suggest some consumers may be more likely to discard packaging in the open environment if they believe it will biodegrade. See section 'Paper-based flexible packaging comes with potential benefits, limitations, and risks' for more details

97 The EU Fertilising Products Regulation and EU REACH Regulation establish precedent for applying ISO-recognised biodegradation test methods linked to pass / fail levels as criteria to mitigate environmental risks. Commission Delegated Regulation (EU) 2024/2770 of 15 July 2024 amending Regulation (EU) 2019/1009 of the European Parliament and of the Council as regards biodegradability criteria for coating agents and water retention polymers,

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