Compilation of information on best practices and identification of challenges for improving the design of plastic products to increase their durability, reusability, repairability and recyclability, as well as to reduce hazardous constituents in plastic products

BASEL CONVENTION

PLASTIC WASTE PARTNERSHIP
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UN environment programme

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Abbreviations and acronyms

ABS - Acrylonitrile Butadiene Styrene

ACM - Advanced Composite Material

BYO - Bring Your Own

CBMs - Circular Business Models

CE - Circular Economy

CLP - Classification, Labelling and Packaging

CPPdb - database of Chemicals associated with Plastic Packaging

DDT - Dichlorodiphenyltrichloroethane

DfR - Design for recycling

EDC - Endocrine disrupting chemicals

EEE - Electrical and electronic equipment

EoL - End-of-life

EPS - Expanded polystyrene

EU – European Union

EVA - Ethylene-vinyl acetate

EVOH - Ethylene vinyl alcohol

FCAs - Food contact articles

FCCdb database of intentionally added food contact chemicals

FCCs - Food contact chemicals

FCMs - Food contact materials

FMCG - Fast-Moving Consumer Goods

FDA - Food and Drug Administration

GHS - United Nations' Globally Harmonized System

GPP - Green Public Procurement

HDPE - High-density polyethylene

HORECA – Hotels, Restaurants, and Cafes

IAS - Intentionally added substances

LCA - Life Cycle Assessment

LDPE - Low-density polyethylene

MMPP - Multi-material multilayer materials plastic packaging

MRF - Material Recovery Facility

NIAS - Non-intentionally added substances

NOL - Letter of Non-Objection

OBP - OceanBound Plastic

OECD - The Organisation for Economic Co-operation and Development

PA - Polyamide

PBT - Polybutylene terephthalate

PC - Polycarbonate

PCR - Post-consumer Resin

PE - Polyethylene

PCBs - Polychlorinated biphenyls

PEIT - Polyethylene-co-isosorbide terephthalate

PET - Polyethylene terephthalate

PIR - Post-industrial Resin

PLA - Biobased polymer such as Polylactic acid

PLE - Product life extension

POM - Placed on the market

PP - Polypropylene

PS - Polystyrene

PBT - Polybutylene terephthalate

PUR - Polyurethane

PVC - Polyvinyl Chloride

PVDC - Polyvinylidene chloride

PWP - Plastic Waste Partnership

R&D - Research and Development

REACH - EU Registration, Evaluation, Authorisation and Restriction of Chemicals

RoHS - EU Restriction of Hazardous Substances Directive.

RPO - Retain product ownership

RSPO - Roundtable on Sustainable Palm Oil

SAP - Superabsorbent polymer

SUPPs - Single use Plastic Products

TEP - Thermoplastic elastomers

UNEP - United Nations Environment Programme

VOCs - Volatile organic compounds

WEEE - Waste from electrical and electronic equipment

Launched in November 2019, the Basel Convention Plastic Waste Partnership was established with the goal to improve and promote the environmentally sound management of plastic waste at the global, regional and national levels and prevent and minimize their generation so as to, among other things, reduce significantly and in the long-term eliminate the discharge of plastic waste and microplastics into the environment, in particular the marine environment.

Organised into a working group and four project groups addressing different thematic issues, the Partnership supports the achievement of the Sustainable Development Goals and sharing of solutions to tackle the triple planetary crisis as a trusted source of information on best practices, successes, and challenges in the prevention, minimisation and environmentally sound management of plastic waste.

The Partnership seeks to create a collaborative environment to promote action and dialogue among governments, regional and local authorities, intergovernmental organizations, the private sector, non-governmental organizations and academia on initiatives that can be carried out at the local, regional and global levels to tackle plastic pollution.

I. Introduction

1. This publication was prepared for Project Group 1 "Plastic waste prevention and minimization", under Output 1 of Activity 2 of its workplan: "Compilation of information on best practices and identification of challenges for improving the design of plastic products to increase their durability, reusability, repairability, and recyclability, as well as to reduce hazardous constituents in plastic products".

II. Context

2. Global plastics production has increased 230-fold from 2 million tonnes (Mt) in 1950 to 460 Mt in 2019. Despite a temporary decrease during the COVID-19 pandemic in 2020, the upward trajectory of plastics production and waste generation resumed in 2021 as economic activity picked up again. In 2019, 22 Mt of plastic waste leaked into the environment. The vast majority of leaked plastics are macroplastics (88 percent by weight), while the share of microplastics is smaller (12 percent). As of 2019, an estimated 109 Mt of leaked plastics have accumulated in rivers and 30 Mt in the ocean[1].

3. According to the 2022 OECD Global Plastics Outlook, plastics use is projected to almost triple, from 460 Mt in 2019 to 1,231 Mt in 2060, mainly driven by population and economic growth. Primary plastics from fossil fuel will continue to dominate (88 percent in 2060), while recycled (secondary) plastics are still expected to only make up 12 percent of the total share of plastics use in 2060.

4. Single use Plastic Products (SUPPs) represent the largest plastics application category and account for a third of all plastics used globally[2]. In particular, the packaging sector is expected to more than double by 2060, with the polymers commonly used to produce packaging, such as polyethylene terephthalate (PET) and polyethylene (PE), projected to also more than double in use by 2060[3].

5. The United Nations Environment Programme (UNEP) defines SUPPs as "an umbrella term for different types of products that are typically used once before being disposed of or recycled"[4]. The EU Directive on the reduction of the impact of certain plastic products on the environment (EU 2019/904) identifies SUPPs as a product that is "made wholly or partly from plastic and is not conceived, designed, or placed on the market to accomplish, within their lifespan, multiple trips or rotations by being returned to a producer for refill or reused for the same purpose for which they were conceived"[5].

6. Also referred to as disposable plastic products, SUPPs are more likely to end up in the environment than reusable options. Their impacts on the environment and human health are global and can be dramatic[6,7]. SUPPs stranded in the marine environment can cause lethal and sub-lethal effects in a wide range of marine species through direct entanglement, starvation, drowning, laceration of internal tissues, or indirectly by damaging critical marine ecosystems. Exposure to plastics and plastic-associated chemicals can have adverse impacts at multiple levels from molecular and biochemical to population and ecosystem. In addition, once broken down, microplastics can act as vectors for pathogenic organisms harmful to humans and faunas[8,9].

1 OECD (2022) "Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options," OECD Publishing. Available at: https://doi.org/10.1787/de747aef-en.
2 Charles D & Kimman L 2023, Plastic Waste Makers Index 2023, Minderoo Foundation.
3 OCDE (2022) "Global Plastics Outlook: Policy Scenarios to 2060," Éditions OCDE, Paris, https://doi.org/10.1787/aa1edf33-en.
4 United Nations Environment Programme (2018) "Legal Limits on Single-Use Plastics and Microplastics: A Global Review of National Laws and Regulations." Available at: https://www.unep.org/resources/report/legal-limits-single-use-plastics-and-microplastics
5 Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment (Text with EEA relevance) Available at: https://eur-lex.europa.eu/eli/dir/2019/904/oj
6 Gallo, F. et al. (2018) "Marine litter plastics and microplastics and their toxic chemicals components: the need for urgent preventive measures," *Environmental Sciences Europe*, 30(1). Available at: https://doi.org/10.1186/s12302-018-0139-z
7 Chen, Y. et al. (2021) "Single-use plastics: Production, usage, disposal, and adverse impacts," *Science of the Total Environment*, 752, p. 141772. Available at: https://doi.org/10.1016/j.scitotenv.2020.141772.
8 Landrigan, P.J. et al. (2023) "The Minderoo-Monaco Commission on Plastics and Human Health," *Annals of Global Health*, 89(1). Available at: https://doi.org/10.5334/aogh.4056.
9 United Nations Environment Programme (2021) "From Pollution to Solution: A global assessment of marine litter and plastic pollution." Nairobi. Available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/36963/POLSOL.pdf

7. SUPPs are made of:
   a. Intentionally added substances (IAS) as monomers used to make the polymer, additives added to the polymer to impart a desired property or function, and other chemicals intentionally used during manufacturing (e.g., solvents, coatings, auxiliaries[10], or processing aids). Thermoplastics are a class of polymers that are commonly used to produce SUPPS as they can be softened and melted by the application of heat and can be processed either in the heat-softened state (e.g., by thermoforming) or in the liquid state (e.g., by extrusion and injection moulding).
   b. Non-intentionally added substances (NIAS) as impurities, reaction by-products, oligomers, or degradation products.

8. More than 10,000 relevant chemical substances have been identified in plastic production as plastic monomers, additives, and processing aids. These substances may be released throughout the entire life cycle of the plastic, posing risks to human health, the environment, and recycling systems. Over 2,400 substances are identified as substances of potential concern as they meet one or more of the persistence, bioaccumulation, and toxicity criteria in the European Union[11].

9. The database of Chemicals associated with Plastic Packaging (CPPdb),[12] developed in 2019 by researchers from the Food Packaging Forum,[13] lists 906 substances likely associated with plastic packaging and 3,377 substances that are possibly used in plastics, as monomers, intermediates, solvents, surfactants, plasticizers, stabilizers, biocides, flame retardants, accelerators, and colorants, among other functions[14]. Of the 906 substances likely associated with plastic packaging, 63 rank highest for human health hazards and 68 for environmental hazards according to the harmonized hazard classifications assigned by the European Chemicals Agency within the Classification, Labelling and Packaging (CLP) regulation implementing the United Nations' Globally Harmonized System (GHS). Further, 7 of the 906 substances are classified in the EU as persistent, bio accumulative, and toxic (PBT), or very persistent, very bio accumulative (vPvB), and 15 as endocrine disrupting chemicals (EDC). Thirty-four of the 906 substances are also recognized as EDC or potential EDC in the recent EDC report by the United Nations Environment Programme[15].

10. A database of intentionally added food contact chemicals (FCCdb),[16] developed in 2021, lists 12,285 substances that could possibly be used worldwide to make food contact materials (FCMs) or food contact articles (FCAs), of which 608 hazardous substances have been prioritized for further assessment and substitution in FCMs/FCAs. The list is incomplete as for over a quarter of all FCCdb chemicals, no hazard information could be found in the sources consulted, revealing a significant data gap and research need. Plastics and coatings, as well as paper and board FCMs, appear to be a significant source of hazardous substances, even when printing inks are not considered. The printing inks' FCM type in fact includes the highest number of identified hazardous substances so far, many of them remaining unassessed. In addition to printing inks, paper based FCAs can also contain coatings and adhesives. Both FCM types are characterized by a high diversity of potentially hazardous FCCs and rather little oversight to ensure their safe use.

10 Substances needed during manufacturing processes, e.g., solvents.
11 Wiesinger, H., Wang, Z. and Hellweg, S. (2021) "Deep Dive into Plastic Monomers, Additives, and Processing Aids," *Environmental Science & Technology*, 55(13), pp. 9339–9351. Available at: https://doi.org/10.1021/acs.est.1c00976.
12 https://zenodo.org/records/1287773#.W9gqgWhKhaR.
13 https://www.foodpackagingforum.org
14 Groh, K.J. et al. (2019) "Overview of known plastic packaging-associated chemicals and their hazards," *Science of the Total Environment*, 651, pp. 3253–3268. Available at: https://doi.org/10.1016/j.scitotenv.2018.10.015.
15 United Nations Environment Programme Endocrine disrupting chemicals. Available at: https://www.unep.org/explore-topics/chemicals-waste/what-we-do/emerging-issues/endocrine-disrupting-chemicals.
16 Groh, K.J. et al. (2021) "Overview of intentionally used food contact chemicals and their hazards," *Environment International*, 150, p. 106225. Available at: https://doi.org/10.1016/j.envint.2020.106225.

11. Today, not all plastics are compatible with a Circular Economy (CE)[17]. Though the reversible nature of thermoplastics makes them ideal for recycling, recycling rates of plastic products are low: it has been estimated that only nine percent of the global plastic waste ever produced has been recycled[18], and under a business-as-usual scenario, recycled plastics are projected to make up only 12 percent of total plastics use in 2060[19]. The likelihood of being recycled depends on what type of plastic an item is made of, as well as on the availability of a recycling system to collect, sort, process, and market much of the specific polymer. Current infrastructure and technologies are limited in their ability to transform all the diverse types of plastics used today into high-value feedstocks that can compete with primary (virgin) plastics. Even PET, the world's most widely recycled plastic, is not currently managed in a circular way since leakage from the circular system is high, with material lost at all stages of the PET lifecycle. In the European Union, for example, it is estimated that bottles placed on the market (POM) only comprise of an average of 17 percent rPET, with the remaining rPET downcycled into other, lower grade manufacturing applications and therefore considered a loss from the circular bottle stream[20].

12. In addition, substances unintentionally added or used for performance reasons can be potentially hazardous when released at any stage of the life cycle of the plastic products, contaminating soil, air, water, and food. In particular, they can be released from plastics during the various recovery and recycling processes and from the products produced from recyclates[21].

13. The design stage is considered as determining 70 percent of the environmental impacts of a product[22]. An analysis carried out by McKinsey suggests that while Research and Development (R&D) accounts for 5 percent or less of the total cost of a product, it influences up to 80 percent of that product's resource footprint[23]. It is at this stage that crucial decisions are made, which radiate across the entire system, affecting sourcing, production, logistics, collection, and infrastructure systems, and how we use and dispose of the products[24].

14. Design is at the heart of the CE as it represents the first step to rethink linear business models. CE offers a framework built on the principles of eliminating waste and pollution from the outset, keeping products and materials in use at their highest value, and regenerating natural systems. Circular design encourages to rethink how products are made, used, and disposed of, while considering the system surrounding them[25].

> While R&D accounts for 5 percent or less of the total cost of a product, it influences up to 80 percent of that product's resource footprint.
>
> McKinsey

15. Today, innovative circular design practices have been developed to tackle the challenges and mounting expectations that organisations face as they need to deliver excellent user experience and remain relevant and innovative, while also recognising and addressing their role in global challenges, including climate change, plastic pollution, and biodiversity loss.

17 Crippa, M., De Wilde, B., Koopmans, R., Leyssens, J., Muncke, J., Ritschkoff A-C., Van Doorsselaer, K., Velis, C. & Wagner, M. (2019) "A circular economy for plastics – Insights from research and innovation to inform policy and funding decisions." (M. De Smet & M. Linder, Eds.). European Commission, Brussels, Belgium. Available at: https://data.europa.eu/doi/10.2777/269031

18 Geyer, R., Jambeck, J. and Law, K.L. (2017) "Production, use, and fate of all plastics ever made," *Science Advances*, 3(7). Available at: https://doi.org/10.1126/sciadv.1700782.

19 OECD (2022) "Global Plastics Outlook Policy Scenarios to 2060: Policy Scenarios to 2060". OECD Publishing. Available at: https://www.oecd-ilibrary.org/environment/global-plastics-outlook_aa1edf33-en

20 Zero Waste Europe (2023) "How circular is PET?" Available at: https://zerowasteeurope.eu/library/how-circular-is-pet/.

21 Zimmermann, L. et al. (2019) "Benchmarking the in Vitro Toxicity and Chemical Composition of Plastic Consumer Products," *Environmental Science & Technology*, 53(19), pp. 11467–11477. Available at: https://doi.org/10.1021/acs.est.9b02293.

22 Navi Radjou and Jaideep Prabhu (2014) "Frugal Innovation. How to do more with less." The Economist. Available at: http://naviradjou.com/wordpress/wp-content/uploads/2016/12/Frugal-Innovation_Intro-Chapter.pdf

23 McKinsey (2022) "Product sustainability: Back to the drawing board." Available at: https://www.mckinsey.com/business-functions/operations/our-insights/product-sustainability-back-to-the-drawing-board?cid=eml-web.

24 The Ellen MacArthur Foundation (no date) "Design and the circular economy." Available at: https://ellenmacarthurfoundation.org/articles/design-and-the-circular-economy.

25 Ibid.

III. Scope and Objective

16. This study report focuses on Single-use Plastic Products (SUPPs) for their relevance in terms of volume produced yearly and their contribution to mismanaged plastic waste, the frequency with which these products are littered, the ubiquitous presence as breakdown products in every eco-system across the globe[26] that makes human exposure inevitable[27].

17. In line with the CE principles and to contribute to the plastic waste prevention and minimization efforts of the PWP under the Basel Convention, the study report illustrates examples of design practices that have proved successful in:

    a. Eliminating, safely and effectively, unnecessary, and avoidable SUPPs,

    b. Increasing, safely and effectively, the durability, reusability, and the recyclability of SUPPs, when plastic is the material of choice.

18. The SUPPs addressed in this document are fourteen of the most commonly found plastic items during international coastal clean-ups[28], as detailed in the Table 1 below.

Table 1 – The SUPPs targeted by the study report, their material composition, and the possible substances of concern they might contain.

	Single-use Plastic Products (SUPPs)	Materials	Substances of concern		
			Monomers	Additives	Other substances
Convenience products	**Cigarette butts/ filters**	Cellulose acetate			4,000+ toxic chemicals
	Single-use plastic bags (SUPBs)	Polypropylene (PP) High-density polyethylene (HDPE) Low-density polyethylene (LDPE)			Chromium oxide Benzoyl peroxide Hexane Cyclohexane
	Cotton bud plastic sticks	Polypropylene (PP)		2,6-di-tert-butyl-4-methyl phenol as UV stabiliser	In PP: Methanol Nickel Dibutyl dithiocarbamate
	Wet wipes	Polypropylene (PP) Polyester		2,6-di-tert-butyl-4-methyl phenol as UV stabiliser in PP	In PP: Methanol Nickel Dibutyl dithiocarbamate
	Sanitary items	Polypropylene (PP) Polyethylene (PE) film Superabsorbent polymer (SAP)		2,6-di-tert-butyl-4-methyl phenol as UV stabiliser	In PP: Methanol Nickel Dibutyl dithiocarbamate

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26 Evangeliou, N. et al. (2020) "Atmospheric transport is a major pathway of microplastics to remote regions," *Nature Communications*, 11(1). Available at: https://doi.org/10.1038/s41467-020-17201-9.

27 Center for International Environmental Law (2022) "Plastic & Health - Center for International Environmental Law." Available at: https://www.ciel.org/plasticandhealth.

28 United Nations Environment Programme (2018) "Single-use Plastics: A Roadmap for Sustainability." (Rev. ed., pp. vi; 6). According to the 2018 UNEP report on SUPPs, the most common finds during international coastal clean-ups are, in order of magnitude: cigarette butts, plastic beverage bottles, plastic bottle caps, food wrappers, plastic grocery bags, plastic lids, straws and stirrers, glass beverage bottles, other kinds of plastic bags, and foam take-away containers.

> Table 1 continued

Single-use Plastic Products (SUPPs)		Materials	Substances of concern		
			Monomers	Additives	Other substances
Primary Packaging	**Plastic bottles and caps**	High-density polyethylene (HDPE) Fluorine-treated HDPE as a barrier to hydrocarbons and aromatic solvents. Low-density polyethylene (LDPE) for squeeze applications. Polyethylene terephthalate (PET) Polyester for carbonated beverages, water bottles, and food packaging. Polycarbonate (PC) for large milk and water bottles. Polypropylene (PP) for jars and closures. Polystyrene (PS) commonly used with dry products as vitamins and spices. Post-consumer resin (PCR) a blend of reclaimed natural HDPE (primarily from milk and water containers) and virgin resin.	• Bisphenols (e.g., BPA)	• PFAS	In PET: Antimony Oxide Bromine Diaszomethane Lead Oxide Nickel Ethylene Oxide Benzene In LDPE: Benzene Chromium oxide Cumene hydroperoxide Tert-butyl hydroperoxide
	Plastic straws and stirrers	Polypropylene (PP)			
	Food and Beverage plastic containers	Polypropylene (PP) Polyethylene Terephthalate (PET) High-density polyethylene (HDPE) Polyvinyl Chloride (PVC) Low-density polyethylene (LDPE) Linear low density polyethylene (LLDPE) Polystyrene (PS), expandable PS (EPS) High impact polystyrene (HI-PS) Polyethylene (PE) Acrylonitrile Butadiene Styrene (ABS) Polyamide (PA) Polycarbonate (PC) Polybutylene terephthalate (PBT)	• Bisphenols (e.g., BPA)	• Phthalates • Arylamines • PFASs	Benzene Carbon tetrachloride Ethylene oxide Lead chromate Methyl acrylate Methanol Tetrahydrofuran Tribasic lead sulphate Mercury Cadmium
	Plastic tableware (plates, cutlery, etc.)	Polystyrene (PS) Polyethylene (PE)	• Bisphenols (e.g., BPA)		
	Flexible plastic packaging (pouches, bags, shrink films, liners, shrink sleeves, film wrap around labels, and other pliable products) **Rigid plastic packaging**	Polyolefins such as (PE) and (PP) HDPE, LDPE, LLDPE, OPP Polyesters such as PET and PLA Polyvinyl Chloride (PVC) Polyamide (PA) Ethylene vinyl alcohol (EVOH) Ethylene-vinyl acetate (EVA) Polyurethane (PUR) Polyvinylidene chloride (PVDC) Biobased polymer such as Polylactic acid (PLA) Aluminium foils Paper or paperboard	• Bisphenols (e.g., BPA)	• PFASs • Phthalates in plastic films • NPEs/NPs as surfactants, phosphate antioxidants in food wraps	

Continued on next page >

> Table 1 continued

	Single-use Plastic Products (SUPPs)	Materials	Substances of concern		
			Monomers	Additives	Other substances
Secondary packaging	**Expanded polystyrene (EPS) packaging**	Expanded polystyrene (EPS)	• Styrene		Ethylbenzene Benzene Ethylene Carbon tetrachloride Polyvinyl alcohol Antimony oxide Tertbutyl hydroperoxide Benzoquinone
Secondary packaging	**Flexible plastic packaging (shrink wrap, stretch wrap, bulk shipping, etc.)**				
Tertiary packaging	**Plastic pallets and crates**	Polypropylene (PP) High Density Polyethylene (HDPE) for higher weights and hygienic regulations pallets. HDPE and PP blends. Advanced Composite Material (ACM) a 100 percent recycled from a mixture of post-industrial scrap, forming into an inexpensive but relatively durable plastic resin, commonly used for export as cheaper and less durable.		• 2,6-di-tert-butyl-4-methyl phenol as UV stabiliser in PP	In PP: Methanol Nickel Dibutyl dithiocarbamate

IV. Methodology and study limitation

19. Practices applying circular economy principles at the design stage of the target products were identified through extensive literature review.

20. To the extent possible, for each SUPP at least one example of design practice has been identified that has proved successful in:

    a. Eliminating safely and effectively the SUPPs, either by rethinking the product, the packaging, or the business model, without diminishing the user experience/convenience,

    b. Increasing, safely and effectively, the reusability or the recyclability of the SUPP, when plastic was the material of choice.

21. A special focus was given on identifying practices that help eliminate hazardous substances associated with SUPPs (Annex 1), when plastic is the material of choice.

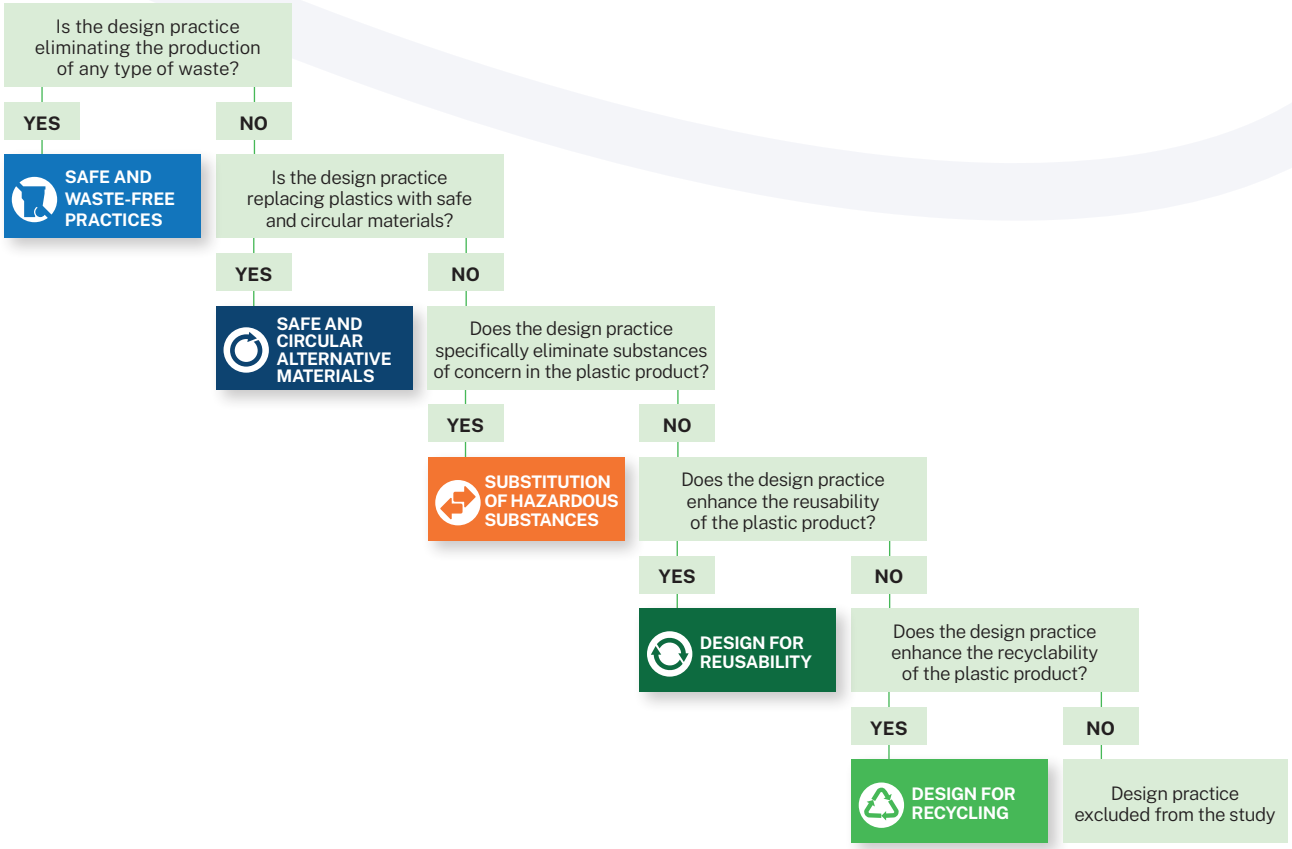
22. Practices were selected based on their level of innovation, geographical representation, data availability to describe the practice in sufficient detail, and degree of replicability. Design practices were not ranked or rated in terms of their effectiveness.

A special focus was given on identifying practices that help eliminate hazardous substances associated with SUPPs.

23. The following categories have been defined to organise the design practices:

SAFE AND WASTE-FREE PRACTICES	Design practices that rethink the production, delivery, application, consumption, and end-of-life (EoL) of the SUPP to avoid waste.
SAFE AND CIRCULAR ALTERNATIVE MATERIALS	Design practices that substitute plastics with safe and circular materials.
SUBSTITUTION OF HAZARDOUS SUBSTANCES	Design practices that allow to avoid substances of concern when plastic is the material of choice.
DESIGN FOR REUSABILITY	Design practices that enable multiple trips or rotations within the life cycle of the plastic item, by being refilled or reused for the same purpose for which it was conceived.
DESIGN FOR RECYCLING	Design practices focused on the end of life of the SUPP to facilitate the recovery of the materials for additional use, in open-loop (or downcycling) when the recycled materials are turned into new raw materials of lower value, or in closed-loop when the recycled materials are used in the same item or with comparable value.

24. The distribution of the design practices among these 5 categories is the result of the following decision-making tree:



25. To the extent possible, each design practice has been described through a common set of attributes (Annex 2), using publicly available information and data. Particular attention has been given to the critical (legislative/policy, technical and market/financial) enablers that should be in place for the practice to be successful, as well as the replicability in comparable sectors, market conditions and policy contexts. When several design practices were identified for the same product and objective, geographical distribution was considered. Similar case studies have been recorded in the practice factsheet.

26. The study report is not meant to be an exhaustive manual, but rather a source of inspiration to tackle plastic waste through a circular economy perspective. The practices included in this document only represent a sample of what is available.

V. Organisation of the Study Report

27. The study report is organised as follows:

    a. **PART 1** Presents a table summarising the design practices identified by the study to prevent and minimize plastic waste and hazards from SUPPs, and the factsheets describing each practice in detail.

    b. **PART 2** Presents the main considerations stemming from the study that might be of use to the members of the PWP Project Group 1 on "Plastic waste minimisation and prevention".

    c. **PART 3** Lists guidebooks, guidelines, and other resources that might further support the work of the PWP Project Group 1 towards the minimisation and prevention of plastic waste.

28. Further information on the main substances of concern addressed within this study is provided in Annex 1, while Annex 2 lists the attributes used to describe the design practices.

PART 1
Examples of circular design practices to safely minimize and prevent single use plastic waste.

	Single-use Plastic Products (SUPPs)	SAFE AND WASTE-FREE PRACTICES	SAFE AND CIRCULAR ALTERNATIVE MATERIALS	SUBSTITUTION OF HAZARDOUS SUBSTANCES	DESIGN FOR REUSABILITY	DESIGN FOR RECYCLING
Convenience products	**Cigarette butts/ filters**		Biobased cigarette filters/butts			
	Single-use plastic bags (SUPBs)		A wet strength reusable paper shopping bag		Bring Your Own (BYO) Reusable shopping bags lending system	
	Cotton bud/ swabs		Biodegradable and renewable straws and cotton swabs		Reusable alternative to cotton swabs	
	Wet wipes		Plastic-free flushable wet wipes Plastic-free reusable wet wipes			
	Sanitary items		Reusable sanitary cloth pads Reusable baby cloth diapers rental service		Reusable period underwear	
Primary Packaging	**Plastic bottles and caps**	Dissolvable packaging materials	Reuse on-the-go refill (B2C) self-vending units for fresh milk in glass bottles		Grocery-store drinking water refill system	Additives to increase recyclability of PET bottles
	Plastic straws and stirrers		Biodegradable and renewable straws and cotton swabs Paper straw for beverage cartons			
	Food and Beverage plastic containers	Dissolvable packaging materials	Biodegradable and compostable packaging made from agriculture residue Plastic-free and PFAS-free recyclable single-use food and beverage containers	Alternatives to anti-fog and anti-stats additives Biobased Bisphenols and Phthalate-free plasticizers	reCIRCLE: a circular solution for take away containers	A system to divert organic waste and compostable packaging from landfills to composting facilities
	Plastic tableware (plates, cutlery, etc.)			Alternatives to anti-fog and anti-stats additives		Table-to-farm solution for single-use food ware A store drop-off recycling system for mono-material multilayer flexible packaging

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Single-use Plastic Products (SUPPs)		SAFE AND WASTE-FREE PRACTICES	SAFE AND CIRCULAR ALTERNATIVE MATERIALS	SUBSTITUTION OF HAZARDOUS SUBSTANCES	DESIGN FOR REUSABILITY	DESIGN FOR RECYCLING
Primary Packaging	**Flexible plastic packaging**	Dissolvable packaging materials	Non-plastic food contact foil Plastic-free packaging solutions from food waste Pinyapel: Plastic-free alternative material from discarded pineapple leaves Non-toxic, marine-safe, and soluble in warm or hot water barrier films Micro fibrillated Cellulose		A reuse refill system for consumer goods	Recyclable flexible packaging A recyclable fibre-based packaging
	Rigid plastic packaging	Packaging-free personal care products	A vegan and compostable packaging material	Alternatives to anti-fog and anti-stats additives	A (B2C) reuse refill-on-the-go tricycle system for homecare products	Solid concentrated products in recyclable packaging
	Expanded polystyrene (EPS) packaging		Moulded fibre/pulp packaging Plastic-free packaging solutions made of mycelium		Reusable refillable at home packaging system	
Secondary Packaging	**Flexible plastic packaging**		A circular paper alternative to plastic pallet wrapping Bubble wrap made of paper Bubble wrap made of sheep wool leftover			
Tertiary Packaging	**Plastic pallets and crates**				B2B reusable transport packaging system	Additive solutions to improve plastics mechanical recycling

SAFE AND WASTE-FREE PRACTICES

IMPLEMENTATION: START UP

REPLICABILITY: MEDIUM

Name of the practice

Dissolvable packaging materials

Target plastic product	**Food contact primary packaging**
Examples	**Packets and wrappers** **Plastic bottles** **Food and Beverage plastic containers**
Application	**Healthcare & Pharmaceutical** **Food and Beverage Manufacturing / Brand owners** **Hospitality and hotel, restaurant, and catering (HORECA) sector**

Plastic materials/ Polymer types in the original product

Polyethylene terephthalate (PET/PE)
Nylon/PE
PET/metalized PET/PE
PET/Foil/PE
Low Density Polyethylene (LDPE) and Linear Low-Density Polyethylene (LLDPE)

Name and type of the substances of concern in the original product

- Phthalates
- Perchlorate
- Bisphenols
- Ethyl and methyl glycol, toluene, and n-methyl-pyrrolidone (NMP)
- Contaminants: Heavy metals

Abstract

Notpla is a UK-based start-up that develops non-chemically modified polysaccharide-based materials for food contact packaging mainly from seaweeds. Non-chemically modified means the structure remains unchanged even if it has gone through chemical processes. By sharing similar status with natural organic materials, like a fruit peel, Notpla material is biodegradable, as well as industrially and home compostable.

Notpla material is used to produce various food contact packaging, such as the Notpla Rigid - a mouldable material for primary packaging from the fibrous by-product of industrially processed seaweed, the award winning Notpla coating - a grease and water-resistant layer for takeaway packaging, and the Notpla Ohoo, a 100 percent edible sachet for liquids. Notpla is finetuning the manufacturing machines used to produce their packaging. Once tested and scaled up, Notpla believes in expanding its business model to lease these machines and sell cartridges of the materials to food manufacturing companies for them to directly manufacture their sauces, condiments, and drinks in the Notpla packaging.

State of implementation

START UP

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment, understand the combined effect of multiple substances within a product-packaging system, and ensure materials can be recycled safely.

- Regulatory approaches, such as bans or restrictions, on the manufacture, use, distribution, sale, or trade of SUPPs.
- Implement spatial planning policies to enhance material flow and create business opportunities, such as industrial symbiosis.
- Enforce green claim codes to stop greenwashing.

Technical enablers

- Introduce universal criteria, standard and certification on biodegradability and compostability.
- Incorporate CE principles in higher education curricula, training programmes and apprenticeships.
- Promote the establishment and adoption of multi-stakeholder, cross-value-chain, inclusive and responsive working mechanisms to develop system solutions and to build public private capacity.
- Establish collaboration and international harmonisation between the public and private sectors to ensure synergies and trade-offs between upstream design policies, chemical legislation, and waste legislation.

Market and financial enablers

- Innovation awards, prizes, challenges, and platforms, such as the World Economic Forum's Scale360° Playbook and UpLink.
- Design Extended Producer Responsibility (EPR) scheme to reflect the true lifetime cost of SUPPs and use money from EPR to fund research and scaling of safe and circular alternative materials.
- Policies promoting ethically responsible, reliable, expanded, diversified, and optimised supply chains for seaweed sourcing. Regional and global organisations such as Seaweed for Europe and the Safe Seaweed Coalition, are advancing the seaweed industry by mobilising investment, ensuring environmentally friendly farming practices, defining safety standards for seaweed products, and overseeing the safety and sustainability of the seaweed industry as it scales up.
- Equity crowdfunding platforms, such as PledgeMe, can help support innovation.
- Economic instruments aligned with the CE, such as taxes to deter production or use of SUPPs or tax breaks, subsidies, or other fiscal incentives to encourage the production and use of alternatives to SUPPs.
- Review existing competition laws to fit within the CE.
- Use Green Public Procurement (GPP) to create market demand and showcase solutions.
- Apply early-stage public funding to establish proof-of-concept and spur further private investments in circular innovations (e.g., the Scotland's Circular Economy Investment Fund, have been developed to support innovative circular economy SMEs).

Challenges

There is huge potential for growing industrial-scale volumes of seaweeds. However, for this to happen, more efficient technologies to produce seaweed are required, the value of seaweed biomass needs improving, along with a proper consideration of the environmental risks associated with the introduction of alien species and the risk of transmission of parasites and pathogens to wild populations, the impact of escapees, and the management of waste, amongst others. The production of seaweed is also still quite costly, as seaweed packaging requires manual processing to some extent. Like any new material, the consumption of Notpla edible packaging must be regulated.

Opportunities/ Benefits

Seaweed is a renewable fast-growing resource globally abundant. Seaweed can grow in both seawater and freshwater, is inert, and doesn't require any additional media for its growth. More than 12,000 species exist in the oceans, each with unique characteristics that make them useful for different applications. The benefits of seaweed and the increasing range of applications means the industry is growing incredibly quickly, helping renew coastal economies and revitalise ecosystems. Seaweed is indeed regenerative, offering habitat, nursery grounds, and shelter for other sea creatures. Seaweeds contribute towards the deacidification of the ocean and promote the production of oxygen by consuming carbon dioxide for its growth. Some studies have reported that it takes a hectare of the ocean to create 40 tons of dry seaweed. Seaweeds are also rich in vitamins, fibre, and minerals, boasting many health benefits, including anti-cancerous, anti-ageing, and antibacterial properties.

Notpla material biodegrade naturally in 4-6 weeks without the need for industrial composting or special conditions. Unlike PLA, they are fully compatible with the compostable food waste stream, home compostable, and do not contaminate PET recycling, besides being edible.

The rise in hygiene conditions promotes the production and use of edible packaging. This can prevent various communal and infectious diseases. For these reasons, Notpla Ooho has been a success at large sports events, such as city marathon, or at top tier events.

Replicability
Low, Medium, High

The practice requires certain specific requirements to be successfully replicated.

MEDIUM

Geographical area of implementation

Europe

Country

UK

Contacts

Notpla is a sustainable packaging start-up founded in 2014, including a combination of designers, chemists, engineers, and entrepreneurs. Notpla headquarters are in London, UK, with over 50 percent of revenue in 2022 originated in Europe.
info@notpla.com

For more information

https://www.notpla.com/

Similar case studies

Mori - **https://www.mori.com/** - USA

Apeel - **https://www.apeel.com/** - USA

Sway - **https://swaythefuture.com/** - USA

Evoware - **https://rethink-plastic.com/home/** - Indonesia

MonoSol - **https://www.monosol.com/** - USA

Others: **https://www.sourcegreenpackaging.com/10-seaweed-packaging-start-ups-algae/**

Comments

Notpla is working on new materials such as Notpla paper produced from the by-products of industrial seaweed processing. Notpla paper requires 30 percent less recycled wood pulp, lowering pressure on forests while reducing waste from the seaweed supply chain.

SAFE AND WASTE-FREE PRACTICES

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: MEDIUM

Name of the practice

Packaging-free personal care products

Target plastic product	**Primary packaging**
Examples	**Plastic bottles**
Application	**Healthcare & Pharmaceutical** **Brand owners** **Retailers**

Plastic materials/ Polymer types in the original product

High Density Polyethylene (HDPE) and fluorine-treated HDPE
Low-Density Polyethylene (LDPE)
Polyethylene terephthalate (PET, PETE)
Polycarbonate (PC)
Polypropylene (PP)
Polystyrene (PS)
Polyvinyl chloride (PVC)

Name and type of the substances of concern in the original product

- Phthalates
- Bisphenols

Abstract

Ethique creates solid bars for haircare, skincare, body care, home cleaning, and pet care. The solid bars are designed to dissolve with water. They are wrapped in paper designed to minimise the use of water (Ethique's packaging production uses just 10-25 kg of water per kilo as it's recirculated and recycled). All orders placed from Etique's website are shipped plastic-free, in a cardboard box, with paper bubble wrap, all sealed with paper tape. Etique's packaging is made in New Zealand from PEFC-certified, chlorine and acid-free paper stock from sustainably sourced forestry, without plastic, laminate, and chlorines.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment, understand the combined effect of multiple substances within a product-packaging system, and ensure materials can be recycled safely.
- Regulatory approaches, such as bans or restrictions, on the manufacture, use, distribution, sale, or trade of SUPPs.
- Enforce green claim codes to stop greenwashing.

Technical enablers

- Design and technology can help address some of the short-comings of packaging-free solutions (e.g., The Dissolving Bottle, the Lush Lens App).
- Promote the establishment and adoption of multi-stakeholder, cross-value-chain, inclusive and responsive working mechanisms to develop system solutions and to build public private capacity.
- Establish collaboration and international harmonisation between the public and private sectors to ensure synergies and trade-offs between upstream design policies, chemical legislation, and waste legislation.

- Rethink the whole supply chain to solve the dependency of product logistics from packaging; inducing suppliers, distributors, and retailers to change their packaging practices and develop new handling, processing, and logistics operations; eventually, introducing appropriate certification schemes for zero-packaging supply chains.
- Educate consumers and influence their behaviour for them to demand more transparency and sustainability; rethink marketing and consumer-brand relationships.
- Establish trust in product safety.

Market and financial enablers

- Equity crowdfunding platforms, such as PledgeMe, can help support innovation.
- Economic instruments aligned with the CE, such as taxes to deter production or use of SUPPs or tax breaks, subsidies, or other fiscal incentives to encourage the production and use of alternatives to SUPPs.
- Review existing competition laws to fit within the CE.
- Use Green Public Procurement (GPP) to create market demand and showcase solutions.
- Apply early-stage public funding to establish proof-of-concept and spur further private investments in circular innovations (e.g., the Scotland's Circular Economy Investment Fund, have been developed to support innovative circular economy SMEs).

Challenges

Producing solid bars is limiting and formulation is hard. Logistics is also extremely challenging as the use of plastic is deeply intertwined into most warehousing systems. Logistics facilities must be engaged, to understand and work together with plastic-free producers to change the way they do business and to expand their environmental actions. How to list ingredients without a label and how to provide a customer with directions on how to use the product are two other challenges.

Opportunities/ Benefits

Ethique's ingredients are sourced through direct trade to ensure that local growers in Africa, South America, and Southeast Asia receive stable prices, reliable income, and good working conditions. Ethique is rethinking refillable with a world-first, patent-pending, range of concentrates that is two years in the making. Each concentrated bar saves 700ml of water and one plastic bottle from manufacture and disposal into landfill. This also reflects cost savings as solid products reduce expenses associated with transport, storage space, and packaging material. By requiring less cupboard space and eliminating the need to carry bulky, heavy bottles when travelling, solid shampoos are also convenient for consumers.

Replicability
Low, Medium, High

The practice requires certain specific requirements to be successfully replicated.

MEDIUM

Geographical area of implementation

Oceania

Country

New Zealand

Contacts

Ethique produces solid home, personal and pet care products with the goal of preventing plastic bottles from being made and disposed of in landfills around the world.

For more information

https://ethiqueworld.com/

Similar case studies

The dissolving bottle - **https://www.thedissolvingbottle.com/** - Philippines

Lush - **https://www.lush.com/uk/en** - UK

B.O.B. - **https://www.usebob.com.br/** - Brazil

SAFE AND CIRCULAR ALTERNATIVE MATERIALS

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: MEDIUM

Name of the practice

Biodegradable biobased cigarette filters/butts

Target plastic product	**Cigarette filters/butts**
Application	**Consumer Goods / Lifestyle**
Plastic materials/ Polymer types in the original product	Cellulose acetate
Name and type of the substances of concern in the original product	• Nicotine • Heavy metals
Abstract	**Woodland Craft Cigarettes** claims to be a 100 percent biodegradable cigarette. The product has a biodegradable cigarette filter made from wood-pulp. The tobacco is locally sourced and does not contain artificial additives. The cigarette paper is not bleached with chlorine or any other harmful chemicals. After just three months the remainder of the smoked cigarette dissolves completely. In addition, Woodland cigarette's packaging is also made from recycled cardboard and soy ink.
State of implementation	COMMERCIAL USE
Legislative/ Policy enablers	• Mainstream CE principles into national and international policies. • Align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment, understand the combined effect of multiple substances within a product-packaging system, and ensure materials can be recycled safely. • Regulatory approaches, such as bans or restrictions, on the manufacture, use, distribution, sale, or trade of SUPPs. • Enforce green claim codes to stop greenwashing. • Bans or restrictions on the manufacture, use, distribution, sale, or trade of SUPPs. In the US, for example, the California State bill (SB 424) seeks to ban all filters on cigarettes. • Bans on smoking and vaping in public parks and on beaches.
Technical enablers	• Introduce harmonized criteria, standard and certification on biodegradability and compostability. • Labelling and marking to inform consumers on the presence of plastic in the products. In the EU, for example, following the Directive (EU) 2019/904, tobacco products with filters and filters marketed for use in combination with tobacco products placed on the market should bear a marking on the packaging or product itself. Additional requirements regarding extended producer responsibility (EPR) and awareness raising measures should support the effectiveness of these marking.

Market and financial enablers

- Market-based instruments, such as taxes or levies, on SUPPs. In some cities around the world, such as in San Francisco USA, fees or fines are already levied on cigarette packets to fund street cleaning.
- Green tax incentives where eco-cigarettes that are plastic-free are charged a reduced excise tax or not charged at all.

Challenges

Replacing cigarette plastic butts has proved more difficult than expected, mainly due to the changes in taste and nicotine level that can pass through the filter. Alternative materials (such as paper or cotton filters) make the smoke taste differently and cigarettes less satisfying. In addition, biodegradable biobased filters still contain toxins that could take a long time to degrade.

It is also important to note that:

- Biodegradable biobased cigarettes might make smokers feel "permitted" to litter biodegradable filters, aggravating the waste problem.
- The concept of eco-cigarette might also be misleading: while eco-cigarettes might be less harmful for the environment, they still are harmful to long-term users. Aggregating pro-environment and health-related claims is nothing new in marketing. However, while it may be justified for organic agriculture products, for example, it is not a generally valid principle when it comes to cigarettes.

Opportunities/ Benefits

Smokey Treats ensures that international standards of labour practices, and equitable pay, are strictly enforced. They help to uplift small local communities that rely on the quality of their tobacco to make a good living. In addition, Smokey Treats donates one percent of all net profits to reforesting South Africa.

Replicability
Low, Medium, High

The practice requires certain specific requirements to be successfully replicated.

MEDIUM

Geographical area of implementation

Africa

Country

South Africa

Contacts

Smokey Treats was launched at the end of 2018 by Davide Scott and Adam van Wyngaarden in South Africa.
sales@smokeytreats.co.za

For more information

https://www.smokeytreats.co.za/

Similar case studies

Greenbutts - **https://www.greenbutts.com/** - USA

Comments

E-cigarettes are viewed as an alternative to conventional cigarettes; however, they still contain plastics, they are not recyclable, poorly reusable and are considered both as hazardous waste and e-waste, further complicating the waste management. The effects of e-cigarette waste on the environment are only starting to be studied. The anti-smoking laws, which restricted smokers from lighting up indoors, are also having unexpected impacts, as they drove smokers outdoors where there are few, if any, ashtrays, or other receptacles for their spent filters. Most of those filters end up in storm drains and find their way to our beaches and river ways where birds, fish and other wildlife tend to mistake them for food, clogging up their intestines.

SAFE AND CIRCULAR ALTERNATIVE MATERIALS

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: HIGH

Name of the practice

A wet strength reusable recyclable paper shopping bag

Target plastic product	**Single-use Plastic Bags (SUPBs)**
Application	**Consumer Goods / Lifestyle** **Healthcare & Pharmaceutical** **Food and Beverage Manufacturing / Brand owners** **Retailers** **Hospitality and hotel, restaurant, and catering (HORECA) sector**
Plastic materials/ Polymer types in the original product	Polyethylene (PE) High Density Polyethylene (HDPE) Linear Low-Density Polyethylene (LLDPE) Low Density Polyethylene (LDPE)
Name and type of the substances of concern in the original product	NA

Abstract

The packaging and paper firm **Mondi** has partnered with **Taurus Packaging** to develop a wet strength shopping paper bag for the South African retail market. Designed to carry groceries, the fit-for-purpose reusable shopping paper bag has replaced plastic bags in two major retailers in South Africa - SPAR South Africa and Food Lover's Market, following a voluntary commitment to ban plastic bags from their stores. Suitable for South African weather conditions, the new sustainable packaging is estimated to help eliminate two million plastic bags entering the waste stream in South Africa each month. The paper bag is reusable, renewable, PEFC certified, and recyclable at the end of its life.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment, understand the combined effect of multiple substances within a product-packaging system, and ensure materials can be recycled safely.
- Regulatory approaches, such as bans or restrictions, on the manufacture, use, distribution, sale, or trade of SUPPs.
- Enforce green claim codes to stop greenwashing.
- Voluntary agreements, commitments, and pledges from major retailers.
- Binding quantitative reuse targets.

Technical enablers

- Change the design and use model of the bags from single use to reusable to nudge consumer behaviour towards reuse.

Market and financial enablers

- Market-based instruments, such as taxes or levies, on SUPPs.

A wet strength reusable recyclable paper shopping bag

Challenges	According to a 2020 study of the UN Environment Programme and the Life Cycle Initiative, while less prone to be littered, paper bags have a greater impact on climate, eutrophication, and acidification, compared to SUPPs. However, they can be better for the climate if the SUPB is heavy, the paper mills use renewable fuel, the paper bags are reused multiple times, and/or the waste bags are incinerated rather than deposited at landfills.
Opportunities/ Benefits	Mondi's paper bag has the potential to resist tearing even when cold products and liquids condense rapidly, as well as withstands longer customer journeys on public transport.
Replicability Low, Medium, High	The practice can be easily replicated in similar economic, technological, and political settings. **HIGH**
Geographical area of implementation	Africa
Country	South Africa
Contacts	Mondi is a global leader in sustainable packaging and paper, employing 22,000 people across 100 production sites in more than 30 countries, with key operations located in Europe, North America, and Africa. **https://www.mondigroup.com/en/about-mondi/corporate-contacts/**
For more information	**https://www.mondigroup.com/en/products-and-solutions/speciality-kraft-paper/speciality-kraft-paper-products/advantage-mf-kraft/**
Similar case studies	WellBag - **https://www.klingele.com/en/packaging/products/showroom/sports-leisure-fabrics/einkaufstasche-wellbag** - Germany

SAFE AND CIRCULAR ALTERNATIVE MATERIALS

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: HIGH

Name of the practice

Biodegradable and renewable bamboo cotton swabs

Target plastic product	**Cotton bud plastic sticks/swabs** **Plastic straws**
Application	**Healthcare & Pharmaceutical** **Retailers** **Hospitality and hotel, restaurant, and catering (HORECA) sector**

Plastic materials/ Polymer types in the original product

Polyethylene (PE)

Abstract

Bali Boo Bamboo cotton swabs are made from Moso Bamboo, a species of giant bamboo that comes from China sourced from FSC certified (Forest Stewardship Council) plantations. The cotton is organically grown, and it comes from the same source of Global Organic Textile Standard certified textiles. All packaging is made with recycled carton or paper, 100 percent recyclable and plastic free.

Bali Boo Bamboo straws are made from Balinese Buluh bamboo locally sourced in Bali.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment, understand the combined effect of multiple substances within a product-packaging system, and ensure materials can be recycled safely.
- Regulatory approaches, such as bans or restrictions, on the manufacture, use, distribution, sale, or trade of SUPPs.
- Enforce green claim codes to stop greenwashing.
- Campaigns and awareness raising projects such as the Cotton Bud Project set up in 2013 in UK to stop marine pollution from plastic stemmed cotton buds, using scientific research, citizen science data and best practice to establish dialogue with industry, the public and governments to influence positive environmental change at national and international levels.

Market and financial enablers

- Use Green Public Procurement to create market demand and showcase solutions, by creating standards and defining circular requirements for goods purchased by public bodies, as well as purchasing locally where appropriate.
- Market-based instruments such as taxes or levies on SUPPs.
- Waste disposal fees or charges, or higher excise taxes for SUPPs.

Challenges

Chinese products are usually less expensive but lack certifications or other proof of sustainability. Certifications help increase consumer trust in the products. However, certification schemes are not always easily accessible in all countries and no harmonized standards exist.

Opportunities/ Benefits

For the cotton swabs, Bali Boo demands its suppliers to be compliant with the highest standards of working conditions and quality, as well as having the EU Declaration of Conformity (CE), the US Food and Drug Administration (FDA), the Global Organic Textile Standard (GOTS), and Forest Stewardship Council (FSC) certificates.

Bali Boo is based in Bali, Indonesia, where it works together with women-led small producers and local farmers.

Replicability Low, Medium, High

The practice can be easily replicated in similar economic, technological, and political settings. **HIGH**

Geographical area of implementation

Asia

Country

Indonesia

Contacts

Bali Boo is a leading supplier of bulk Bamboo Straws wholesale in the world based in Bali (Indonesia). It offers a wide portfolio of other eco-friendly products, such as bamboo cotton swabs, bamboo cutlery, coconut cups, etc.

For more information

https://bali-boo.com/

Similar case studies

Staramaki SCE (Greece) - **https://www.staramaki.gr/en** - Greece

Agave Straws - **https://www.agavestraws.com/** - Mexico

Ligun - **https://www.ligun.cl/** - Chile

Comments

It is important to differentiate products made a 100 percent from bamboo, as the one sold by Bali Boo, and those made from polymers mixed with ground bamboo, bamboo flour, and many similar substances including corn. The use of bamboo and other unauthorized ground plant materials in plastic Food Contact Materials (FCM) may represent a public health risk as this may allow the accelerated degradation of certain plastics. Migration studies have demonstrated that bamboo-containing plastics leach melamine (Food Packaging Forum (FPF) reported and here), a compound that has been associated with impacts on neurological functions, behaviour, reproduction, and growth (FPF reported) and that was also classified as “possibly carcinogenic to humans” (FPF reported). In addition, these materials are often labelled as ‘organic’, ‘natural’, ‘eco-friendly’, ‘compostable’ or ‘recyclable’. This allegedly sustainable alternative to the plastic materials, however, is in fact made of plastic, where the bamboo or other plant-based additive are added only as a filler (to give it volume and shape). This practice is actually making the plastic non-recyclable and even less eco-friendly. In the EU, FCM based on plants and not produced with the intention of being sold as food, are outside the scope of the Regulation (EC) No 834/2007 and cannot bear the EU organic logo.

SAFE AND CIRCULAR ALTERNATIVE MATERIALS

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: MEDIUM

Name of the practice

Plastic-free flushable wet wipes

Target plastic product	**Cotton bud plastic sticks/swabs** **Plastic straws**
Application	**Healthcare & Pharmaceutical** **Retailers** **Hospitality and hotel, restaurant, and catering (HORECA) sector**

Plastic materials/ Polymer types in the original product

Polyester
Polyethylene (PE)
Polypropylene (PP)

Name and type of the substances of concern in the original product

- Formaldehyde
- Phenoxyethanol
- Parabens
- Ethylhexylglycerin

Abstract

Natracare's biodegradable and compostable wet wipes are made from 100 per-cent organic cotton, ethically sourced and certified to the Global Organic Textile Standard (GOTS), cloth, or 100 percent chlorine-free paper. The wet wipes are free from parabens, Sodium Lauryl Sulphate (SLS), methylisothiazolinone (MIT), alcohol, and other synthetic fragrances or preservatives of concern.

In particular, Natracare's 'Safe to Flush Moist Toilet Tissues' are moist tissues made of 100 percent paper and an organic and natural formula and are certified flushable. This certification guarantees that the product breaks down safely after flushing with no harm to marine life. The paper is FSC ecologically certified and bleached using the Totally Chlorine Free (TCF) method.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment, understand the combined effect of multiple substances within a product-packaging system, and ensure materials can be recycled safely.
- Regulatory approaches, such as bans or restrictions, on the manufacture, use, distribution, sale, or trade of SUPPs.
- Enforce green claim codes to stop greenwashing.
- Accountable standards and certification systems. Water Industry Specification (WIS-4-02-06) for Fine to Flush is the only standard approved by Water UK and the water authorities in the UK for flushing.

Technical enablers	Cooperation between producers and waste treatment authorities. Natracare has worked closely with Water UK and IWSFG to meet water industry standards for a truly flushable product. The IWSFG specification documents, developed by a coalition of national water services associations in Australia, Canada, Japan, New Zealand, Spain, describes the criteria that a product should meet to be compatible with being flushed down a toilet, and are intended as a Code of Practice for manufacturers to adhere to label a product as flushable.
Challenges	The primary packaging is still made of plastic, though recyclable and BPA-free.
Opportunities/ Benefits	The moist tissues should begin to break down in the sewer pipes just 20 minutes after flushing, while they will break down completely within 8 flushes (the average number of flushes a day in a household).
Replicability Low, Medium, High	The practice requires certain specific requirements to be successfully replicated. **MEDIUM**
Geographical area of implementation	Europe
Country	UK
Contacts	Natracare was created as a campaign to shake up the menstrual products industry and finally provide viable eco-friendly alternatives for periods. **info@natracare.com**
For more information	**https://www.natracare.com/products/wipes/**

SAFE AND CIRCULAR ALTERNATIVE MATERIALS

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: HIGH

Name of the practice

Plastic-free reusable wet wipes

Target plastic product	**Wet wipes**
Application	**Healthcare & Pharmaceutical** **Brand owners** **Retailers**
Plastic materials/ Polymer types in the original product	Polyester Polyethylene (PE) Polypropylene (PP)
Name and type of the substances of concern in the original product	• Formaldehyde • Phenoxyethanol • Parabens • Ethylhexylglycerin
Abstract	**Cheeky Wipes** is a UK-based company that makes a range of cloth-based items, designed to replace disposable cotton wool, wipes, sanitary pads and tampons. Wipes are made of cotton, bamboo, or a combination of the two. The Cheeky Wipes All-In-One Reusable Wipes Kit contains all the needed cloths, essential oils, bags, and boxes to safely use the reusable baby wipes at home and on the go.
State of implementation	**COMMERCIAL USE**
Legislative/ Policy enablers	• Mainstream CE principles into national and international policies. • Align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment, understand the combined effect of multiple substances within a product-packaging system, and ensure materials can be recycled safely. • Regulatory approaches, such as bans or restrictions, on the manufacture, use, distribution, sale, or trade of SUPPs. • Enforce green claim codes to stop greenwashing. • Binding waste reduction targets linked to effective sanctioning mechanisms for non-compliance. • Binding quantitative reuse targets.
Technical enablers	Design can help address some of the short-comings of reusable personal care solutions, such as convenience on-the-go.
Challenges	Cloth wipes are manufactured in Turkey, Pakistan, and China. Production in the UK is too expensive and would prevent selling at a price point which would make the reusables competitive on the market. Cheeky Wipes has accepted the increased carbon footprint from shipping by hoping to offset it by making the products available at a lower price point, and therefore lowering carbon emissions overall by replacing disposables for a greater number of people than if the price was higher.

Opportunities/ Benefits	Cheeky Wipes offers a system that is designed to be safer, convenient, environmentally friendly and money saving.
Replicability Low, Medium, High	The practice can be easily replicated in similar economic, technological, and political settings. **HIGH**
Geographical area of implementation	Europe
Country	UK
Contacts	Cheeky Wipes is a UK-based company on a mission to get more people use reusable products instead of SUPPs. **helenr@cheekywipes.com**
For more information	**https://www.cheekywipes.com/how-it-works.html**

SAFE AND CIRCULAR ALTERNATIVE MATERIALS

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: HIGH

Name of the practice

Reusable sanitary cloth pads

Target plastic product	**Sanitary items**
Examples	**Hygiene pads**
Application	**Healthcare & Pharmaceutical**

Plastic materials/ Polymer types in the original product

Polypropylene (PP)
Polyethylene (PE)
Superabsorbent polymer (SAP)

Name and type of the substances of concern in the original product

- Volatile organic compounds (VOCs)
- Endocrine-disrupting chemicals (e.g., phthalates)

Abstract

Eco Femme produces and sells washable cloth pads, provides menstrual health education, and opens dialogues on menstruation.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment, understand the combined effect of multiple substances within a product-packaging system, and ensure materials can be recycled safely.
- Regulatory approaches, such as bans or restrictions, on the manufacture, use, distribution, sale, or trade of SUPPs.
- Enforce green claim codes to stop greenwashing.
- Binding and enforceable waste reduction targets.
- Binding and enforceable reusable products targets.
- Policies designed to increase efforts on transitioning to low-carbon electricity and ensure access to clean water.
- Policies on sanitary items should be context specific, locally relevant and respond to gender inequalities and norms to avoid putting a higher burden on women.
- Information and awareness rising campaigns to educate consumers on efficient laundering practices and multiple reuses of sanitary items, as part of promoting a circular economy. Start-ups and companies are also playing an activist role, helping break taboos and offering reusable consumers high-tech underwear.

Technical enablers

- Research to develop renewable, plastic-free, chemical-free materials with comparable absorbent power than plastic polymers (such as thermoplastic polyurethane and polyester).

- Technology and design (e.g., weight reduction), coupled with consumer education on how to maximise the number of uses, washing, drying, and ironing behaviour, can increase the environmental performance of reusable sanitary items.
- Clear labelling and information on what sanitary items are made of. Particularly, considering that consumers are increasingly affected by skin allergies and urinary tract infections (UTIs) due to chemicals present in disposable items.

Market and financial enablers

- The improving consumer living standards and increasing expenditures on high-grade and premium-quality sanitary items in many countries.
- The rising consumer consciousness towards the detrimental impact of disposable sanitary items on the environment.
- Financing solutions to help carry the higher upfront costs of reusable sanitary items among low-income families.
- Incentivize, support, and promote through e-commerce platforms and delivery services.
- Supermarkets are also expected to have a significant revenue contribution to the sales of reusable sanitary items due to increasing infrastructure projects across regions.

Challenges

A reusable (washable) sanitary pad is clearly a design challenge because of the complexity involved with designing a wearable, intimate hygiene product that can handle the variable and often messy nature of periods, and keep doing so, use after use.

Opportunities/ Benefits

Reusable pads are already being produced in many countries across the world, each production based on local materials and available technologies.

Replicability
Low, Medium, High

The practice can be easily replicated in similar economic, technological, and political settings.

HIGH

Geographical area of implementation

Asia

Country

India

Contacts

Eco Femme is a women-led social enterprise founded in 2010. Based in Tamil Nadu, India, its goal is to create environmental and social change through revitalising menstrual practices that are healthy, environmentally sustainable, culturally responsive, and empowering.

For more information

https://ecofemme.org/

Similar case studies

FabPad - **https://fabpad.in/** - India

Rebelle Pads - **https://www.rebellepads.com/** - India

Moontime - **https://www.moontime.africa/** - South Africa

Eco-africa - **https://eco-padsafrica.com/** - Uganda

The Woman's Company - reusable and biodegradable hygiene items - **https://www.thewomanscompany.com/** - India

LastPad - produced by LastObject - Denmark

SAFE AND CIRCULAR ALTERNATIVE MATERIALS

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: HIGH

Name of the practice

Reusable baby cloth diapers rental service

Target plastic product	**Sanitary items**
Examples	**Baby diapers/nappies**
Application	**Healthcare & Pharmaceutical**

Plastic materials/ Polymer types in the original product

Super Absorbent Polymer (SAP) such as sodium polyacrylate
Polyethylene/Polypropylene PE/PP wrapping film
Polyethylene (PE) film
Spandex yarn comprises natural rubber, synthetic rubber, and raw elastane fibre pattern

Name and type of the substances of concern in the original product

- Polycyclic aromatic hydrocarbons (PAHs)
- Dioxins (PCCD/Fs) and dioxin-like polychlorobiphenyls (DL-PCBs)
- Tributyltin (TBT) or other organotin compounds like dibutyltin (DBT) and monobutyltin (MBT) – persistent organic pollutants
- Dioxin
- Phthalates
- VOCs
- Heavy metals

Abstract

Botanic Baby allows customers to rent a suitable amount of reusable cloth diapers for daily use, that are then collected, washed, and altered as the child grows. Through the weekly subscription, the washable nappies are collected from the house and commercially cleaned on a weekly basis, providing the customers with fresh, clean nappies the very same day. Cloth diaper pre-folds are made with 100 percent unbleached cotton.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment, understand the combined effect of multiple substances within a product-packaging system, and ensure materials can be recycled safely.
- Regulatory approaches, such as bans or restrictions, on the manufacture, use, distribution, sale, or trade of SUPPs.
- Enforce green claim codes to stop greenwashing.
- Binding waste reduction targets linked to effective sanctioning mechanisms for non-compliance.
- Binding and enforceable reusable products targets.
- Policies designed to increase efforts on transitioning to low-carbon electricity and ensure access to clean water.

- Policies on sanitary items should be context specific, locally relevant and respond to gender inequalities and norms to avoid putting a higher burden on women.
- Information and awareness rising campaigns to also educate consumers on efficient laundering practices and multiple reuses of sanitary items, as part of promoting a circular economy.

Technical enablers

- Research to develop renewable, plastic-free, chemical-free materials with comparable absorbent power than plastic polymers (such as thermoplastic polyurethane and polyester).
- Technology and design (e.g., weight reduction), coupled with consumer education on how to maximise the number of uses, washing, drying, and ironing behaviour, can increase the environmental performance of reusable sanitary items.
- Clear labelling and information on what sanitary items are made of. Particularly, considering that consumers are increasingly affected by skin allergies and urinary tract infections (UTIs) due to chemicals present in disposable items.

Market and financial enablers

- The improving consumer living standards and increasing expenditures on high-grade and premium-quality sanitary items in many countries.
- The rising consumer consciousness towards the detrimental impact of disposable sanitary items on the environment.
- Financing solutions to help carry the higher upfront costs of reusable sanitary items among low-income families.
- Incentivize, support, and promote through e-commerce platforms and delivery services.
- Supermarkets are also expected to have a significant revenue contribution to the sales of reusable sanitary items due to increasing infrastructure projects across regions.

Challenges

People do not always save money with reusable diapers, particularly when buying high-end diapers or using a laundering service. Those who choose laundering services may still find reusable diapers inconvenient when out and about. In addition, using cloth diapers does not guarantee a lack of chemical exposure. Some cotton and other fabrics may contain dyes, bleaches, fragrances, or remnants of pesticides. Laundry detergent may also include fragrance or other chemicals.

Opportunities/ Benefits

Reusable nappies rental services are particularly convenient and adapted to the busy lives of modern families. BotanicBaby's washable nappies service has a comparative cost to buying disposable diapers. Laundry service follows the AS4146-2000 standard, and only uses green cleaners so that the wastewater is both sterile and ph-neutral. The used nappies are either recycled, pulped, and used to create new fabrics like rayon for other uses like cleaning cloths or donated to community projects. BotanicBaby is committed to involvement within the communities and the small businesses they serve. They help people grow their businesses with their service and create more local jobs in the process. BotanicBaby is also helping councils meet landfill reduction targets.

Replicability
Low, Medium, High

The practice can be easily replicated in similar economic, technological, and political settings.

HIGH

Reusable baby cloth diapers rental service

Geographical area of implementation	Oceania
Country	Australia
Contacts	Botanic Baby Melbourne (Australia) **service.botanicbaby@gmail.com**
For more information	**https://www.botanicbaby.com.au/**
Similar case studies	Monkey Butt Cloth Diaper Service - **https://monkeybuttdiapers.com/** - USA Washcot - **https://www.washcot.be/** - Belgium
Comments	Overall, the environmental impact of reusable diapers is normally lower than disposable ones. A 2021 UNEP meta-analysis shows that reusable options when washed so as to minimise water use (e.g., in a fully loaded, modern washing machine) and in an energy efficient manner have lower environmental impacts than disposable plastic ones. Technology and design developments (e.g., weight reduction), as well as consumer education on how to maximise the number of nappy washings, drying and ironing behaviour can increase the environmental performance of reusable cloth diapers. Consumers can be encouraged to make changes to help reduce environmental impact, for example by changing how they clean reusable diapers (e.g., cold wash/line dry), choosing lighter diapers (less material) with correct fit (avoiding leakage), disposing of diapers correctly at the end of their lives. Manufacturers are becoming increasingly aware of parents' concerns about toxic materials, so many list what potentially harmful chemicals are not included on their website or packaging, but do not specify what the diapers are made of.

SAFE AND CIRCULAR ALTERNATIVE MATERIALS

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: HIGH

Name of the practice

Reuse on-the-go refill (B2C) mobile self-vending units for fresh milk in glass bottles

Target plastic product	**Food contact primary packaging**
Examples	**PET bottles**
Application	**Food and Beverage Manufacturing / Brand owners** **Retailers** **Hospitality**

Plastic materials/ Polymer types in the original product

Polyethylene terephthalate (PET)

Name and type of the substances of concern in the original product

- Antimonies (Sb)
- Aldehydes
- Phthalates
- Bisphenols

Abstract

The **Movin' Milk** is a family-owned farm that sells pasteurised but not homogenized fresh milk directly to consumers through a mobile vending machine. Customers can buy the glass milk bottles and fill them up via the vending unit, then when the bottles are empty, they wash them and bring them back and refill them.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment, understand the combined effect of multiple substances within a product-packaging system, and ensure materials can be recycled safely.
- Regulatory approaches, such as bans or restrictions, on the manufacture, use, distribution, sale, or trade of SUPPs.
- Binding waste reduction targets linked to effective sanctioning mechanisms for non-compliance.
- Laws promoting and encouraging the sale of reusable beverage containers; suppliers must offer reusable bottles and must take-back the returnable bottles (including or not a percentage annual reusable packaging increase).
- Beverage reuse quotas in the hospitality and HORECA sector and a general beverage packaging reuse target for domestic consumption at home.
- Enabling regulations pertaining to the sale of raw milk through vending machines.

Technical enablers

- Technologies that enhance the sanitizing of the vending machine in between purchases.

Reuse on-the-go refill (B2C) mobile self-vending units for fresh milk in glass bottles

Market and financial enablers

- The global milk vending machines market size is expected to growth during the forecast period 2020 to 2027, as new measures aimed to promote reuse refill systems are put in place in countries across the globe.
- Public-private partnerships to promote milk vending machine among local farmers.
- Incentives and attach conditions to state aid and government funds.

Challenges

Vending machines are meant to sell raw, unhomogenised milk, which might not be appreciated by local consumers. Stringent food safety regulations might further hamper the scaling up of this reuse refill model.

Opportunities/ Benefits

For milk producers, the benefits are:

- Cut out the middleman and sell directly to consumers.
- No fluctuations in price achieved per litre of milk sold.
- No additional packaging or bottling costs.
- Reduced carbon footprint.

For consumers, the benefits are:

- A novel and fun way of buying milk, while supporting local producers.
- Access to local products, fresh with true provenance, low food-miles, and carbon footprint.
- Contribute to saving on single-use plastic packaging by using BYO containers.

Replicability

Investment in raw milk vending machines can support local economies and small family run farms. They provide a convenient way for small farmers of bringing the produce directly to the consumers in developing countries.

Replicability Low, Medium, High	The practice can be easily replicated in similar economic, technological, and political settings.	**HIGH**

Geographical area of implementation

Europe

Country

UK

Contacts

The Movin' Milk is a 5th generation of dairy farmers in the UK.
info@moovinmilk.co.uk

For more information

https://www.moovinmilk.co.uk/vending-machines

Similar case studies

Drinkfill - h**ttps://www.drinkfill.com/** - Canada
JeanBouteille - **https://jeanbouteille.fr/** - France

SAFE AND CIRCULAR ALTERNATIVE MATERIALS

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: HIGH

Name of the practice

Paper straw for beverage cartons

Target plastic product	**Plastic straws**
Application	**Food and Beverage Manufacturing / Brand owners Retailers**
Plastic materials/ Polymer types in the original product	Polypropylene (PP)
Abstract	**Tetra Pack** has designed an FSC-certified paper straw that is recyclable with the rest of the package. The paper straw will initially be available for two small carton packages used for dairy and beverage products, which include Tetra Brik Aseptic 200 Base and Tetra Brik Aseptic 200 Base Crystal.
State of implementation	COMMERCIAL USE
Legislative/ Policy enablers	• Mainstream CE principles into national and international policies. • Align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment, understand the combined effect of multiple substances within a product-packaging system, and ensure materials can be recycled safely. • Regulatory approaches, such as bans or restrictions, on the manufacture, use, distribution, sale, or trade of SUPPs. • Binding waste reduction targets linked to effective sanctioning mechanisms for non-compliance. • Binding quantitative recycling targets. • Product policies that focus on high quality design for recyclable packaging. Technologies that enhance the sanitizing of the vending machine in between purchases.
Market and financial enablers	• Use Green Public Procurement (GPP) to create market demand and showcase solutions, by creating standards and defining circular requirements for goods purchased by public bodies, as well as purchasing locally where appropriate. • Innovation awards, prizes, challenges, and platforms, such as the World Economic Forum's Scale360° Playbook and UpLink.
Opportunities/ Benefits	Tetra Pack has decided not to apply for patent protection on the numerous technical improvements they have made on the equipment and the materials, and instead put their innovations into the public domain. The Tetra Pack paper straw is fully functional and meets internationally recognised food safety standards.
Replicability Low, Medium, High	The practice can be easily replicated in similar economic, technological, and political settings. **HIGH**

Paper straw for beverage cartons

Geographical area of implementation	Europe
Country	Sweden
Contacts	Tetra Pak is a world leading food processing and packaging solutions company. It operates in more than 160 countries, with more than 25,000 employees around the world. Tetra Pak is one of three companies in the Tetra Laval Group, a private group that started in Sweden. **https://www.tetrapak.com/solutions/packaging/packaging-material/straws**
For more information	**https://www.tetrapak.com/about-tetra-pak/news-and-events/newsarchive/first-carton-packaging-company-to-launch-paper-straws**

SAFE AND CIRCULAR ALTERNATIVE MATERIALS

IMPLEMENTATION: PILOT

REPLICABILITY: MEDIUM

Name of the practice

Biodegradable and compostable delivery packaging made from agriculture residue

Target plastic product	**Food-contact primary packaging**
Examples	
Application	**Consumer Goods / Lifestyle** **Healthcare & Pharmaceutical** **Food and Beverage Manufacturing / Brand owners** **Retailers** **Hospitality and hotel, restaurant, and catering sector (HORECA)**
Plastic materials/ Polymer types in the original product	High-density polyethylene (HDPE) Low-density polyethylene (LDPE) Linear low-density polyethylene (LLDPE) Polypropylene (PP)
Name and type of the substances of concern in the original product	• Bisphenols • Phthalates • PFASs
Abstract	**Solo Embalagens** is a delivery packaging made of dry palm leaf. The package doesn't require resins, glues, or any kind of chemicals, to be produced. It is biodegradable and compostable, and can go in the microwave, oven, and freezer. Palm leaf is composed of natural fibres (hemicellulose, cellulose, and lignin) which are proven to have excellent properties to be used in delivery packages. Only dry leaves are used for production. Palm leaves fall during the whole year and each one can make two containers on average. The package comes as a rectangular or a round box with a seed paper belt to ensure proper sealing and to inform the properties of the container.
State of implementation	**PILOT**
Legislative/ Policy enablers	• Mainstream CE principles into national and international policies. • Align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment, understand the combined effect of multiple substances within a product-packaging system, and ensure materials can be recycled safely. • Regulatory approaches, such as bans or restrictions, on the manufacture, use, distribution, sale, or trade of SUPPs. • Binding waste reduction targets linked to effective sanctioning mechanisms for non-compliance. • Develop product policies that focus on high quality design for durable goods and packaging (emphasis on recyclability). • Develop and implement awareness raising campaigns.

Technical enablers

- Life-Cycle Assessments (LCA) or alternative assessments should be performed to assess the potential environmental impacts of the alternative (non-plastic) material before promoting it. The sourcing of the raw material, the set-up of the delivery system, the mode of transport and transportation distance during the use phase, and waste management are important factors to consider when performing these assessments.
- Geographical context is an important factor influencing the environmental impact of packaging for take-away food. In this specific case, geography greatly influences access to the feedstock for producing the food-contact take-away package.

Market and financial enablers

- Innovation awards, prizes, challenges, and platforms, such as the World Economic Forum's Scale360° Playbook and UpLink.
- Market-based instruments such as taxes or levies on SUPPs.
- The palm fibre packaging market can be segmented into wood and non-wood. The non-wood segment is expected to hold a larger share in the palm fibre packaging market due to factors such as growing demand for biodegradable packaging in Fast Moving Consumer Goods (FMCG) globally, leading to a demand for packaging products and disposable containers such as those made from palm leaf. Moreover, disposable containers made from palm fibres have good strength and do not break or leak, which is expected to act as a major factor for the segment growth.

Challenges

The best waste management for palm leaf packaging is industrial composting. If these facilities are not available, then palm leaf waste could be placed in the general waste bin. However, this is not the best waste management outcome as the packaging will not easily break down outside of a specialised composting environment. At the same time, as they are so durable, palm leaf boxes can be washed and reused multiple times. Or they can be repurposed by customers as planters, dust bins and for storage.

Opportunities/ Benefits

Palm leaf is composed of natural fibres (hemicellulose, cellulose, and lignin). Once cleaned with high-pressure water, they are mechanically pressed with steam and heat into the specific shape, and no chemicals or coatings are added to this process. Dry palm leaf packaging has equal or even better characteristics compared to plastics, maintaining the food temperature, not absorbing liquid in the short term, and having no smell or taste. In addition, compostable packaging can be collected with food waste and sent directly to industrial composting. Dry palm leaf packaging is an interesting solution that can be replicated in countries in tropical and subtropical areas where palm plantations are common.

Replicability
Low, Medium, High

The practice requires certain specific requirements to be successfully replicated.

MEDIUM

Geographical area of implementation

Latin-America

Country

Brazil

Contacts

Solo Embalagens is an award-winning project of three design students in Brazil. The Solo Embalagens website is under construction.
https://www.soloembalagens.com/

For more information

https://climatelaunchpad.org/finalists/solo-packaging/

Similar case studies

Leef - **https://leef.bio/en/palmblatt/** - Germany

SAFE AND CIRCULAR ALTERNATIVE MATERIALS

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: MEDIUM

Name of the practice

Plastic-free and PFAS-free recyclable single-use food bowl

Target plastic product	**Food and beverage containers**
Examples	**Single-use food containers (e.g., take-away food bowls, clamshells)**
Application	**Food and Beverage Manufacturing / Brand owners** **Retailers** **Hospitality and hotel, restaurant, and catering sector (HORECA)**

Plastic materials/ Polymer types in the original product

Polystyrene (PS)
Polyethylene (PE)
Extruded polystyrene (XPS)
Polypropylene (PP)
Polyethylene terephthalate (PET)

Name and type of the substances of concern in the original product

- PFASs

Abstract

PureFiber™ food bowl range consists of formed fibre products with various finishes to suit exact needs. The core product is completely plastic-and PFAS-free. Products in the PureFiber™ line are made in Sweden from 90-100 percent renewable material Nordic wood fibres, using 100 percent green electricity. All products in the PureFiber™ range can be recycled in the paper stream in most countries. PureFiber™ product line has an approximately 75 percent lower climate impact compared to alternative packaging materials, such as plastic or bagasse.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment, understand the combined effect of multiple substances within a product-packaging system, and ensure materials can be recycled safely.
- Regulatory approaches, such as bans or restrictions, on the manufacture, use, distribution, sale, or trade of SUPPs.
- Binding waste reduction targets linked to effective sanctioning mechanisms for non-compliance.
- Develop product policies that focus on high quality design for durable goods and packaging (emphasis on recyclability).
- Develop and implement awareness raising campaigns.
- Ban or restriction in the use of hazardous substances in Food Contact Materials (FCM).

Technical enablers

- Incorporate CE principles in higher education curricula, training programmes and apprenticeships.
- Promote the establishment and adoption of multi-stakeholder, cross-value-chain, inclusive and responsive working mechanisms to develop system solutions and to build public private capacity.
- Establish collaboration and international harmonisation between the public and private sectors to ensure synergies and trade-offs between upstream design policies, chemical legislation, and waste legislation.
- Pass information about chemical ingredients along the local and global value chains to ensure products and materials are safely managed. This will require joint efforts with business as well as investments in technology.
- Introduce harmonized criteria, standard and certification on biodegradability and compostability.
- Develop standards to support trade in circular economy goods, services, and systems.
- Develop and harmonise collection and sorting policies (such as separate collection and management of materials), leading to the value retention of high-quality materials and products and enabling higher value organic loops as well as regenerative practices through nutrient cycling.
- Availability of certified responsible forests. To increase the use of forest certification in areas where to purchase wood, group certification is promoted to encourage more suppliers and farmers to join these systems.

Market and financial enablers

- Waste disposal fees or charges, or higher excise taxes for SUPPs.
- Align taxation and fee incentives, such as EPR, with circular economy outcomes.
- Attach conditions to state aid and government funds.
- Use Green Public Procurement (GPP) to create market demand and showcase solutions, by creating standards and defining circular requirements for goods purchased by public bodies, as well as purchasing locally where appropriate.
- Ensure transparency through taxonomy and disclosure requirements.
- Adapt accounting rules.
- Offer early-stage venture funding.
- Support blended finance solutions for physical and digital infrastructure, and innovation.
- Business Partnerships help establish closed-loop systems for recyclable biobased alternatives to SUPPs. For example, Tingstad, a family-owned company and the market leading distributor of disposables and food service products to the HORECA sector in the Nordic countries, sells the newly developed PureFiber™ by Stora Enso food bowls directly to customers in the fast-food industry.

Challenges

Removing potentially toxic chemicals from moulded fibres has been made possible thanks to the initiative of companies such as Zume and Solenis that are open-sourcing the recipe and manufacturing process of creating a moulded fibre packaging solution that ensures food grease and water-resistance without the need for PFAS or harmful chemicals.

Opportunities/ Benefits

PureFiber™ food bowl is made of 100 percent of wood from sustainable sources, including forest certification and third-party traceability systems such as the Forest Stewardship Council's (FSC) Chain of Custody/Controlled Wood scheme, the Chain of Custody/Due Diligence System of the Programme for the Endorsement of Forest Certification (PEFC), and the ISO 14001 environmental management standard.

It has substantially lower CO_2 equivalent emissions compared to alternative products, and the products are renewable, recyclable, and plastic-free. New technology enables high-resolution four-colour graphics to be applied directly on the surface of moulded fibre packaging. Benefits include visually appealing graphics and better packaging sustainability (no need for additional outer packaging or wrap with a label on it) at a low per-unit cost and higher production rate with less barrier on time.

Replicability
Low, Medium, High

The practice requires certain specific requirements to be successfully replicated.

MEDIUM

Geographical area of implementation

Europe

Country

Sweden | Finland

Contacts

Stora Enso is a leading global provider of renewable solutions in packaging, biomaterials, wooden construction, and paper.

For more information

https://www.storaenso.com/en/products/formed-fiber

Similar case studies

Zume and Solenis - **https://www.zume.com/zume-x-solenis** - USA

SAFE AND CIRCULAR ALTERNATIVE MATERIALS

IMPLEMENTATION: PILOT

REPLICABILITY: LOW

Name of the practice

Non-plastic food contact foil

Target plastic product	**Food Contact Primary packaging**
Examples	**Packets and wrappers**
Application	**Food and Beverage Manufacturing / Brand owners** **Retailers** **Hospitality and hotel, restaurant, and catering sector (HORECA)**

Plastic materials/ Polymer types in the original product

Polyvinyl chloride (PVC)
Low-density polyethylene (LDPE)
Linear Low-density polyethylene (LLDPE)

In the US and Japan, plastic wrap is sometimes produced using polyvinylidene chloride (PVdC), though some brands have switched to other formulations due to environmental concerns.

Name and type of the substances of concern in the original product

- Phthalates
- Perchlo rate (anti-static agent)
- Bisphenols
- Ethyl and methyl glycol, toluene, and n-methyl-pyrrolidone (NMP)
- Contaminants: Heavy metals

Abstract

UnPlastic is a functional, compostable, and non-plastic alternative to single-use plastics that does not releases toxins into the environment. It is circular, made from food industry sources, by-products, and waste. UnPlastic does not break down into micro-or nano-plastics.

State of implementation

PILOT

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment, understand the combined effect of multiple substances within a product-packaging system, and ensure materials can be recycled safely.
- Regulatory approaches, such as bans or restrictions, on the manufacture, use, distribution, sale, or trade of SUPPs.
- Binding waste reduction targets linked to effective sanctioning mechanisms for non-compliance.
- Develop product policies that focus on high quality design for durable goods and packaging (emphasis on recyclability).
- Develop and implement awareness raising campaigns.
- Ban or restriction in the use of hazardous substances in Food Contact Materials (FCM)

Technical enablers

- Incorporate CE principles in higher education curricula, training programmes and apprenticeships.
- Promote the establishment and adoption of multi-stakeholder, cross-value-chain, inclusive and responsive working mechanisms to develop system solutions and to build public private capacity.
- Establish collaboration and international harmonisation between the public and private sectors to ensure synergies and trade-offs between upstream design policies, chemical legislation, and waste legislation.
- Pass information about chemical ingredients along the local and global value chains to ensure products and materials are safely managed. This will require joint efforts with business as well as investments in technology.
- Develop standards to support trade in circular economy goods, services, and systems.

Market and financial enablers

- Innovation awards, prizes, challenges, and platforms, such as the World Economic Forum's Scale360° Playbook and UpLink.
- Waste disposal fees or charges, or higher excise taxes for SUPPs.
- Align taxation and fee incentives, such as EPR, with circular economy outcomes.
- Attach conditions to state aid and government funds.
- Use Green Public Procurement (GPP) to create market demand and showcase solutions, by creating standards and defining circular requirements for goods purchased by public bodies, as well as purchasing locally where appropriate.
- Ensure transparency through taxonomy and disclosure requirements.
- Adapt accounting rules.
- Offer early-stage venture funding.
- Support blended finance solutions for physical and digital infrastructure, and innovation.

Challenges

Unplastic is in the proof-of-concept phase. The aim is to design a product that can be scaled quickly and effectively, by iteratively developing UnPlastic so it fits the market's needs. To achieve this, Outlander Material is searching for partners within packaging, manufacturing, and consumer goods companies to develop the product stepwise together. By developing it in a lean and agile manner and continuously testing, their goal is to have UnPlastic market-ready within 2 years.

Opportunities/ Benefits

UnPlastic biodegrades in soil and water, and never breaks down into micro-or nano plastics. It is flexible and lightweight, making it ideal for packaging products. It has exceptional barriers against fats, oils, and oxygen, extending the shelf life of products. It is free of toxins, allergens, and animal products. It can be created from already existing food production streams and waste, minimizing the depletion of natural resources. It is semi-transparent, free of odours, leaving no unintended smells or flavours. After commercialization, the idea is to further develop end applications for foils and coatings within the flexible packaging market and explore non-packaging applications for the raw products. Outlander Materials aims to become a technology provider, licensing of and decentralizing the production of the material to as many companies as possible. This will help replace unsustainable materials and reduce waste around the globe.

Replicability
Low, Medium, High

The practice requires a high level of technological advancement, market preparedness, or specific economic/political conditions to be successfully replicated.

LOW

Geographical area of implementation	Europe
Country	The Netherlands
Contacts	Outlander Materials is a biotech company using existing food industry sources, by-products, and waste to create compostable, non-toxic materials. **info@outlandermaterials.nl**
For more information	**https://www.outlandermaterials.com/unplastic**

SAFE AND CIRCULAR ALTERNATIVE MATERIALS

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: MEDIUM

Name of the practice

Plastic-free packaging solutions from food waste

Target plastic product	**Food Contact Primary packaging**
Examples	**Flexible packaging** **Barrier layer** **Single-use takeaway** **Reusable packaging**
Application	**Consumer Goods / Lifestyle** **Healthcare & Pharmaceutical** **Food and Beverage Manufacturing / Brand owners** **Retailers** **Hospitality and hotel, restaurant, and catering sector (HORECA)**

Plastic materials/ Polymer types in the original product

Polyolefins such as (PE) and (PP)
HDPE, LDPE, LLDPE, OPP
Polyesters such as PET and PLA
Polyvinyl Chloride (PVC)
Polyamide (PA)
Ethylene vinyl alcohol (EVOH)
Ethylene-vinyl acetate (EVA)
Polyurethane (PUR)
Polyvinylidene chloride (PVDC)
Biobased polymer such as Polylactic acid (PLA)

Name and type of the substances of concern in the original product

- PFASs
- Phthalates in plastic films
- NPEs/NPs as surfactants, phosphate antioxidants in food wraps

Abstract

Scoby Packaging Materials® (SPM®) is a high-performance nano-fibre composed of bacterial nano-cellulose (BNC). The SPM® material is produced through a patented technology (a biological process), developed by **MakeGrowLab**, that makes cellulose extraction processes a circular approach that does not requires chemicals, additives, other non-biodegradable and potentially hazardous substances, or extensive water usage. The material serves as an oxygen, grease, and water vapour barrier. It is insoluble in water and impermeable to water which makes it a great alternative to plastic-coated paper and plastic foils. SPM®-based material is also approved for food contact, fully recyclable with existing paper stream, biodegradable and ready to use by existing manufactures.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment, understand the combined effect of multiple substances within a product-packaging system, and ensure materials can be recycled safely.

- Regulatory approaches, such as bans or restrictions, on the manufacture, use, distribution, sale, or trade of SUPPs.
- Review and harmonise resource classifications and definitions in waste legislation.

Technical enablers

- Incorporate CE principles in higher education curricula, training programmes and apprenticeships.
- Promote the establishment and adoption of multi-stakeholder, cross-value-chain, inclusive and responsive working mechanisms to develop system solutions and to build public private capacity.
- Encourage regenerative production through product and formulation design, sourcing practices and agricultural and land-use policies.
- Implement spatial planning policies to enhance material flow and use and create business opportunities such as industrial symbiosis.
- Establish collaboration and international harmonisation between the public and private sectors to ensure synergies and trade-offs between upstream design policies, chemical legislation, and waste legislation.
- Pass information about chemical ingredients along the local and global value chains to ensure products and materials are safely managed. This will require joint efforts with business as well as investments in technology.
- Develop standards to support trade in circular economy goods, services, and systems.
- Develop and harmonise collection and sorting policies (such as separate collection and management of materials), leading to the value retention of high-quality materials and products and enabling higher value organic loops as well as regenerative practices through nutrient cycling.

Market and financial enablers

- Innovation awards, prizes, challenges, and platforms, such as the World Economic Forum's Scale360° Playbook and UpLink.
- Waste disposal fees or charges, or higher excise taxes for SUPPs.
- Align taxation and fee incentives, such as EPR, with circular economy outcomes.
- Reform and, where relevant, deploy subsidies.
- Attach conditions to state aid and government funds.
- Use Green Public Procurement (GPP) to grow sustainable products markets.
- Ensure transparency through taxonomy and disclosure requirements.
- Adapt accounting rules.
- Offer early-stage venture funding.
- Support blended finance solutions for physical and digital infrastructure, and innovation.

Challenges

The original project objective of MakeGrowLab was to design an efficient, scalable process that could turn local bio-waste into natural and home compostable materials. The initial experiments began with cellulose grown from the kombucha brewing process. However, due to the mechanical properties, it was determined that this type of cellulose is not suitable for commercial production. Innovation requires time, resources, trial, and error, and start-up such as MakeGrowLab need to be sustained during the first years of operations.

Opportunities/ Benefits	SPM® is a bio fabricated material grown from a variety of bio-waste from agriculture, food, and forestry industries. The process uses significantly less space and time to grow than traditional plant-based materials resulting in scalability and affordability of the future materials. Food waste or agricultural by-products are a common issue to many countries across the globe. Research into how to turn this valuable resource into safe and circular alternatives to fossil-based plastics is also ongoing in many countries. However, a clear legal framework and important investments both in the R&D and the waste treatment system are necessary to ensure the most promising innovations are scaled and reach the market.
Replicability Low, Medium, High	The practice requires certain specific requirements to be successfully replicated. **MEDIUM**
Geographical area of implementation	Europe
Country	Poland
Contacts	MakeGrowLab was founded in 2019 to innovate around sustainability and to grow new materials in a fully circular manner. The project objective was to design an efficient, scalable process that could turn local bio-waste into natural and home compostable materials. After years of trial and error, Scoby Packaging Materials was finally produced. Since then, MGL has created a variety of materials that hold the possibility to take the material industry into a more sustainable path. **info@makegrowlab.com**
For more information	**https://www.makegrowlab.com/scobypackaging**

SAFE AND CIRCULAR ALTERNATIVE MATERIALS

IMPLEMENTATION: PILOT

REPLICABILITY: MEDIUM

Name of the practice

Pinyapel: Plastic-free packaging made from discarded pineapple leaves

Target plastic product	**Primary packaging**
Examples	**Plastic films, bags, beverage cups**
Application	**Consumer Goods / Lifestyle** **Healthcare & Pharmaceutical** **Food and Beverage Manufacturing / Brand owners** **Retailers** **Hospitality and hotel, restaurant, and catering sector (HORECA)**

Plastic materials/ Polymer types in the original product

Polyethylene (PE)
High-density polyethylene (HDPE)
Low-density polyethylene (LDPE)
Linear low-density polyethylene (LLDPE)
Polypropylene (PP)

Name and type of the substances of concern in the original product

- Bisphenols as based liners
- PFASs as grease-proofing agents

Abstract

Developed by the **Design Center** of the Philippines, *Pinyapel* is a specialty paper, reinforced and print-ready for primary packaging applications made from discarded pineapple leaves. The specialty paper can be used to make any of the packaging that usually are lined with plastic to make them water or grease resistant. *Pinyapel* requires no extra plastic film layer as pineapple leaves are naturally water-resistant. *Pinyapel* is locally sourced and manufactured, as well as 100 percent biodegradable. After the *Pinyapel* products are discarded, they can be used again as raw materials, in turn, for brown bags and cardboard products.

State of implementation

PILOT

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment, understand the combined effect of multiple substances within a product-packaging system, and ensure materials can be recycled safely.
- Regulatory approaches, such as bans or restrictions, on the manufacture, use, distribution, sale, or trade of SUPPs.
- Binding waste reduction targets linked to effective sanctioning mechanisms for non-compliance.
- Develop product policies that focus on high quality design for durable goods and packaging (emphasis on recyclability).
- Develop and implement awareness raising campaigns.
- Policies that help develop secondary material and by-product markets.

Technical enablers

- Innovation awards and challenges. *Pinyapel* has for example won the 2019 Wood Pencil award by the UK-based charity D&AD Future Impact for efforts in sustainability, marking the Philippines' first award in the category.
- Promote the establishment and adoption of multi-stakeholder, cross-value-chain, inclusive and responsive working mechanisms to develop system solutions and to build public private capacity.
- Encourage regenerative production through product and formulation design, sourcing practices and agricultural and land-use policies.
- Develop secondary material and by-product markets.
- Implement spatial planning policies to enhance material flow and use and create business opportunities such as industrial symbiosis.
- Review and harmonise resource classifications and definitions in waste legislation.
- Promote establishment and adoption of multi-stakeholder, cross-value-chain, inclusive and responsive working mechanisms to develop system solutions and to build public private capacity.
- Pass information about chemical ingredients along the local and global value chains to ensure products and materials are safely managed. This will require joint efforts with business as well as investments in technology.
- Develop standards to support trade in circular economy goods, services, and systems.
- Develop and harmonise collection and sorting policies (such as separate collection and management of materials), leading to the value retention of high-quality materials and products and enabling higher value organic loops as well as regenerative practices through nutrient cycling.

***Pinyapel:* Plastic-free packaging made from discarded pineapple leaves**

Market and financial enablers

- Market-based policies to support the growth of circular resource management loops (e.g., the use of secondary raw materials, including recyclate and organic by-products).
- Fiscal measures (e.g., research and development (R&D) tax credits) and economic incentives supporting design and uptake of eco-friendly alternatives to single-use plastics.
- Taxing non-renewable resources rather than labour (with adequate safeguards to avoid regressive effects on vulnerable groups) can support innovation and growth in circular economy practices.
- Early-stage public funding to establish proof-of-concept to spur further private investments in circular innovation.
- Provide interdisciplinary research funds.
- Blended finance solutions (including technical assistance, risk underwriting, and market incentives such as match-funding) to close the investment gap for harder-to-finance infrastructure and riskier, long-term innovation, by using development capital to mitigate investor risks. This can include blended instruments (such as insurance or guarantees) and blended vehicle structures (such as layered funds with first loss or technical assistance sidecar facilities), which can be especially catalytic for harnessing investments for infrastructure and innovation across a wide range of sectors with a view to delivering the circular economy.
- Structure international aid flow to deliver on circular economy objectives. Multilateral development banks (MDBs) and development finance institutions can enable challenging projects to become investable, by advising on project structuring and mitigating risk, crowding in additional private capital, and can also enable the funding of early-stage fundamental innovation, as shown by the European Investment Bank's (EIB) InnovFin financing tools.

- Use Green Public Procurement (GPP) to create market demand and showcase solutions, by creating standards and defining circular requirements for goods purchased by public bodies, as well as purchasing locally where appropriate.

Challenges

The process of converting pineapple leaves into paper sheets involves numerous procedure that are still finetuned.

Opportunities/ Benefits

The Philippines is the second biggest pineapple producer globally. *Pinyapel* not only helps reduce waste in agriculture and deforestation associated with paper made from trees, but it also helps local pineapple farmers in the country as it gives the leaves a new purpose and value, increasing their livelihood/providing additional revenues. If further developed into commercial packaging, *Pinyapel* can be easily replicated in other countries producers of pineapple, particularly in Latin America.

In addition, *Pinyapel* decomposes faster than other paper products: according to tests by the Design Center of the Philippines, it reached about 55 percent mass loss in four weeks, much higher than the 21 percent mass loss in commercial paper bags.

Replicability
Low, Medium, High

The practice requires certain specific requirements to be successfully replicated.

MEDIUM

Geographical area of implementation

Asia

Country

Philippines

Contacts

Pinyapel is the result of a close collaboration between the Design Center's Materials Research and Development Program and the Nature's Fresh Pineapples (discarded pineapple leaves supplier), CDO Handmade Paper Crafts (paper sheet processor), and Ideatechs Packaging Corporation (paper converter to food packaging applications). The partnerships aimed to solve the problem of agricultural waste and deforestation in the Philippines by reusing discarded leaves from the locally abundant fruit pineapple cultivations. The innovation won the 2019 Wood Pencil award by the UK-based charity D&AD Future Impact for sustainability. It is also the Philippines' first award for the category.
https://pinyapel.carrd.co/#

For more information

https://www.adobomagazine.com/philippine-news/design-introducing-the-pinyapel-the-sustainable-locally-made-specialty-paper-created-from-waste-pineapple-leaves-by-the-design-center-of-the-philippines/

SAFE AND CIRCULAR ALTERNATIVE MATERIALS

IMPLEMENTATION: PILOT

REPLICABILITY: LOW

Name of the practice

Non-toxic, marine-safe, and soluble in warm or hot water barrier films

Target plastic product	**Barrier films**
Examples	**Plastic lining for food and beverage paper or cardboard**
Application	**Packaging manufacturers** **Consumer Goods / Lifestyle** **Healthcare & Pharmaceutical** **Food and Beverage Manufacturing / Brand owners** **Retailers** **Hospitality and hotel, restaurant, and catering sector (HORECA)**

Abstract

Hydropol™ is a patent-protected polymer technology developed by the British company **Aquapak**, based on thermally processible polyvinyl alcohol (PVOH, PVA). The highly versatile Hydropol™ family of products is produced in pellet form to enable all downstream conversion processing methods to be used. Hydropol™ material has many useful properties: tailored solubility, exceptional barrier properties against solvents, grease, oils, fats, waxes, oxygen, CO2 and nitrogen, high tensile strength, and puncture resistance, heat sealable, electro-static resistant, naturally resistant to ambient UV, printable without pre-treatment, stable and storable, recyclable, biodegradable and environmentally safe. Hydropol™ can be processed into a single layer or co-ex film, a laminate or extrusion coating, a barrier layer, or made into fibres and nonwovens. Hydropol™ is compatible with other biopolymers to form completely new biomaterials with new functionality and multi-end of life options. The thermal stability and properties of Hydropol™ enable its use in other polymer processes such as injection moulding, blow moulding and thermoforming.

State of implementation

PILOT

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment, understand the combined effect of multiple substances within a product-packaging system, and ensure materials can be recycled safely.
- Regulatory approaches, such as bans or restrictions, on the manufacture, use, distribution, sale, or trade of SUPPs.
- Develop product policies that focus on high quality design for durable goods and packaging (emphasis on recyclability and reusability).

Non-toxic, marine-safe, and soluble in warm or hot water barrier films

Technical enablers

- Develop internationally harmonized product labels, tags, and digital passports to inform all actors across the value chain of material content, waste management options, product's carbon, and environmental footprint.
- Collaboration and international harmonisation established across the value chain and among sectors to ensure that the synergies and trade-offs between upstream design policies, chemical legislation, and waste classification legislation, especially as material innovations occur, and legacy materials are dealt with. Aquapak follows national and international protocols appropriate to the testing of new materials and works closely with end users, converters, designers, and NGOs to ensure compliance. In addition, Aquapak is working in several projects with global brands, major converters and waste and recyclers to demonstrate the recycling, recovery solutions at scale, biodegradability in various environments.
- A simplification of the tests and standards might help assess the circularity of new materials, their safety for humans and the environment, and their appropriateness as alternatives to conventional plastics.

Market and financial enablers

- Early-stage public funding to establish proof-of-concept to further private investments in circular innovations.
- Blended finance solutions to close the investment gap for harder-to-finance infrastructure and riskier, long-term innovation.
- Economic and fiscal measures aligned with circular economy outcomes (e.g., research and development (R&D) tax credits).
- Eco-modulated fees EPR to create incentives for producers to adopt circular designs and business models, data and transparency insights into material flows, and coordination and harmonisation between schemes.
- Use Green Public Procurement to create market demand and showcase solutions, by creating standards and defining circular requirements for goods purchased by public bodies, as well as purchasing locally where appropriate.

Challenges

Aquapak's products are undergoing technical and commercial trials in a range of applications (Film, Laminates, Extrusion coating, Thermoforming, Injection Moulding) where the packaging market has major challenges in delivering functionality and a true CE solution. However, there are over 600 standards and tests for plastics globally. In the assessment of the behaviour of plastics in the natural environment many test methods and standards have been found to be unsuitable as they do not reflect the true behaviour of the plastic. An additional complication with Aquapak is that the hydrophilic nature of the material and the fact that in certain situations the material dissolves in water presents further challenges to the existing protocols. Test results are included in a White Paper available online, as well as updated and added to the latest versions of technical data sheets.

Opportunities/ Benefits

Hydropol™ formulation technology enhances the quality and functionality of end products. Its material properties allow for scalability into diverse types of products. As an enabling technology, Hydropol™ can be used on its own or in combination with other materials to enhance the recyclability, compostability and end-of-life options.

Replicability
Low, Medium, High

The practice requires a high level of technological advancement, market preparedness, or specific economic/political conditions to be successfully replicated.

LOW

Non-toxic, marine-safe, and soluble in warm or hot water barrier films

Geographical area of implementation	Europe
Country	UK
Contacts	Aquapak is a UK-based science-led business with over 10 years Research and Development in polyvinyl alcohol (PVOH) resin technology. Aquapak has formed R&D collaborations with a number of major plastics and bioplastics producers to create new materials and innovative combinations of Hydropol™ with well-established plastics and paper, with packaging manufacturers for the major brands and retailers, with DS Smith to develop sustainable and recyclable packaging solutions to replace single-use, hard-to-recycle plastic using Hydropol™ polymer, and a number of universities, who have proven leading expertise in technical environmental polymers.
For more information	**https://www.aquapakpolymers.com/hydropol/**
Similar case studies	EcoFLEXY by Cellugy - **https://www.cellugy.com/ecoflexy** - Denmark

SAFE AND CIRCULAR ALTERNATIVE MATERIALS

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: MEDIUM

Name of the practice

Microfibrillated Cellulose (MFC)

Target plastic product	**Food contact primary packaging**
Examples	**Fast-food packaging, take-away packaging** **Milk cartons, juice cartons and other liquid packaging** **Food packaging** **Candy and snacks packaging** **Barrier films**
Application	**Food and Beverage Manufacturing / Brand owners** **Retailers** **Hospitality and hotel, restaurant, and catering sector (HORECA)**

Plastic materials/ Polymer types in the original product

Multi-material multilayer plastic packaging (MMPP) are made of distinct layers of heteropolymers such as polyolefins and polyesters, with each layer selected to contribute a corresponding property advantage to the bulk material, depending on the application, such as polyethylene (PE) as a moisture barrier, ethylene vinyl alcohol (EVOH) as an oxygen barrier, and polyethylene terephthalate (PET) as an effective gas and moisture barrier that imparts rigidness and strength.

Aluminium foils or paper are also used.

Name and type of the substances of concern in the original product

- Phthalates as plasticisers
- Oleamide, erucamide, and stearamide as slip additives

Abstract

Microfibrillated Cellulose (MFC) is a natural material obtained by fibrillating cellulose fibres longitudinally, and thus obtaining a three-dimensional network of cellulose microfibrils that has a much higher surface area than regular cellulose fibres or powdered cellulose. Microfibrils in MFC have diameters in nanometres and lengths in micrometres, which makes them long and thin. This high aspect ratio makes the material high strength useful in applications such as reinforcements for composites, films, and barriers. When added to the paper making process, MFC can produce a wide range of benefits including increased tensile strength, improved barrier properties, smoother surfaces, leverage renewable materials, reduced reliance on the costly sourcing of virgin fibres. MFC is currently manufactured from a few different cellulosic sources. Wood is obviously the most important industrial source of cellulosic fibres and is thus the main raw material used to produce MFC. Depending upon the source of the cellulose and the method of production, MFC displays similar morphologies but various dimensions. MFC offers one of the most promising prospects, in the form of MFC films, MFC nanocomposites, and paper coating.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment, understand the combined effect of multiple substances within a product-packaging system, and ensure materials can be recycled safely.
- Regulatory approaches, such as bans or restrictions, on the manufacture, use, distribution, sale, or trade of SUPPs.
- Develop product policies that focus on high quality design for durable goods and packaging (emphasis on recyclability and reusability).
- Policies that help develop secondary material and by-product markets.

Technical enablers

- Develop internationally harmonized product labels, tags, and digital passports to inform all actors across the value chain of material content, waste management options, product's carbon, and environmental footprint.
- MFC's mode of production has completely changed over the years. New sources, new mechanical processes, and new pre-and post-treatments are currently under development to enable the use of MFC materials on an industrial scale.

Market and financial enablers

- Early-stage public funding to establish proof-of-concept to further private investments in circular innovations.
- Blended finance solutions to close the investment gap for harder-to-finance infrastructure and riskier, long-term innovation.
- Economic and fiscal measures aligned with circular economy outcomes (e.g., research and development (R&D) tax credits).
- Eco-modulated fees EPR to create incentives for producers to adopt circular designs and business models, data and transparency insights into material flows, and coordination and harmonisation between schemes.
- Use Green Public Procurement to create market demand and showcase solutions, by creating standards and defining circular requirements for goods purchased by public bodies, as well as purchasing locally where appropriate.
- The MFC market is expected to grow due to increased usage in end-use applications like paper and packaging industry coupled with growing investments by government agencies.

Challenges

Although wood-driven nanocellulose was first produced in 1983, its commercial production was postponed till 2010, mainly due to the high production energy consumption and high production cost.

Opportunities/ Benefits

MFC has been present in the academic sector since the 1980's, but the interest for this material has been growing significantly as sustainable packaging material only recently, as its production is becoming economically convenient and commercially available. MFC does not contain fossil-fuel-based polymers or additives. It is a 100 percent biodegradable packaging material, sourced from a renewable resource. It can be extracted from plant waste thus providing a good competitive price point. It preserves the flavour or scent of food, provides an excellent oxygen and grease barrier. It improves wet-and dry strength in paper and multilayer packaging. MFC can be used in the form of film, nanocomposites, and paper coatings.

The MFC fibres can give a material that is stronger and stiffer than glass or carbon fibre and more lightweight at the same time. It can strengthen and lighten fibre materials sustainably, obtaining products with reduced material use but with the same performance.

Replicability Low, Medium, High	The practice requires certain specific requirements to be successfully replicated.	**MEDIUM**

Geographical area of implementation	Europe
Country	UK
Contacts	The UK-based FiberLean® Technologies is a world leading producer of MFC.
For more information	**https://www.fiberlean.com/packaging-solutions/**
Similar case studies	Valmet - **https://www.valmet.com/board-and-paper/stock-preparation/micro-fibrillated-cellulose/** - Finland WEIDMANN Fiber Technology - **https://weidmannfibertechnology.com/products/** - Germany Storaenso - **https://www.storaenso.com/en/products/biobased-materials/MFC-for-packaging** - Finland

SAFE AND CIRCULAR ALTERNATIVE MATERIALS

IMPLEMENTATION: START UP

REPLICABILITY: MEDIUM

Name of the practice

A vegan and compostable packaging material

Target plastic product	**Primary packaging**
Examples	**Plastic bottles and containers**
Application	**Healthcare & Pharmaceutical** **Brand owners** **Retailers**

Plastic materials/ Polymer types in the original product

High-density polyethylene (HDPE)
Low-density polyethylene (LDPE) for squeeze applications
Polyethylene terephthalate (PET)
Polycarbonate (PC)
Polypropylene (PP)
Polystyrene (PS)

Abstract

Vivomer is a completely vegan and compostable material, created by bacteria through fermentation processes. Vivomer is made of Chitosan – a derived from a natural substance called chitin that is found in many animals, particularly the shells of crustaceans. Vivomer products do not leave behind any microplastics and instead, once discarded, microbes found in soil and marine environments view it as a source of food and consume the material. Vivomer is produced by **Shellworks** by extracting chitin from seafood waste, a renewable feedstock. Formulated to suit personal care applications, Vivomer is shelf-stable in storage and is compatible with both water-based and oil-based emulsions.

State of implementation

START UP

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment, understand the combined effect of multiple substances within a product-packaging system, and ensure materials can be recycled safely.
- Regulatory approaches, such as bans or restrictions, on the manufacture, use, distribution, sale, or trade of SUPPs.
- Develop product policies that focus on high quality design for durable goods and packaging (emphasis on recyclability and reusability).
- Policies that help develop secondary material and by-product markets.

Technical enablers

- Introduce harmonized criteria, standard and certification on biodegradability and compostability.
- Incorporate CE principles in higher education curricula, training programmes and apprenticeships.
- Establish collaboration and international harmonisation between the public and private sectors to ensure synergies and trade-offs between upstream design policies, chemical legislation, and waste legislation.
- International standards and policies on imports and exports of materials for recycling and resource management.
- Innovation awards and challenges. The Shellworks are winners of the Venture Catalyst Challenge 2019.

Market and financial enablers

- Market-based policies to support the growth of circular resource management loops (e.g., the use of secondary raw materials, including recyclate and organic by-products).
- Fiscal measures (e.g., research and development (R&D) tax credits) and economic incentives supporting design and uptake of eco-friendly alternatives to SUPPs.
- Taxing non-renewable resources rather than labour (with adequate safeguards to avoid regressive effects on vulnerable groups) to support innovation and growth in circular economy practices.
- Early-stage public funding to establish proof-of-concept is important for spurring further private investments in circular innovations.
- Blended finance solutions (including technical assistance, risk underwriting, and market incentives such as match-funding) can close the investment gap for harder-to-finance infrastructure and riskier, long-term innovation, by using development capital to mitigate investor risks.
- Match-fund or (co-)invest directly in physical infrastructure that will work both for the economies of scale as well as dispersed and local solutions for the CE, and in digital infrastructure that enhances connectivity and data sharing, to test concepts and services, improve planning and decision-making, and coordinate research on technologies to solve emerging and complex challenges.
- Use Green Public Procurement (GPP) to create market demand and showcase solutions, by creating standards and defining circular requirements for goods purchased by public bodies, as well as purchasing locally where appropriate.

Challenges

Significant barriers are price sensitivity, encouraging consumer engagement, and the availability of more affordable and mass-produced materials. In addition, while Vivomer degrades in the environment, if it is made into a large product, it can take up to 5 years to completely dissolve.

Opportunities/ Benefits

Chitin offers an exciting new solution for the next generation of biobased plastics because it is abundant. After cellulose, it is the most common biopolymer in the world. Apart from seashells, they are found in insect exoskeletons and the cell wall of fungi. There are various kinds of chitin that differ in their mechanical properties depending on their natural source and how it is purified. Importantly, chitin can easily be broken down by the enzymes found in fungi, bacteria, archaea, rotifers, and algae. Natural carbon and nitrogen cycles easily absorb the by-products.

Research into chitin and chitosan has been ongoing for several decades but the material has not been commercialised until recently. The scale of production is still small, but the market for this biopolymer is primed for growth. Applications for this versatile material do not end at packaging. It has been made into powders, fibres, films, beads, sponges, gels, and solutions. Already, it is used in wound treatment for its antimicrobial and haemostatic properties.

Replicability
Low, Medium, High

The practice requires certain specific requirements to be successfully replicated.

MEDIUM

Geographical area of implementation

Europe

Country

UK

Contacts

The Shellworks provides end-to-end material formulation to product manufacturing, for companies seeking sustainable, scalable solutions.
hello@theshellworks.com

For more information

SAFE AND CIRCULAR ALTERNATIVE MATERIALS

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: MEDIUM

Name of the practice

Moulded fibre/pulp packaging

Target plastic product	**Secondary packaging**
Examples	**Clamshells, containers, end caps and edge protectors, trays and tray inserts, candle packs, wine shippers, coolers**
Application	**Consumer Goods / Lifestyle** **Healthcare & Pharmaceutical** **Food and Beverage Manufacturing / Brand owners** **Retailers** **Wholesale trade** **Transportation and Warehousing**

Plastic materials/ Polymer types in the original product

Expanded polystyrene (EPS)

Name and type of the substances of concern in the original product

- Styrene and benzene

Abstract

Moulded fibre packaging is made by repurposing fibrous materials, particularly natural fibres (wheat straw, bamboo, sugarcane), as well as recycled papers and cardboard. Packaging's strength, surface roughness, and even colour is all determined in part by the source materials. In contrast to cardboard boxes, the packaging is formed from the very beginning of the production process. Its design incorporates complicated 3D elements as well as rounded edges. Because of technical developments, the finished moulded pulp products now have a more sophisticated appearance, feel, and a smoother surface. Moulded fibre packaging can be re-used for up to 7 times. After it has served its purpose, it can be recycled. The moulded pulp, in contrast to EPS and plastic packaging, is biodegradable in the environment. Moulded technology can replace formed plastics in tray, tub, and even potentially, bottle formats.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment, understand the combined effect of multiple substances within a product-packaging system, and ensure materials can be recycled safely.
- Bans or restrictions on the use of polystyrene single-use products (e.g., in nearly a dozen cities in the USA).
- Binding quantitative recycling targets.

Technical enablers

Several technological advancements have led to superior techniques producing, printing, and coating moulded fibre pulp products:

- The use of biobased coatings is used for paper-based packaging, as it helps to keep up with sustainability objectives while also enhancing moisture resistance and printability.
- Impulse drying has helped reduce the overall cost of manufacturing and energy consumption. The use of such advanced techniques is a noteworthy trend aiding expansion of the moulded fibre pulp packaging market.
- The use of 3D printed mould tooling also has helped not only reduce the cost of operations, but also reduce the procurement timeframe significantly. In addition to this, manufacturers are also using virtual representation techniques to create prototypes of packaging solutions.
- Innovation awards, prizes, challenges can also contribute to identify alternatives to EPS packaging.

Market and financial enablers

- Growing emphasis on sustainable development and stringent regulations by food and beverage and consumer goods manufacturers is expected to drive the growth of the global moulded fibre packaging market.
- Owing to inexpensive labour costs, the availability of domestically produced raw materials, and the changing lifestyle and expanded annual disposable income of customers are also improving their preferences for sustainability, Asia Pacific is predicted to be the quickest growing region in the moulded fibre packaging market, in terms of utility.

Challenges

Moulded fibre packaging cannot be used if the product cannot be exposed to fibre particles, and in an environment that is susceptible to electrostatic discharge (ESD). Another main challenge is to develop moulded fibre forming lines that can match the speed of existing thermoformed plastics.

Opportunities/ Benefits

Moulded fibre packaging is not a new product despite the numerous innovations that are happening. They have been around for over a century in retail stores, such as fast-food carriers, grocery store egg cartons, and many more. Moulded fibre/pulp packaging is durable in wet and high-temperature conditions; it has superior vibration absorption capacity; it provides resealing and re-usability characteristics; it nests and stacks easily, enhancing use efficiency in shipping and storage space; it comes ready to use with no assembly needed, reducing labour required for packaging end products; it is cost efficient and can be domestically produced, simplifying what are typically complex import logistics systems, reducing risk in the supply chain, and reducing the carbon footprint. It is exempt to packaging penalties as with polystyrene in many countries and has zero or negligible disposable costs. As technology improves moulded fibre is going to find more applications. Igloo, for example, recently expanded moulded fibre into the sports and outdoors market with a moulded fibre cooler. The product is high-performing and completely compostable and recyclable.

Replicability
Low, Medium, High

The practice requires certain specific requirements to be successfully replicated.

MEDIUM

Geographical area of implementation	North America
Country	USA
Contacts	UFP Technologies is a leading designer and manufacturer of moulded pulp/moulded fibre packaging solutions made from 100 percent recycled paper. **info@moldedfiber.com**
For more information	**https://www.moldedfiber.com/eps-alternative.html**
Similar case studies	Huhtamaki Group - **https://www.huhtamaki.com** - Finland Copulas - **https://ecopulpack.co/** - Colombia PulPack - **https://www.pulpac.com/** - Sweden

SAFE AND CIRCULAR ALTERNATIVE MATERIALS

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: MEDIUM

Name of the practice

Plastic-free packaging solutions made of mycelium

Target plastic product	**Secondary packaging**
Examples	**Insulated plastic foam packaging**
Application	**Consumer Goods / Lifestyle** **Healthcare & Pharmaceutical** **Agriculture & Fisheries** **Food and Beverage Manufacturing / Brand owners** **Wholesale trade** **Retailers** **Transportation and Warehousing** **Hospitality and hotel, restaurant, and catering (HORECA) sector**
Plastic materials/ Polymer types in the original product	Expanded polystyrene (EPS) Polyethylene (PE) Foam Extruded Polystyrene (XPS) Foam
Name and type of the substances of concern in the original product	• Styrene and benzene

Abstract

Mushroom® Packaging produces a high-performing packaging material by mixing mycelium with agricultural by-products from hemp, corn, wheat, and timber production, as well as sawdust. Mycelium is the root-like structures. Mycelium itself is made of chitin, a natural glue that is water resistant and flame retardant.

Once the agricultural waste is mixed with the mycelium hyphae, the mixture is put in moulds of any desired capacity and placed in the dark, where the mycelium grows for about a week as the fungi feeds on the agricultural waste. As it moves through the mixture, the fungi form a network of tiny white fibres throughout the substrate. This eventually fills all the available space and forms a solid structure: the mycelium foam. The foam is then removed from the mould and dried to stop the mycelium from growing and producing mushrooms or spores. From here, the foam can be used as packaging material or further fabricated to make everything from handbags to faux-leather jackets.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment, understand the combined effect of multiple substances within a product-packaging system, and ensure materials can be recycled safely.
- Regulatory approaches, such as bans or restrictions, on the manufacture, use, distribution, sale, or trade of SUPPs.

Plastic-free packaging solutions made of mycelium

Technical enablers

- Incorporate CE principles in higher education curricula, training programmes and apprenticeships.
- Establish collaboration and international harmonisation between the public and private sectors to ensure synergies and trade-offs between upstream design policies, chemical legislation, and waste legislation.
- Research funds and programs such as the EU Research and Technological Development framework programmes.

Market and financial enablers

- Market-based policies to support the growth of circular resource management loops (e.g., the use of secondary raw materials, including recyclate and organic by-products).
- Fiscal measures (e.g., research and development (R&D) tax credits) and economic incentives supporting design and uptake of eco-friendly alternatives to SUPPs.
- Taxing non-renewable resources rather than labour (with adequate safeguards to avoid regressive effects on vulnerable groups) to support innovation and growth in circular economy practices.
- Early-stage public funding to establish proof-of-concept is important for spurring further private investments in circular innovations.
- Blended finance solutions.
- Increase government initiatives to innovate mycelium-based products and packaging solutions to drive the growth of the Mycelium industry. North America is anticipated to be the major contributor to the mycelium market in coming years, followed by Europe, due to the high demand for mycelium-based food products and the increasing efforts of companies for developing mycelium materials. The European Structural and Investment Funds and the Eco-Innovation Initiative, and others, can help support circular innovations such as the mycelium packaging.

Challenges

Mycelium packaging is not 100 percent waterproof: if stored in wet areas, the mycelium can lose its strength, other fungi might grow on the mycelium and start to degrade it. The material is not recommended for direct food and beverage contact.

Opportunities/ Benefits

Mycelium is lightweight, easy to mould, easy to produce, cost-competitive with polystyrene foam. Mycelium foam is strong but breaks down naturally in the ground without any help from industrial composting facilities. It is also flame resistant. In certain countries, mycelium packaging avoids the plastic packaging tax.

Replicability Low, Medium, High — The practice requires certain specific requirements to be successfully replicated. **MEDIUM**

Geographical area of implementation

Global

Country

Global

Contacts

The Magical Mushroom Company produces Mushroom® Packaging that is entirely home compostable. It uses packaging developed by Ecovative Design. Ecovative has licensed its mycelium growing technology for worldwide manufacture. Today there are 4 producers worldwide in the USA, UK, New Zealand, and the Netherlands. IKEA and Dell companies have recently entered a partnership to use the material in their packaging to replace polystyrene.
hello@magicalmashroom.com

For more information

https://www.magicalmushroom.com/

Similar case studies

Radialbio - **https://radialbio.com/** - Mexico
GrownBio - **https://www.grown.bio/** - The Netherlands

SAFE AND CIRCULAR ALTERNATIVE MATERIALS

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: LOW

Name of the practice

A circular paper alternative to plastic pallet wrapping

Target plastic product	**Secondary packaging**
Examples	**Plastic stretch film**
Application	**Healthcare & Pharmaceutical** **Food and Beverage Manufacturing / Brand owners** **Retailers** **Wholesale trade** **Transportation and Warehousing**

Plastic materials/ Polymer types in the original product

Polyethylene (PE)
Polyvinyl Chloride (PVC)
Polypropylene (PP)

Name and type of the substances of concern in the original product

- Bisphenols
- Phthalates
- Contaminants: heavy metals

Abstract

Mondi's kraft paper **Advantage StretchWrap** is made with sustainably sourced Nordic fibres, famous for their strength and quality. The paper is made with 100 percent fresh fibres, and it can be recycled at the end of its life. It can be used for wrapping homogeneous filled pallets with flat sides and no sharp corners, such as pallets packed with PET water bottle multipacks, PET soda bottle multipacks, baby food jars, food jars, boxed goods, empty loose paper bags or packed in boxes.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Regulatory approaches, such as bans or restrictions, on the manufacture, use, distribution, sale, or trade of SUPPs.
- Develop and harmonise collection and sorting policies (such as separate collection and management of materials), leading to the value retention of high-quality materials and products and enabling higher value organic loops as well as regenerative practices through nutrient cycling.

Technical enablers

- Cooperation across value chain. Mondi has partnered with ACMI, an Italian machine producer that offers bottling and packaging solutions, to develop a highly performing wrapping machine for Mondi's wrapping paper. Due to the SCARA robotic technology designed by ACMI, the machine replaces the existing film wrappers in the market without any issue, which is a concern of plant and operation managers.

Market and financial enablers

- Use Green Public Procurement (GPP) to grow sustainable products markets.
- Align taxation and fee incentives, such as EPR, with circular economy outcomes.
- Market based measures such as waste disposal fees or charges, or taxes aimed at reducing SUPPs as a category of waste, managing plastic waste, or increasing the rate of postconsumer recovery or recycling, or other environmental and CE initiatives.
- Plastic tax over non-recycled plastic (in EU, this tax is active since January 2021).
- Strengthening resource loops through Extended Producer Responsibility (EPR) policies and Deposit Return Systems (DRS) to support circular opportunities from reuse to recycling.

Opportunities/ Benefits

The recyclable paper has an outstanding stretch and high-tensile strength, even in the low grammage of 70 gsm, making it a reliable lightweight wrapping solution for products transported on pallets. It has been tested and passed the compression holding force test according to EUMOS standard, which means that the pallets can be safely transported. The paper is made with 100 percent responsibly sourced fibre and without any coating. Mondi commissioned an independent life cycle assessment (LCA) comparing the Advantage StretchWrap paper to conventional plastic stretch film. The ISO-based approach showed that the paper pallet packaging performs better in several environmental impact categories including climate change.

Replicability
Low, Medium, High

The practice requires a high level of technological advancement, market preparedness, or specific economic/political conditions to be successfully replicated.

LOW

Geographical area of implementation

Global

Country

Global

Contacts

Mondi is a global leader in packaging and paper. The business is integrated across the value chain, from managing forests and producing pulp, paper, and plastic films, to developing and manufacturing effective industrial and consumer packaging solutions.

For more information

https://www.mondigroup.com/en/products-and-solutions/speciality-kraft-paper/speciality-kraft-paper-products/advantage-stretchwrap/

SAFE AND CIRCULAR ALTERNATIVE MATERIALS

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: HIGH

Name of the practice

Bubble wrap made of paper

Target plastic product	**Secondary packaging**
Examples	**Bubble-wrap, tape, and foamed materials**
Application	**Consumer Goods / Lifestyle** **Healthcare & Pharmaceutical** **Food and Beverage Manufacturing / Brand owners** **Retailers** **Wholesale trade** **Transportation and Warehousing**

Plastic materials/ Polymer types in the original product

Polyethylene (LDPE) film
Polymeric foams based on polyurethane (PUR) polystyrene (PS), polyvinylchloride (PVC), polyethylene (PE) and several elastomers such as ABS, natural rubber, and silicone

Name and type of the substances of concern in the original product

- Bisphenols
- Phthalates
- Contaminants: heavy metals

Abstract

Flexi-Hex® is a honeycomb-design, flexible cardboard used as an alternative to bubble-wrap, tape, and foamed materials. It is plastic-free, made from 85 percent recycled paper and 15 percent FSC certified paper and has a minimal amount of printed surface. It is fully recyclable and compostable. The PVA adhesive is non-toxic and under the right conditions will biodegrade in 6 weeks. The product itself can be reused up to 5 times. The Flexi-Hex Air is a lighter sleeve made from tissue paper ideal for protecting smaller fragile goods like cosmetics and electronics.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Regulatory approaches, such as bans or restrictions, on the manufacture, use, distribution, sale, or trade of SUPPs.
- Develop product policies that focus on high quality design for durable goods and packaging (emphasis on recyclability and reusability).
- Recycling mandates, with or without recycling targets.

Technical enablers

- Innovation awards and incentives for eco-innovation can support the identification of safe and circular materials that can be used as alternatives to SUPPs.
- Life-Cycle Assessments (LCA) or alternative assessments should be performed to assess the potential environmental impacts of the alternative (non-plastic) material before promoting it.
- Develop standards to support trade in circular economy goods, services, and systems.

- Introduce harmonized criteria, standard and certification on biodegradability and compostability.
- Develop and harmonise collection and sorting policies (such as separate collection and management of materials), leading to the value retention of high-quality materials and products and enabling higher value organic loops as well as regenerative practices through nutrient cycling.
- Product innovations to enhance the efficiency of the product and to produce visually appealing variants.

Market and financial enablers

- Align market-based measures such as waste disposal fees or charges, taxes aimed at reducing SUPPs as a category of waste, or EPR, with circular economy outcomes.
- Use Green Public Procurement (GPP) to grow sustainable products markets.
- The growing retail and e-commerce industries, along with the growing demand for environment-friendly packaging products, currently represent as the key factors driving the growth of the paper packaging market. With the rapid increase in the number of online shopping platforms, the requirement for secondary and tertiary paper packaging products has escalated significantly.

Challenges

Flexi-hex ships products across 5 different territories from the manufacturing centre in China, using ships and lorries, avoiding the high-emission airfreight option. However, distribution accounts for most of its carbon emissions. This is a key area for improvement, and they are working with partners to find low-emission solutions to make the distribution as efficient and low-impact as possible. For the time being, the carbon footprint related to operations and staff is offset through the partnership with Mossy Earth.

Opportunities/ Benefits

Flexi-Hex breaks down and biodegrades readily and is made of recycled material, which has a lower carbon footprint than using virgin cardboard. The compact nature makes Flexi-Hex cost effective to ship and transport as well as saving space within dispatch warehouses. Flexi-Hex packaging solutions are protected by patents; however, similar technical innovations can be spurred through training, exchanges, guidelines (such as the MacArthur and IDEO guides, etc.).

Replicability Low, Medium, High	The practice can be easily replicated in similar economic, technological, and political settings.	**HIGH**

Geographical area of implementation

Europe

Country

UK

Contacts

Flexi-Hex started in 2018. The following year it was awarded the first patent in the UK, a government grant from Innovate UK and received an investment from Sky Ocean Ventures. Today Flexi-Hex is a global producer of protective transport packaging.
sales@flexi-hex.com

For more information

https://www.flexi-hex.com/

Similar case studies

Ranpak's Geami GreenWrap - **https://www.ranpak.com/products/geami-wrap-pak-ex/** - USA

SAFE AND CIRCULAR ALTERNATIVE MATERIALS

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: HIGH

Name of the practice

Bubble wrap made of sheep wool leftover

Target plastic product	**Secondary packaging**
Examples	**Bubble wrap**
Application	**Consumer Goods / Lifestyle** **Healthcare & Pharmaceutical** **Food and Beverage Manufacturing / Brand owners** **Retailers** **Hospitality and hotel, restaurant, and catering (HORECA) sector**

Plastic materials/ Polymer types in the original product

Polyethylene (PE)
Low-density polyethylene (LDPE)

Name and type of the substances of concern in the original product

- Bisphenols
- Phthalates

Abstract

Woola Envelope is made of a protective packaging (bubble wool, wool envelope, and bottle sleeve) from leftover wool, a biobased binder and recycled paper, which are all biodegradable materials. The wool is washed, but no chemicals are used to remove the natural scent. A biobased biodegradable binder is then used to turn raw wool into a Woola packaging. Even if they end up in nature or in landfill, Woola packaging will eventually break down into biomass, CO2, and water, without leaving any microplastics behind. The time frame depends on the conditions of the environment (temperature, moisture and oxygen levels, microbes): it can be from some months to some years.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment, understand the combined effect of multiple substances within a product-packaging system, and ensure materials can be recycled safely.
- Bans or restrictions on the manufacture, use, distribution, sale, or trade of SUPPs.
- Develop product policies that focus on high quality design for durable goods and packaging (emphasis on recyclability).
- Implement spatial planning policies to enhance material flow and use and creating business opportunities such as industrial symbiosis.

Bubble wrap made of sheep wool leftover

Technical enablers

- Incorporate CE principles in higher education curricula, training programmes and apprenticeships.
- Promote the establishment and adoption of multi-stakeholder, cross-value-chain, inclusive and responsive working mechanisms to develop system solutions and to build public private capacity.
- Establish collaboration and international harmonisation between the public and private sectors to ensure synergies and trade-offs between upstream design policies, chemical legislation, and waste legislation.
- Pass information about chemical ingredients along the local and global value chains to ensure products and materials are safely managed. This will require joint efforts with business as well as investments in technology.
- Develop internationally harmonized product labels, tags, and digital passports to inform all actors across the value chain of material content, waste management options, product's carbon, and environmental footprint.
- Develop standards to support trade in circular economy goods, services, and systems.
- Introduce harmonized criteria, standard and certification on biodegradability and compostability.
- Develop and harmonise collection and sorting policies (such as separate collection and management of materials), leading to the value retention of high-quality materials and products and enabling higher value organic loops as well as regenerative practices through nutrient cycling.
- Establish a fair industrial-scale leftover wool supply chain. Currently, 90 percent of the wool waste is either buried or burnt: an accessible return system for Woola products should be established to keep the wool material in the production loop.
- Life-Cycle Assessments (LCA) or alternative assessments should be performed to assess the potential environmental impacts of the alternative (non-plastic) material before promoting it.
- Product standards, certification, and labelling requirements can be designed to target sustainable alternatives to SUPPs. Companies should support any projects that help maintain and improve the company's sustainability credentials, such as certifications and accreditations.

Market and financial enablers

- Align market-based measures such as waste disposal fees or charges, taxes aimed at reducing SUPPs as a category of waste, or EPR, with circular economy outcomes.
- Use Green Public Procurement (GPP) to grow sustainable products markets.
- Offer early-stage venture funding.
- Support blended finance solutions for physical and digital infrastructure, and innovation.
- Business Partnerships to help establish closed-loop systems for recyclable biobased alternatives to SUPPs.
- Provide interdisciplinary research funds.
- Green consumers whose purchasing behaviour, such as the preference for quality, authenticity, and transparency, is driving the market for wool. Several measures undertaken by the International Wool Textile Organization (IWTO), a regulating authority for wool quality and traceability, are fetching a higher price for the wool, thus encouraging production.

Challenges

To make the supply chain fully transparent and lower the transport emissions, Woola is now working on a new supply plan that involves sourcing wool directly from local farmers in Estonia. This will allow them to choose the partners sharing the same values, especially when it comes to prioritising animal welfare. Woola is aiming to make the supply chain fully local and transparent by the end of 2021.

Opportunities/ Benefits

Scrap wool, which would otherwise be burned or buried, is largely available in many countries across the world and makes the perfect material for e-commerce packaging. In Europe alone, more than 200,000 tonnes of wool are thrown away yearly. According to Woola, this is enough to fulfil 120 percent of the global bubble wrap demand, which is now dominating the e-commerce packaging industry. Wool is a naturally high-tech fibre. Its elasticity, water repellence, and resistance to temperature extremes make it a perfect material for packing items that need extra cushioning. Packaging made of wool is durable and can be reused multiple times.

Replicability
Low, Medium, High

The practice can be easily replicated in similar economic, technological, and political settings.

HIGH

Geographical area of implementation

Europe

Country

Estonia

Contacts

Woola is an Estonian start-up that produces bubble wrap made from leftover sheep's wool. Woola's mission is to reduce the amount of plastic waste that comes from e-commerce and therefore reduce its impact on the environment. Woola opened a production facility in Estonia and launched its first product in December 2020. It's now expanding to the U.K., France, and Germany.

For more information

https://www.woola.io/

SUBSTITUTION OF HAZARDOUS SUBSTANCES

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: LOW

Name of the practice

Bio-based food grade anti-fog and anti-stats additives

Target plastic product	**Food contact primary packaging**
Examples	**Foams, films, injection moulding packaging**
Application	**Recyclers, compounders, and converters**

Plastic materials/ Polymer types in the original product

Polyethylene (PE)
Polypropylene (PP)
Polyvinyl chloride (PVC)

Name and type of the substances of concern in the original product

- Surfactants

Abstract

Palsgaard offers a portfolio of renewable, food-grade, anti-fog, and anti-stats additives (i.e., surfactants used to reduce fogging and the accumulation of static electricity on plastic packaging material) branded as **Einar®**. These additives are derived from polyglycerol esters, monoglycerides and other vegetable sources (e.g., sunflower oil, rapeseed oil and RSPO-certified palm oils), providing alternatives to fossil-based additives without compromising mechanical or barrier properties. The portfolio comprises migratory solutions tailored to polyethylene, polypropylene, ethylene-vinyl acetate, and polyvinyl chloride packaging films. The additives are available in pellet, paste and liquid form, ideal for dust-free blending in film extrusion compounds and masterbatches.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Develop and align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment and enable a circular plastic economy.
- Collaboration and international harmonisation between the public and private sectors to ensure synergies and trade-offs between upstream design policies, chemical legislation, and waste classification legislation, especially as material innovations occur.
- Agriculture policies encouraging regenerative productions.

Technical enablers

- Internationally harmonized product labels, tags, and digital passports to inform product users of material content, durability, upgradeability, reuse, repair, and recycling options, and to provide information on a product's carbon and environmental footprint, as well as other actors across the value chain on how to manage them.
- Enhance Research and Development (R&D) and inter-and intra-sectorial cooperation. Palsgaard's independently operated Nexus R&D resource runs research activities that extend to investigations in completely new raw materials and technologies, such as algae and natural nanoparticles, seeking answers to practical issues. Innovations can then be tested in the company's Polymer Application Centre - a state-of-the art resource for product development and

customer project support. The Centre is fully equipped for meticulous testing and validation to make the transition of sustainable plant-based technology into successful additive solutions as flawless as possible. It offers realistic industrial pilot testing of new or modified polymer formulations, which can significantly facilitate the proper upscaling and time-to market of innovative, sustainable applications with plant-based additives.

- CE principles integrated in school and higher education curricula, and training programmes and apprenticeships geared towards CE.
- Public and private cooperation in support to the development and use of voluntary and mandatory standards and certificates to create confidence and trust in CE products, materials, services, and systems.

Market and financial enablers

- Subsidies reformed and/or aligning with CE principles, by phasing in regenerative criteria as a qualification or by repurposing subsidies to compensate farmers for ecosystem services.
- Fiscal measures (e.g., research and development tax credits) and economic incentives supporting design and uptake of eco-friendly alternatives to SUPPs.
- Interdisciplinary research funds and early-stage venture funding.
- Blended finance solutions provided for innovation.

Challenges

Palsgaard's Einar® series of functional additives is the result of years of R&D, cross sector cooperation and knowledge creation.

Opportunities/ Benefits

By being exclusively based on renewable plant sources, which are also widely used in food additives, Einar®'s additives are not governed by any migration limits and have full food-contact, kosher, and halal approvals. In addition, as they migrate and increase the surface tension of the film, they develop anti-fog/anti-static performance even at reduced concentrations, which maximizes their cost-efficiency.

Einar®'s additives are sold as 'dual use' plant-based additives with full FDA and EU food contact approvals. Produced in CO2-neutral factories, with 100 percent renewable content, they avoid fossil depletion, and by extending the shelf-life of packaged products they also contribute to the reduction of food losses.

Replicability
Low, Medium, High

The practice requires a high level of technological advancement, market preparedness, or specific economic/political conditions to be successfully replicated.

LOW

Geographical area of implementation

Europe | Asia

Country

Denmark | The Netherlands | Malaysia

Contacts

Palsgaard develops and explores the use of plant-based additives across multiple applications, ranging from food to cosmetics and polymer additives, helping producers to deliver quality products that meet stringent demands from regulatory bodies, customers, and consumers. It is present in more than 100 countries around the world
polymers@palsgaard.com | palsgaard.com/polymers

For more information

https://www.palsgaard.com/polymers/solutions/anti-fog-additives

SUBSTITUTION OF HAZARDOUS SUBSTANCES

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: HIGH

Name of the practice

Biobased Bisphenols and Phthalate-free plasticizers

Target plastic product	**Primary and Secondary packaging**
Examples	**Polycarbonate bottles** **Polyethylene-co-isosorbide terephthalate (PEIT) containers for food contact**
Application	**Converters and packaging manufacturers**

Plastic materials/ Polymer types in the original product

Polycarbonate (PC)
Polyethylene-co-isosorbide terephthalate (PEIT) for food contact

Name and type of the substances of concern in the original product

- Phthalates
- Bisphenols

Abstract

Isosorbide is a plant starch-derived bicyclic diol with rich functionality for a range of applications in the packaging, coating, adhesives, sealants, and automotive sectors. Starch from annually renewable feedstocks is hydrolysed to produce glucose, which is then converted to sorbitol and subsequently isosorbide by hydrogenation. **Roquette**, the world's leading manufacturer of isosorbide, has refined and optimised this manufacturing route to produce stable, high purity isosorbide in industrial quantities. The company produces isosorbide of three different grades, each tailored to specific industrial applications. **POLYSORB®** ID is a blend of diesters obtained from esterification of isosorbide with plant-based fatty acids. Phthalate-free and 100 percent biobased, POLYSORB® isosorbide offers the same level of performance as standard and general-purpose primary plasticizers for many applications. Thanks to its rigid structure, POLYSORB® isosorbide enhances the properties of polymers, such as polycarbonate, polyester, and polyurethane. When using POLYSORB® isosorbide the polymers become more resistant to temperature and have better mechanical and optical properties. Suitable for food contact packaging, heat resistant packaging and technical polymers.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Develop and align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment and enable a circular plastic economy.
- Collaboration and international harmonisation between the public and private sectors to ensure synergies and trade-offs between upstream design policies, chemical legislation, and waste classification legislation, especially as material innovations occur.
- Agriculture policies encouraging regenerative productions.

Technical enablers

- Internationally harmonized product labels, tags, and digital passports to inform product users of material content, durability, upgradeability, reuse, repair, and recycling options, and to provide information on a product's carbon and environmental footprint, as well as other actors across the value chain on how to manage them.
- Enhance R&D and inter-and intra-sectorial cooperation.
- CE principles integrated in school and higher education curricula, and training programmes and apprenticeships geared towards CE.

Market and financial enablers

- Fiscal measures (e.g., research and development tax credits) and economic incentives supporting design and uptake of eco-friendly alternatives to SUPPs.
- Interdisciplinary research funds and early-stage venture funding.
- Blended finance solutions provided for innovation.
- Rising environmental awareness among consumers, stringent regulations, and technological advancements are expected to have a positive impact on market growth of phthalate-and bisphenol-free plasticisers. Isosorbide has emerged as an attractive renewable feedstock for high-performance materials. Developments in the production scale and cost of isosorbide have further stimulated research interest. Step-growth polymerization of isosorbide has yielded polymers with excellent properties and applications ranging from packaging to automobile parts to biomedical devices. Demand for isosorbide is expected to increase for applications in polycarbonate and polyethylene isosorbide terephthalate (PEIT).

Challenges

Challenges associated with direct use of isosorbide in step-growth polymerization remain, demanding new synthetic strategies for producing tailored polymers from this building block.

Opportunities/ Benefits

Isosorbide is non-toxic, non-carcinogenic, non-endocrine disrupting, EU REACH compliant, and suitable for food contact and for the manufacture of cosmetics and pharmaceuticals. Risk assessment studies demonstrated that POLYSORB® isosorbide is nontoxic to mammalian life and is readily biodegradable,. Registered in accordance with chemical control laws in main plastic producing areas,

Replicability
Low, Medium, High

The practice can be easily replicated in similar economic, technological, and political settings.

HIGH

Geographical area of implementation

Europe

Country

France

Contacts

Roquette is a family-owned company that produces a variety of products from starch extracted from plant-based raw materials. Roquette's products include speciality pharmaceutical excipients and food ingredients, tailored to the pharma, nutrition, food, and selected industry markets.
https://www.roquette.com/industrial-markets-isosorbide-diester

For more information

https://www.roquette.com/media-center/resources/article-scientific-biobased-isosorbide-diester-readily-biodegradable-plasticizers

Similar case studies

SABIC - **https://www.sabic.com/en/news/6237-sabic-extends-its-impact-copolymers-with-the-new-phthalate-free-sabic-pp-flowpact-fpc70-grade-for-rigid-packaging** - Saudi Arabia

Comments

More information: **https://www.ondrugdelivery.com/introducing-isosorbide-a-sustainable-safe-high-performance-plant-based-feedstock-for-packaging/**

DESIGN FOR REUSABILITY

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: HIGH

Name of the practice

Bring Your Own (BYO) reusable/refillable bags or containers website and campaign

Target plastic product	**Single-use plastic bags (SUPBs)** **Food and beverage plastic containers**
Examples	**Plastic carrier bags** **Take-away plastic containers**
Application	**Consumer Goods / Lifestyle** **Healthcare & Pharmaceutical** **Food and Beverage Manufacturing / Brand owners** **Retailers** **Hospitality and hotel, restaurant, and catering (HORECA) sector**

Plastic materials/ Polymer types in the original product

Polyethylene (PE)
High-density polyethylene (HDPE)
Low-density polyethylene (LLDPE)
Polypropylene (PP)

Name and type of the substances of concern in the original product

- Bisphenols and PFAS in food and beverage plastic containers

Abstract

A national campaign addressing retailers, businesses, and organisations in Australia that encourages customers to bring their own reusable containers and bags and refuse SUPPs. The campaign includes incentives, disincentives and active public education and engagement. Customers can bring their own containers or bags to the affiliated businesses and have it refilled with food, beverage, or other content. **BYO Containers**' map helps search by postcode or category the businesses accepting BYO. Food containers need to be clean and quite new. Once in the store, the employee will weigh the container first, fill with the chosen item, reweigh, and subtract the weight of the container.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Bans or restrictions on the manufacture, use, distribution, sale, or trade of SUPPs.
- Binding and enforceable reuse targets (e.g., retailers are obligated to provide a min percentage of water in reusable packaging).
- Binding quota of reusable packaging put on the market of any material.
- Binding obligation for suppliers to offer and take-back the reusable bottles or containers.
- Binding beverage reuse quotas in the hospitality and Hotels, Restaurants, and Cafés (HORECA) sectors.
- A beverage packaging reuse target for domestic consumption at home.
- Consumer education and awareness raising campaigns.

Bring Your Own (BYO) reusable/ refillable bags or containers website and campaign

Technical enablers	• Clear health and safety regulations and standards applying to the use of reusable containers in food outlets. • Training of staff on how to provide food and beverage to customers in their own containers safely in accordance with the local safety program and risk assessments.
Market and financial enablers	• Financial incentives to help scale the BYO movement as the food-to-go is a growing market. For example, in UK, the retailer Marks & Spencer has introduced a discount off each meal to customers that bring their own re-usable containers. • Waste disposal fees or charges. • Green Public Procurement (GPP) to scale BYO movement. • Market-based instruments such as taxes, fees, or levies on SUPPs.
Challenges	Retailers tend to be afraid that offering incentives to motivate consumers to use fewer plastic products might end up raising their operating costs. The COVID-19 pandemic has reduced the number of businesses accepting BYO despite in 2020 over one hundred doctors, scientists, and academics in related fields signed a joint statement indicating reusables could be used safely.
Opportunities/ Benefits	Setting up an in-house reusables scheme can help reduce costs associated with the constant purchasing of new single-use options.
Replicability Low, Medium, High	The practice can be easily replicated in similar economic, technological, and political settings. **HIGH**
Geographical area of implementation	Oceania
Country	Australia
Contacts	The BYO Containers website and campaign was started by Bianca Cottle in 2018 after realising there was confusion and anxiety from members of the Zero Waste Victoria Facebook group asking businesses to shop with reusables containers. Bianca decided to make it easy, collating information and resources for both businesses and customers. In 2021, BYO Containers website was merged with Trashless Takeaway: the united aim going forward is to encourage customers and businesses to reduce plastic and waste by championing refilling, reusing, and bringing their own containers.
For more information	**https://www.byocontainers.org/**
Similar case studies	BYO **Singapore - http://www.byosingapore.com/** - Singapore Tackling Single-Use Plastics (MOSSUP) project - **https://www.seariousbusiness.com/morocco –** The project aims to contribute to the reduction the amount of single-use plastic waste in Morocco by introducing reusable packaging as an alternative to single-use plastic food in two major Moroccan supermarket chains. Deli-counter customers are encouraged to opt for a reusable container. They pay a small deposit for the container which will be returned when they bring the container back to store. The reusable containers are washed and reused.

Bring Your Own (BYO) reusable/ refillable bags or containers website and campaign

Comments

The businesses below offer assistance and reusable products to help get a business started with an in-house BYO program in Australia:

- The award winning Retub program (**https://retub.com.au/**) offers a Reswap program allowing a container exchange where the customers can bring in their Retub to a participating food-vendor and swap their used containers for a clean one when ordering. The rectangle containers are designed to standard takeaway container size, made of glass with a detachable silicone tub. Retub are offering a free basic set up for food vendors in Australia.
- Replated (**https://www.replated.co/**) offer recycled lunchbox style containers made of single-use plastic bottles and glass fibres, suitable to be washed in a commercial dishwasher. They offer support services to help set up and accept back containers that are at the end of their life, worn or broken for responsible disposal.
- Returnr (**https://returnrmarketplace.com/**) offer a lease scheme on a range of double-walled stainless-steel bowls and cups for retailers to purchase and start your business on reducing single-use products.

DESIGN FOR REUSABILITY

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: HIGH

Name of the practice

Reusable shopping bags lending system

Target plastic product	**Single-use plastic bags (SUPBs)**
Application	**Retailers** **Hospitality and hotel, restaurant, and catering (HORECA) sector**
Plastic materials/ Polymer types in the original product	Polypropylene (PP) High-density polyethylene (HDPE) Low-density polyethylene (LDPE)
Abstract	Shoppers can rent reusable shopping bags from **GOATOTE** kiosks in their convenient store and return them when finished. GOATOTE cleans and quality checks each bag for continued reuse. To be able to use the reusable bag system, customers need to sign up at any GOATOTE kiosk, and then choose between a pay-per-use or monthly subscription. Customers have unlimited access to GOATOTE kiosks and number of bags. Bags need to be returned within 30 days to any return kiosk. Bags not returned within 30 days will incur additional fee.
State of implementation	COMMERCIAL USE
Legislative/ Policy enablers	• Mainstream CE principles into national and international policies. • Bans or restrictions on the manufacture, use, distribution, sale, or trade of SUPPs. • Binding and enforceable reuse targets. • Binding quota of reusable packaging put on the market of any material. • Consumer education and awareness raising campaigns.
Technical enablers	• Enabling Technology, such as the Internet of Things (IoT), integrated in the reusable packaging to simplify payments, deposit refunds, rewards, and track usage. • Develop a cost-efficient ecosystem with infrastructure across the entire value chain, from brands to converters, filling operations, and retailers, with harmonization and standardization of reusable containers/bags to reach cost parity or even below the single-use alternative. • Standardized packaging and cross-utilization among different products, brands, stores, or restaurants to achieve a large-scale reuse solution. Product differentiation can still be achieved through labelling and late-stage customization to communicate content. • Analysis of data from pilot schemes and early adopters could help build best practices and guidance for businesses, customers, and public administrations.
Market and financial enablers	• Market-based measures to encourage and lower cost of reusable solutions. However, deposits can put people off and rewards can lead to over-complication. It is thus important to choose the right incentives to prioritise reuse above recycling, and subsidies or charges to close the cost gap between reusable and single-use packaging. Adapt Extended Producer Responsibility (EPR) to support reuse, adding charges on single-use packaging or removing VAT from deposit payments. • Waste disposal fees or charges. • Innovation challenges, such as the Beyond the Bag Initiative launched by the Consortium to Reinvent the Retail Bag, to support the development new packaging designs and integrated logistics.

Challenges

- The scaling up of reusable/refillable packaging is limited by several barriers within the current packaging value chain, mainly linked to acceptance, convenience, lack of infrastructure, regulatory push for overall packaging reduction, product safety, and cost.
- Changing shopping habits to ensure that the reusable bags are actually reused is hard to achieve, particularly in emerging economies where convenience is still preferable over sustainability.
- The suitability and "true sustainability" of reusable packaging, compared with disposable solution depends on the use case considered. In some cases, single-use packaging might be more sustainable, and in other cases, reusable packaging will perform better.
- Finally, the packaging standardization required to scale the reuse systems might limit some of the differentiation that packaging offers today to brand owners.

Opportunities/ Benefits

Having "pick up stations" where consumers can pick up a reusable bag is a simple and yet effective way of helping the reusable/refillable movement.

Replicability
Low, Medium, High

The practice can be easily replicated in similar economic, technological, and political settings.

HIGH

Geographical area of implementation

North America

Country

USA

Contacts

GOATOTE is a reusable bag service provider with reusable bag kiosks in 14 US and three Canadian locations. GOATOTE was a 2021 winner of the Beyond the Bag Challenge.

GOATOTE's parent company is The Kroger Co.

For more information

https://goatote.com/#page-1

Similar case studies

Returnity Reusable shipping and delivery packaging systems - **https://www.returnity.co/** - USA

DESIGN FOR REUSABILITY

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: MEDIUM

Name of the practice

Reusable alternative to cotton swabs

Target plastic product	**Cotton bud plastic sticks/swabs**
Application	**Healthcare & Pharmaceutical** **Retailers** **Hospitality and hotel, restaurant, and catering (HORECA) sector**
Plastic materials/ Polymer types in the original product	Polypropylene (PP)
Abstract	**LastSwab**'s rod is a reusable cotton swab made from biobased polypropylene (PP) that is reinforced with glass fibre and the soft tip ends are produced using thermoplastic elastomers (TPE). The carry case is made from recycled ocean-bound plastic. LastSwab is carefully designed and rigorously tested to last up to 1,000 uses.
State of implementation	**COMMERCIAL USE**
Legislative/ Policy enablers	• Mainstream CE principles into national and international policies. • Bans or restrictions on the manufacture, use, distribution, sale, or trade of SUPPs. • Binding and enforceable reusable products targets. • Binding waste reduction targets linked to effective sanctioning mechanisms for non-compliance. • Consumer education and awareness raising campaigns.
Market and financial enablers	• Market-based measures to encourage and lower cost of reusable solutions. • Waste disposal fees or charges. • Green Public Procurement (GPP) to promote reusable alternative to SUPPs. • Innovation awards, prizes, challenges, and platforms, such as the World Economic Forum's Scale360° Playbook and UpLink. • Offer early-stage venture funding to sustain start-ups such as I-Drop. • Support blended finance solutions for physical and digital infrastructure, and innovation.
Replicability Low, Medium, High	The practice requires certain specific requirements to be successfully replicated. **MEDIUM**
Geographical area of implementation	Europe
Country	Denmark
Contacts	LastSwab Basic is produced by LastObject, a Danish company founded in 2018. **hello@lastobject.com**
For more information	**https://lastobject.com/**

DESIGN FOR REUSABILITY

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: HIGH

Name of the practice

Reusable period underwear

Target plastic product	**Sanitary items**
Examples	**Hygiene pads**
Application	**Healthcare & Pharmaceutical**

Plastic materials/ Polymer types in the original product

Polypropylene (PP)
Polyethylene (PE)
Superabsorbent polymer (SAP)

Name and type of the substances of concern in the original product

- Volatile organic compounds (VOCs)
- Phthalates
- PFAS

Abstract

Aisle underwear have a multilayered leak proof and highly absorbent panet. The underwear is made of the following materials:

- Oeko-Tex Standard 100 Certified **Tencel**™, a fibre harvested from sustainable wood sources. Wood pulp is transformed into soft, silky-smooth yarns that are then knit into fabric that has high breathability, is less susceptible to odour-causing bacterial growth, and absorbs 50 percent more than cotton. Certified Control Union, under the Global Recycled Standard (GRS).
- Oeko-Tex Standard 100 Certified **Truetex**™, a blend of hydrophilic and hydrophobic fibres that creates an inherently wicking and absorbent material at the yarn level, that you would not achieve with a singular fibre type. This intimate blend ensures performance without the need for added chemical finishes. This means that performance does not decrease with multiple washes.
- GRS certified recycled polyester ensuring that only post-consumer plastic materials are used.
- Oeko-Tex Standard 100 Certified organic cotton and **TransDRY®** Technical Cotton, made from a blend of water-repellent and absorbent yarns that creates a quick-wicking material that draws fluid away from your body. This blend of yarns dries 50 percent faster than standard cotton and moves fluid more efficiently than synthetic fabrics.
- Oeko-Tex Standard 100 certified PTFE-free thermoplastic polyurethane membrane to ensure that the products are reliable: the TPU has a 10k/10K rating, which means it can stand up to heavy flow, while also maintaining breathability.
- Virgin Polyester: Aisle pads still use virgin polyester in the absorbent core.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Bans or restrictions on the manufacture, use, distribution, sale, or trade of SUPPs.
- Binding and enforceable reusable products targets.
- Binding waste reduction targets linked to effective sanctioning mechanisms for non-compliance.
- Consumer education and awareness raising campaigns.

Technical enablers
- Clear and transparent information on certification claims.

Market and financial enablers
- Market-based instruments such as taxes, fees, or levies on SUPPs
- Producing reusable period underwear at affordable prices, at mass scale, is difficult but as more retailers are investing in their own brand reusable period underwear, scale helps to keep manufacturing costs low.

Challenges

Most governments focus primarily on sanitary items' efficacy in absorbing blood, and do not require companies to disclose the full list of ingredients. There have not been comprehensive, longitudinal studies about how pesticides, synthetic materials, and other toxic chemicals like dioxin found in mainstream tampons affect women's bodies.

To provide superior performance, Aisle products (as all other period underwear assessed within this study) do still use virgin polyester as recycled polyester still raises a number of challenges: it might be highly contaminated, particularly it might contain per-and polyfluoroalkyl substances (PFASs), known to persist in the environment and are commonly described as persistent organic pollutants. Research has shown that PFAS can lead to decreased fertility and lower responses to vaccines, and in some cases, increased cancer risk. PFAS are commonly used in waterproofing and stain-resistant finishes, and they have been used across many industries. In addition, the synthetic fibres used in the gusset can degrade into microplastics and ultimately leach into our oceans.

Opportunities/ Benefits

Aisle has built a reporting system to self-monitor its CO2 emissions, energy and waste and give consumers a "cradle to grave" analysis, other brands can learn from. Aisle publishes an annual environmental impact report and shares a supplier code of conduct with its manufacturing partner in Cambodia. Also at the centre of Aisle's approach is its Life Cycle Analysis project, which compares the impact of Aisle's underwear, pads and liners to traditional tampons and disposable pads and looks at CO2 emissions, energy and waste created through the supply chains of all raw materials, manufacturing facilities, production, transportation and use phase (including washing and drying of products). In 2020, the company also introduced a widget to its website that provides data on how its products compare to disposable period-care products in terms of climate impact, making the information accessible to customers outside of its reports.

Aisle underwear are manufactured in Phnom Penh, Cambodia, in a factory that is woman owned and operated. Employees receive a comprehensive pension plan; they are provided free hot lunch every day. New mothers receive 6 months paid maternity leave. There is a wastewater treatment facility on site, to ensure the water the factory uses in manufacturing is clean and safe before leaving the facility.

Replicability Low, Medium, High — The practice can be easily replicated in similar economic, technological, and political settings. **HIGH**

Geographical area of implementation North America

Country Canada

Contacts Aisle (formerly Lunapads) is a Canadian business that manufactures washable feminine hygiene products, including cloth menstrual pads and underwear, and it distributes a commercial menstrual cup via its website.

For more information **https://periodaisle.com/**

Similar case studies Knix - **https://knix.com/** - USA

DESIGN FOR REUSABILITY

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: HIGH

Name of the practice

Grocery-store drinking water refill system

Target plastic product	**Plastic bottles**
Examples	**PET bottles**
Application	**Retailers** **Hospitality and hotel, restaurant, and catering (HORECA) sector**
Plastic materials/ Polymer types in the original product	Polyethylene terephthalate (PET)
Name and type of the substances of concern in the original product	• Phthalates
Abstract	**I-Drop** offers a grocery-store purified drinking water refill system called the Waterpod. The Waterpod combines an advanced purification technology into a compact, user-friendly design, connected to the internet for remote monitoring and control. I-Drop signs a contract with a grocery store owner and instals a Waterpod at no capital cost to the shop-owner. After every installation, water is tested to make sure it is safe. The shop-owner sells the purified water, shoppers refill their own drinking water containers and pay by the litre for the water.
State of implementation	COMMERCIAL USE
Legislative/ Policy enablers	• Mainstream CE principles into national and international policies. • Bans or restrictions on the manufacture, use, distribution, sale, or trade of SUPPs. • Binding and enforceable reuse targets (e.g., retailers are obligated to provide a min percentage of water in reusable packaging). • Binding quota of reusable packaging put on the market of any material. • Binding beverage reuse quotas in the hospitality and HORECA sectors. • A general beverage packaging reuse target for domestic consumption at home. • Binding waste reduction targets linked to effective sanctioning mechanisms for non-compliance. • Consumer education and awareness raising campaigns.
Technical enablers	• Enabling Technology, such as the Internet of Things (IoT), integrated in the reusable packaging to simplify payments, deposit refunds, rewards, and track usage.

Market and financial enablers

- Market-based measures to encourage and lower cost of reusable solutions. Use Green public procurement to expand the market of reuse refill water systems such as the Waterpod.
- Innovation awards, prizes, challenges, and platforms, such as the World Economic Forum's Scale360° Playbook and UpLink.
- Offer early-stage venture funding to sustain start-ups such as I-Drop.
- Support blended finance solutions for physical and digital infrastructure, and innovation.
- Green Public Procurement (GPP) to promote reusable alternative to SUPPs.

Opportunities/ Benefits

In most developing countries, plastic bottles represent the only option for consumers to access safe drinking water. To effectively prevent the use of plastic bottles, retailers and shops should provide access to drinking water. Solutions such as those proposed by I-Drop are welcomed and should be promoted across the board.

Waterpods deliver low-cost, high profit-margins to shop-owners through I-Drop's remote monitoring technology and innovative revenue-share commercial model. I-Drop tracks all water sold through each Waterpod and invoices monthly in arrears, typically for 50 percent of water sales volumes.

Water is purified through a two-stage Nanomesh technology that removes viruses, bacteria, cysts, and other contaminants to NSF248 and NSF231 testing standards by the Water Quality Association. Water goes then through sediment filters, as well as a final-stage UV sterilisation that provides extra protection against any microbiological contaminants. Activated carbon polishing filters ensure that the water is not only safe but tastes good. Alkaline mineralisation cartridges are added to balanced water.

For the shop owners, no drainage plumbing, and a compact form enables installation just about anywhere in the store.

For the shoppers, a built-in dispenser provides pre-programmed refills for common 5L and 10L sizes containers. A hose-gun helps refill larger containers that can stay in the shopping cart while filling.

Replicability
Low, Medium, High

The practice can be easily replicated in similar economic, technological, and political settings.

HIGH

Geographical area of implementation

Africa

Country

South Africa

Contacts

I-Drop Water is a South Africa-based company.

For more information

https://www.purewaterpod.com/

DESIGN FOR REUSABILITY

IMPLEMENTATION: START UP

REPLICABILITY: MEDIUM

Name of the practice

reCIRCLE: a circular solution for take away food and beverage containers and cutlery

Target plastic product	**Food and beverage containers**
Application	**Retailers** **Hospitality and hotel, restaurant, and catering (HORECA) sector**

Plastic materials/ Polymer types in the original product

Polypropylene (PP)
Polyethylene (PE) plastic lining of paper or board cups
Polyethylene Terephthalate (PET)
High-density polyethylene (HDPE)
Low-density polyethylene (LDPE) and linear low-density polyethylene (LLDPE)
Polyvinyl Chloride (PVC)
Polystyrene (PS) and expandable PS (EPS)
High impact polystyrene (HI-PS)
Polycarbonate (PC)

Name and type of the substances of concern in the original product

- Plasticisers (e.g., phthalates)
- Stabilisers (e.g., Bisphenol A)

Abstract

reCIRCLE replaces single-use food and beverage containers and cutlery with reusable, high-quality, affordable, and more eco-friendly alternatives. reCIRCLE packaging can be purchased or borrowed for free via the app and returned at any partner business, such as restaurants, bakeries, canteens, and takeaways. They can be used, refilled, and washed hundreds of times. At the end of their life, the reCIRCLE products can be exchange for new ones, or get reimbursed. reCIRCLE containers are made of a heat-and frost-resistant, odourless, microwave-and dishwasher-safe material that can be easily cleaned, completely dry, stacked, ensuring enough ventilation. reCIRCLE boxes are made 70 percent of polybutylene terephthalate (PBT) and 30 percent of glass fibre, while the lid is 100 percent polypropylene (PP). The boxes are free of BPAs, contain no plasticisers and are unbreakable. Transparent BOXes are made of Tritan, a transparent, heat-resistant, dishwasher-safe, tasteless, BPA-and plasticisers free. According to the Life Cycle Assessment (LCA), only after 15 uses the carbon footprint of the reCIRCLE box drops below the one of an average single-use take-away box, and circularity has already reached 95 percent.

State of implementation

START UP

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Bans or restrictions on the manufacture, use, distribution, sale, or trade of SUPPs.
- Binding and enforceable reuse targets.
- Binding quota of reusable packaging put on the market of any material.
- Binding waste reduction targets linked to effective sanctioning mechanisms for non-compliance.

reCIRCLE: a circular solution for take away food and beverage containers and cutlery

- Develop product policies that focus on high quality design for durable goods and packaging (including emphasis on reusability; the sharing of information and tracking through product labels, tags, and digital product material passports).
- Consumer education and awareness raising campaigns. Binding quota of reusable packaging put on the market of any material.

Technical enablers

- Innovation both in the design of the packaging, to encourage returns and reduce the environmental footprint of packaging and transportation, and the logistics, through for example the creation of centralised logistics networks in cities, backhauling through existing systems and developing new washing processes.
- Public-private partnerships to generate designs and processes for scalable infrastructure (e.g., washing and sanitation) that allows for sufficient levels of differentiation.
- Enabling Technology, such as the Internet of Things (IoT), integrated in the reusable packaging and/or tailored apps can support and enhance the user experience.
- Packaging designed to ensure enjoyable experience for consumer and food outlet. For example, reCIRCLE reusable packaging was developed for the specific needs of takeaway restaurants and their customers, with the assistance of materials experts and tested in laboratory to ensure its safety.
- Clear health and safety regulations and standards applying to the use of reusable containers in food outlets.
- Guidance and regulations on washing processes from central food standard agencies/ministries could help reduce hygiene concerns for businesses and users.
- Enabling Technology, such as the Internet of Things (IoT), integrated in the reusable packaging to simplify payments, deposit refunds, rewards, and track usage.
- Standardized packaging and cross-utilization among different products, brands, stores, or restaurants to achieve a large-scale reuse solution. Product differentiation can still be achieved through labelling and late-stage customization to communicate content.

Market and financial enablers

- Market-based measures to encourage and lower cost of reusable solutions.
- Green Public Procurement (GPP) to promote reusable alternative to SUPPs.
- Public-private partnerships help create unique levers for overcoming scale barriers such as financial viability and behavioural change in favour of reuse. An example is the Plastic Pact Network organized by the Ellen MacArthur Foundation.

Challenges

Major challenges are the inconvenience of having to bring empty containers to be re-filled; ineffective communication, which may result in the disposal of reusable systems, and bad pricing policy by retailers or manufacturers (resulting in equal or higher costs for a reusable system). At the end of their life, due to restrictions regarding food safety regulations, reCIRCLE containers cannot be recycled in a closed to produce new reCIRCLE containers.

Opportunities/ Benefits

Because the idea is revolutionarily simple, many versions of circular deposit return systems for reusable food and beverage containers have been developed worldwide. However, ideally, a harmonized reuse system, widely accepted, convenient and easily accessible should be established instead of many different ones to enhance scalability.

Replicability
Low, Medium, High

The practice requires certain specific requirements to be successfully replicated.

MEDIUM

reCIRCLE: a circular solution for take away food and beverage containers and cutlery

Geographical area of implementation	Europe
Country	Switzerland
Contacts	reCIRCLE started in 2013 as a pilot project, financially supported by the Federal Office for the Environment (FOEN). Today, reCIRCLE is a network of more than 1800 partner businesses in Switzerland and 600 in Europe, saving more than 55,000 single-use packages per day. **info@recircle.ch**
For more information	**https://www.recircle.ch/en/**
Similar case studies	ClubZero - **https://www.clubzero.co/** - UK Bettercup - **https://bettercup.club/** - Australia/New Zealand Suppli - **https://www.mysuppli.ca/** - Canada Faircup - **https://en.fair-cup.de/** - Germany Muuse - **https://muuse.io/** - Singapore/Hong Kong/Canada RECUP - **https://recup.de/** - Germany VYTAL - **https://en.vytal.org/** - Austria/Germany/France
Comments	In general, reusable cups have a lower environmental impact than disposable cups, although this is highly dependent on the number of uses a reusable cup needs to be better than a disposable cup. The losses of a reusable cup may be higher if the consumer does not own the cup. Most reusable cups need to be used 10-140 times to have a better environmental footprint than a disposable cup. On the other side, the littering potential of reusable cups is lower than that of disposable cups due to their higher weight. Among reusable cups, the PP cup has an environmental advantage over the ceramic cup and therefore needs to be reused less often to be comparable to disposable cups. The geographical region plays a major role in the environmental impact of food containers. For disposable options, the production phase has the greatest environmental impact. The environmental performance of the production phase is directly linked to the energy mix used in the region. The same is true for reusable systems in the use phase of washing the container. (**https://greentechknowledgehub.de/sites/default/files/2021-10/Material_choices_211020.pdf**)

DESIGN FOR REUSABILITY

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: MEDIUM

Name of the practice

A blockchain-inspired, tech-enabled refill system of reusable packaging for consumer goods

Target plastic product	**Primary and secondary packaging**
Examples	**Plastic sachet and wrappers**
Application	**Consumer Goods / Lifestyle** **Healthcare & Pharmaceutical**

Plastic materials/ Polymer types in the original product

Multi-material multilayer plastic packaging (MMPP) are made of distinct layers of heteropolymers such as polyolefins and polyesters, with each layer selected to contribute a corresponding property advantage to the bulk material, depending on the application, such as polyethylene (PE) as a moisture barrier, ethylene vinyl alcohol (EVOH) as an oxygen barrier, and polyethylene terephthalate (PET) as an effective gas and moisture barrier that imparts rigidness and strength.

Aluminium foils or paper are also used.

Name and type of the substances of concern in the original product

Tie layers [such as ethylene vinyl acetate (EVA)], wet bond adhesives, or additives (such as TiO2)

Abstract

Alner operates a blockchain-inspired, tech-enabled refill system of reusable packaging for consumer goods spread through the network of local warungs (high-frequency stores) in Indonesia. Alner supplies reusable packaging to Fast Moving Consumer Goods brand owners. Customers buy the finished goods from community-based points of sale, such as waste banks, warung (convenience) stores, and peer-to-peer sellers or directly from Alner via online platforms. If they buy through a point of sale, the packaging will be scanned by the points of sale using the Alner online channels to track it digitally. Customers use their products and return the empty packaging to the same points of sale they bought from. If they buy directly from Alner, they can swap it with pre-filled packaging in the next purchase. Customers receive a cashback on the next purchase, as a token of appreciation for their reuse habit. Alner collects the empty packaging at the points of sale, restocks, cleans, and provides them again to the brand owners. Alner provides the reverse logistics by arranging for the empty bottles to be returned and cleaned. To ensure cleaning quality, Alner developed a cleaning procedure using a semi-automated machine and specific cleaning agents to avoid contamination. Laboratory tests ensure the rate of microorganisms in the packaging is negative or zero.

Alner's packaging is made with durable PET, PP, or HDPE, designed to be reused 10-20 times. The QR Code system on the packaging enables brand owners to track and cycle their lifespans, which is crucial to determining affordability.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Bans or restrictions on the manufacture, use, distribution, sale, or trade of SUPPs.
- Binding obligation for retailers to offer reusable bottles and take-back the returnable packaging/containers.
- Binding and enforceable reusable products targets.
- Binding waste reduction targets linked to effective sanctioning mechanisms for non-compliance.
- Consumer education and awareness raising campaigns.

Challenges

The versatility and affordability of multilayer plastic films have created a large demand for them. Accordingly, more than 100 million tons of multilayer thermoplastics are produced globally each year. Single use sachets provide low-income customers with easy access to household essentials such as shampoo, dish soap and detergent. In addition, MMPP are usually extremely light and perform very well under these extreme conditions. This creates substantial savings in production, transportation, and other costs. However, MMPP cannot be recycled and is thus bound to leak into the environment. Replacing these packaging with reusable solutions can lead to:

- Reduced convenience and affordability: the system relies heavily on consumers following directions and reusing packages as intended, and often involves upcharges that exclude consumers without disposable income.
- The environmental benefits of these initiatives have been questioned due to a "payback" period associated with any reusable item, that is several times it must be reused before it's actually better for the environment than the single-use alternative. But there aren't many studies on how often consumers refill multi-use packages. If someone buys a metal shampoo bottle and discards it in the garbage instead of refilling it, that may end up being worse for the environment than simply buying a single-use bottle, because more energy went into making the durable metal version.
- Reduced packaging safety.
- Brand differentiation: Industry-wide packaging standardization, using shared infrastructure, is often identified as an essential means of achieving scale for reuse systems. However, such standardization can come at the cost of brand differentiation.
- A lack of scaled precedents makes business cases difficult to develop for this new model, so stakeholders (especially retailers) are reluctant to make investments in reuse and refill models.
- Incentive misalignment: many municipal systems reward high levels of recycling, as opposed to outright waste reduction. An increase in reuse levels would reduce the single-use waste, bringing down the recycling rates. The recycling incentive structure could serve as a disincentive to the development of reuse processes.

Opportunities/ Benefits

Reuse refill programmes, such as Alner, can build brand loyalty, improve consumers' experience by enhancing the look, feel and functionalities of the reusable packaging, adapted to individual needs, and gather intelligence on consumers' preferences by incorporating digital technology. Alner makes the reuse system affordable: low-income consumers can get their essential products 5-10 percent cheaper upon the packaging return. Alner provides an economically attractive opportunity for partner point of sale, which can increase their earnings by 10-15 percent per month. Alner's system is convenient. Points of sale, also as drop-off points, are widely available at the neighbourhood level and are accessible to low-income consumers. This helps increase the adoption rate of the reuse solution.

A blockchain-inspired, tech-enabled refill system of reusable packaging for consumer goods

Replicability Low, Medium, High — The practice requires certain specific requirements to be successfully replicated. **MEDIUM**

Geographical area of implementation: Asia

Country: Indonesia

Contacts: Koinpack is a venture between Zero Waste Living Lab, a venture building program by serial entrepreneur Enviu (https://enviu.org/). Rebranded from Koinpack to Alner, the Enviu venture is Indonesia's first returnable and reusable packaging system provider for consumer goods such as detergent, shampoo, and food products. **indonesia@enviu.org**

For more information: **https://www.alner.id/**

Similar case studies:

Siklus Refill -

Saponetti - **https://www.saponetti.ca/** - Canada

Puurbezorgd - **https://www.pieter-pot.nl/** - Netherlands

ReturnR - **https://returnrmarketplace.com/** - Australia

DESIGN FOR REUSABILITY

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: HIGH

Name of the practice

A (B2C) reuse refill-on-the-go system for homecare products

Target plastic product	**Primary packaging**
Examples	**Plastic bottles and containers**
Application	**Consumer Goods / Lifestyle** **Healthcare & Pharmaceutical** **Food and Beverage Manufacturing / Brand owners** **Retailers**

Plastic materials/ Polymer types in the original product

High-density polyethylene (HDPE)
Low-density polyethylene (LDPE) for squeeze applications.
Polyethylene terephthalate (PET)
Polycarbonate (PC)
Polypropylene (PP)
Polystyrene (PS)

Name and type of the substances of concern in the original product

- Bisphenols
- Phthalates
- Contaminants: Heavy metals

Abstract

Algramo is a platform system that allows consumers to refill products at low prices by using smart powered dispensing machines (refill stations) and Smart Packaging chipped with Radio-frequency identification (RFID). Customers charge their account through an app and bring their Smart Packaging to an Algramo dispenser. The Smart Packaging is equipped with a **Wallet™** technology. This allows the packaging to be associated with its owner, turning into a unique and reusable valuable object. The Algramo's Internet of Things (IoT) dispensers allow a Digitally Verified Refill with full product traceability and a simple and friendly user experience: the dispenser recognises the packaging and dispenses the right product at a desired quantity without the need for login or payment as the packaging itself becomes a wallet. Users can use the Algramo app to create their profile and link it to their Smart Packaging to access their refill records, environmental impacts, and other benefits. When it has completed its life cycle, the Smart Packaging can be recycled as part of regular household plastic recycling. The Smart Packaging is made of high-density polyethylene (HDPE), the label is polyethylene (PE), and the lid is polypropylene (PP).

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Bans or restrictions on the manufacture, use, distribution, sale, or trade of SUPPs.
- Develop product policies that focus on high quality design for durable goods and packaging (including emphasis on reusability; the sharing of information and tracking through product labels, tags, and digital product material passports).
- Binding and enforceable reuse targets.
- Binding quota of reusable packaging put on the market of any material.
- Binding waste reduction targets linked to effective sanctioning mechanisms for non-compliance.
- Consumer education and awareness raising campaigns.

A (B2C) reuse refill-on-the-go system for homecare products

Technical enablers

- Health and safety regulations and standards applying to the use of reusable containers to build trust and confidence.
- Innovation and digital technology to improve the shopping experience, reduce contamination risks, and address food safety concerns, while facilitating the integration of reuse systems in traditional business models. If well designed and implemented, reuse business models can also increase the understanding of consumers' behaviour and enhance brand loyalty.
- Collaboration, integration, and transparency amongst all actors in the packaging value chain.

Market and financial enablers

- Market-based measures to encourage and lower cost of reusable solutions.
- Well-designed extended producer responsibility (EPR) schemes, extended to both producers and retailers or distributors.
- Economic stimulus to public and private investments in the infrastructure and technology that is required (such as collection vehicles and washing facilities) for reuse systems to spread at a larger scale.

Challenges

The development of convenient reuse refill models such as Algramo requires a "Patient capital": investments that allow room to fail, and patience for return on investment. This capital can come in many forms, such as the allocation of internal funding, external investment into impact funds, research and development grants, or human resources.

Opportunities/ Benefits

The Algramo system ensures product traceability, generates loyalty, and gathers business intelligence. The pilot phase saw some customers refill their detergent bottle 15 times, with each refill eliminating the need to recycle or send to landfill a plastic bottle. There are financial benefits too: lower-income consumers are often unable to buy in bulk, forcing them to buy smaller amounts for higher prices (up to 30-50 percent more than the same product in a larger container). Algramo supplies small stores in poor areas of the city with vending machines dispensing household products in the amount needed.

Replicability
Low, Medium, High

The practice can be easily replicated in similar economic, technological, and political settings.

HIGH

Geographical area of implementation

North America | Latin America | Asia

Country

Chile | USA | Indonesia

Contacts

Algramo was born of José Manuel Moller's first prototypes of powder detergent dispensing machines in Santiago de Chile (Chile). The company has since expanded with its home delivery service, launched pilots with Unilever, Purina and most recently with Walmart and is now present in Santiago, New York, and Jakarta.
contacto@algramo.com

For more information

https://algramo.com/

Similar case studies

Loop - **https://buydurable.com**/ - UK
MIWA - **https://www.miwa.eu/** - Poland

DESIGN FOR REUSABILITY

IMPLEMENTATION: START UP

REPLICABILITY: MEDIUM

Name of the practice

Reusable refillable at home packaging system

Target plastic product	**Primary packaging**
Examples	**Plastic bottles**
Application	**Consumer Goods / Lifestyle (household products and natural cosmetics)**

Plastic materials/ Polymer types in the original product

High Density Polyethylene (HDPE)
Polypropylene (PP)
Polyethylene terephthalate (PET)

Abstract

Everdrop is a German start-up selling household cleaning products in concentrated tablets that the customer mixes with water at home in reusable bottles. The reusable bottles can be made of glass bottles, containing at least 10 percent waste glass from nearby recycling centres, or of 100 percent recycled polyethylene terephthalate (rPET) or recycled high-density polyethylene (rHDPE); durable tinplate boxes made in Germany. The products come in sachets made of FSC/PEFC-certified paper with an innovative coating based on harvest waste to protect the content from moisture. These sachets are 100 percent free of plastic films, aluminium, fluorocarbons, chlorinated hydrocarbons, and optical brighteners. The latest generation of Everdrop powder and tab sachets is made of FSC/PEFC-certified paper. The shipping packaging is made of corrugated cardboard.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Bans or restrictions on the manufacture, use, distribution, sale, or trade of SUPPs.
- Binding and enforceable reuse targets.
- Binding quota of reusable packaging put on the market of any material.
- Binding waste reduction targets linked to effective sanctioning mechanisms for non-compliance.
- Consumer education and awareness raising campaigns.

Technical enablers

- Collaboration and cooperation across the value chain and with other sectors. Everdrop joins forces with other sustainable companies as “Start-ups for Tomorrow” in 2020.

Market and financial enablers

- Market-based measures to encourage and lower cost of reusable solutions
- (e.g., the production of reusable packaging rewarded through adequate tax benefits, for example a reduced VAT rate).
- Green Public Procurement (GPP) to promote reusable alternative to SUPPs.
- Innovation awards, prizes, challenges, and platforms, such as the World Economic Forum’s Scale360° Playbook and UpLink.
- Everdrop receives the German Sustainability Award Design 2021.
- Offer early-stage venture funding to sustain start-ups such as I-Drop.
- Support blended finance solutions for physical and digital infrastructure, and innovation.

Challenges

Everdrop is constantly optimizing the formulations of its products. That is why existing products are not all certified, as their composition has changed over time. To date, 100 percent of all Everdrop NATURAL CARE products and 50 percent of the household products carry the Ecocert seal. A life cycle analysis of Everdrop products hasn't been done yet. Despite their effort to become plastic-free, Everdrop still uses plastic packaging for certain products that are more sensible to moisture.

Opportunities/ Benefits

Removing water from products is a growing trend in reuse innovation. It reduces shipping costs and carbon emissions compared to heavy, diluted products and the compact concentrated products lend themselves well to e-commerce. In Everdrop's case, transport volume is reduced by 95 percent. Most of the suppliers (95 percent) are based in Europe (of which almost 80 percent are located within a radius of 350km from the warehouse). In addition, Everdrop does not use chemicals for its detergents, but mainly raw materials of natural origin, such as citric acid, baking soda and soda - with very good environmental compatibility, based on renewable and certified raw materials. Products are also vegan and free from microplastics.

Replicability
Low, Medium, High

The practice requires certain specific requirements to be successfully replicated.

MEDIUM

Geographical area of implementation

Europe

Country

Germany

Contacts

Everdrop company was founded in Munich in 2019 and produces innovative, sustainable, and stylish household products & natural cosmetics. Everdrop products are almost all plastic-free.

For more information

https://www.everdrop.de/en

DESIGN FOR REUSABILITY

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: HIGH

Name of the practice

B2B reusable transport packaging (RTP) pooling system for fresh supply chain

Target plastic product	**Tertiary packaging**
Examples	**Plastic trays**
Application	**Food and Beverage Manufacturing / Brand owners** **Wholesale trade** **Retailers** **Transportation and Warehousing**

Plastic materials/ Polymer types in the original product

High Density Polyethylene (HDPE)
Plastic granules originated from the previous trays used by Europe Pool System and produced in an authorized recycling process according to Regulation (EC) no 282/2008, listed under EC Register number RECYC0142.

Abstract

Euro Pool System offers a fully outsourced foldable recycled plastic tray pooling service (open-loop shipping system). With an extensive network of service centres across Europe, Euro Pool System ensures its customers 100 percent availability of the reusable pooling foldable trays, in the right quantity. After every use, Euro Pool System inspects, washes, and sanitizes the containers in accordance with food safety policies to maintain one of the world's most stringent food safety management standards. With the online "My E-web" application, customers simply place their orders, having the full control over the packaging flows, of the financial transactions, such as automated invoicing and crediting of deposit amounts. This ensures optimal control of assets and of costs.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Bans or restrictions on the manufacture, use, distribution, sale, or trade of SUPPs.
- Binding and enforceable reuse targets.
- Binding quota of reusable packaging put on the market of any material.
- Binding waste reduction targets linked to effective sanctioning mechanisms for non-compliance.
- Consumer education and awareness raising campaigns.

Technical enablers

- Packaging standardisation to enable reverse logistics, facilitate transport, logistics, cleaning processes and machinery, resulting in overall cost reduction.
- Standardisation can also lead to an increase in reuse and extend the product's life when parts need to be replaced. Reduced complexity of packaging materials to enhance its recyclability and consequently, its overall environmental impact.
- Design functionality and technology are driving supply-chain innovations in transport packaging, optimise the flows and anticipate any future needs of the customers. This helps optimise the transport process in terms of transport distance, costs, and volumes. Transport price market tools are also used to select

the best carriers, based on transport type and transport cost, and market trends. This is especially helpful to collect management information for new routes, carriers, and actors, including multimodal transport. Sustainability criteria are also used in the selection of carriers.

- Standardization of reusable packaging for e-commerce to introduce reusable packaging at scale. This would make logistics more efficient for companies and carriers and facilitate automation.

Market and financial enablers

- Market-based measures to encourage and lower cost of reusable solutions.
- Economic stimulus to public and private investments in the infrastructure and technology that is required (such as collection vehicles and washing facilities) for reuse systems to spread at a larger scale.
- Green Public Procurement (GPP) to promote reusable alternative to SUPPs.
- A growth area for reusable packaging providers is in e-commerce, particularly regarding transporting orders for curb side pickup.

Challenges

The adoption of a pooling system entails some entry costs and adaptation of the supply chain. Since transportation is usually responsible for the highest greenhouse gases emissions in a product's life cycle, the emissions associated with a reusable packaging are deeply influenced by the number of cycles it undergoes, but only to a certain point, at which point a plateau is reached. This plateau can be explained by the fact that there are emissions that occur in every regular cycle of the reusable packaging, associated with cleaning and transportation. Therefore, the impacts that are only present in the initial and last cycle, such as those related to transport between the stages of raw material extraction and packaging production and to disposal after its service life, are less significant in the overall impact rather than the distances that will be travelled in every cycle of a reusable packaging, here called backhaul and resupply distances. Thus, shorter backhaul and resupply distances should be prioritised. Transport emissions are also affected by the packaging design (e.g., product weight and volume). The weight of a reusable packaging, for instance, is generally higher than single-use packaging because it must be able to withstand the number of reuse cycles it will undergo over its lifetime.

Choice of material is also important. The material chosen should satisfy its application needs while being sufficiently durable and lightweight to ensure that transport emissions are minimised. Materials with high energy-intensive production processes will usually show much higher emissions, while incorporating recycled content into the production process will lead to further decreases in emissions, reducing the total environmental impacts of the product's life cycle. Hygiene requirements mean that a washing step is an essential element to consider for returnable plastic packaging and is particularly applicable for the food industry. Where a system for washing crates internally does not exist and is too expensive to be put in place, it must be outsourced (e.g., https://www.glanaris.com/services).

Opportunities/ Benefits

The foldable trays are reusable and recyclable at the end of their life. The folding trays' specifications allow for perfect stacking, realising a volume reduction of 86 percent when stored and transported – significantly reducing CO2 emissions. The reusable plastic trays have an average lifespan of more than seven years. Their strength results in considerably less product loss (0.1 percent) compared to single-use packaging (4 percent). The standard packaging makes it possible to automate logistics processes throughout the entire supply chain. Euro Pool Group also offers return service for some of their customers, taking crates, pallets, but also beer bottles, and other materials that are either returned to the producers (in case of beer bottles for example) or taken to recyclers (e.g., paper and plastic).

B2B reusable transport packaging (RTP) pooling system for fresh supply chain

Replicability	Pooling systems allow different companies, particularly SMEs, to share the same resources and optimize operations and costs.
Replicability Low, Medium, High	The practice can be easily replicated in similar economic, technological, and political settings. **HIGH**
Geographical area of implementation	Europe
Country	The Netherlands | Belgium | Germany
Contacts	Euro Pool Group is the largest logistics service provider of reusable standard packaging in Europe. With the Euro Pool System (EPS) trays and the La Palette Rouge (LPR) pallets, it offers optimum reliability, sustainability, and efficiency in the (fresh) supply chain.
For more information	**https://www.europoolgroup.com/**
Similar case studies	Tosca - **https://www.toscaltd.com/pooling/** - Europe
Comments	For more information on reusable transport packaging (RTP): **https://www.reusables.org/**

DESIGN FOR RECYCLING

IMPLEMENTATION: PILOT

REPLICABILITY: HIGH

Name of the practice

Additives to increase recyclability of PET bottles

Target plastic product	**Plastic bottles**
Examples	**PET bottles**
Application	**Compounders** **Plastic manufacturers** **Food and Beverage Manufacturing / Brand owners** **Retailers** **Hospitality and hotel, restaurant, and catering (HORECA) sector**

Plastic materials/ Polymer types in the original product

Polyethylene terephthalate (PET)
Recycled polyethylene terephthalate (rPET)
High Density polyethylene (HDPE)

Name and type of the substances of concern in the original product

Various hazardous substances, such as bisphenols, used as catalysts and/or additives during the PET production, or that result of the degradation that can happen during the PET bottle's lifecycle.

Abstract

PET-Yield™ are a series of liquid additives that can be added during the PET bottle manufacturing process to significantly increase the amount of rPET material in new bottles, without the loss of properties compared to virgin PET bottles. Testing is still underway to see how the additive improves the performance of rPET blends in several critical properties that directly affect the PET bottle behaviour, such as gas permeability through the plastic, which has a direct impact on the product shelf-life. To have a long shelf-life the plastic must prevent oxygen permeating into the bottle and affecting its content, but also stop CO2 escaping so that carbonated drinks don't go 'flat'. PET-Yield™ are expected to help manufacturers use the correct blend ratios and automatically maintain the processing conditions to produce consistently predictable products. PET-Yield™ is a patented plug-and-play solution developed by **ENVIROPET Ltd** to enable the plastic bottle industry to transition to a CE model, achieve the binding recycling targets (UK and EU requirements), and adopt closed loop recycling policies.

State of implementation

PILOT

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Develop and align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment and enable a circular plastic economy.
- Bans or restrictions on the manufacture, use, distribution, sale, or trade of SUPPs.
- Mandatory minimum recycled content requirements for pre-consumer, post-industrial and pre-consumer recycled content to drive innovation and markets and fosters continual improvement through increasing requirements over time (e.g., the EU Single-use Plastic Directive that sets a specific target of incorporating 25 percent of recycled plastic in PET beverage bottles from 2025, and 30 percent in all plastic beverage bottles from 2030. UK is applying the same requirements). Ensure effective reporting and implement enforcement and penalties to incentivize compliance.
- Strong supply-side policies to increase the collection and processing of recyclables, such as the extended producer responsibility (EPR) and beverage container deposit return system (bottle bills).

Technical enablers

- Novel approaches support risk assessment of recycled Food Contact Materials (FCM) by addressing the chemical exposure to unknown substances and mixtures with biological activity (e.g., in vitro bioassays, in vitro bioassays with planar chromatography).
- Combine the assessments of human health and environmental effects through life-cycle assessment (LCA) including models for estimating chemical exposure from, e.g., food packaging, and comparing the human health impact of chemical migration from recycled packaging versus virgin materials. Focusing on chemical safety within the CE might add a new level of complexity during assessment but it allows to identify additional conflicting goals, for example between reduced environmental impacts and protection of human health.
- Harmonized certification program for recycled content that benchmarks average content within a category of products or packaging.
- Increase packaging's recyclability while also using an optimal level of additives to reduce the overall additive content, and phenol-free solutions.

Market and financial enablers

- Use GPP policies to favour recycled content products and packaging.
- Market-based measures such as a tax on virgin resin used to produce SUPPs to help make post-consumer recycled (PCR) resins more economically competitive in the marketplace. The funding created through the tax could then be used for plastic waste prevention and recycling activities. The tax on virgin plastic resin, coupled with the design for recycling requirements, can also reduce contamination in the recycling stream.

Challenges

Highly recyclable products, such as PET drink bottles, can be inapt for closed-loop recycling when poorly designed. New PET plastic bottles are difficult to manufacture with rPET content due to the high degree of variation in the recycled plastic feedstock, which makes it difficult to maintain the necessary uniformity in mechanical and optical properties required, leading to potential issues with bottle failures, carbonated fluids going flat and colour or clarity variations of the final plastic bottles. In addition, rPEt may not only contain degradation products of polymers and additives, but also incidental contaminants arising from previous use and misuse by consumers, cross-contaminations from waste disposal, and environmental contaminants. Furthermore, polymers of the same type, but not of food-grade quality, may also enter the recycling stream and increase the level of possible contaminants. Some types of plastic additives, e.g., antioxidants and stabilizers, form unintended reaction products, thereby losing their original function. To compensate for such unwanted changes, mechanical recycling processes require the addition of virgin polymers and/or further additives.

Traceability of components within the rPET is also a challenge.

Opportunities/ Benefits

The PET-Yield additives are expected to save firms millions' by reducing the amount of raw material and energy needed to manufacture new PET bottles. The scientists at the University of Strathclyde (UK) are also integrating artificial intelligence and deep learning to ensure that the appropriate quantity of additives are included during melt processing of the PET mixtures. This will create a system where processing conditions and blend ratios can be automatically maintained for consistent bottle results.

Replicability Low, Medium, High	The practice can be easily replicated in similar economic, technological, and political settings.	**HIGH**

Additives to increase recyclability of PET bottles

Geographical area of implementation	Europe
Country	UK
Contacts	Established in 2014 in the UK, ENVIROPET Ltd has partnered with scientists from Heriot-Watt University and University of Strathclyde to develop new additives that enhance the recycled content of plastic bottles. Supported by Interface Scotland, the two-year project is being backed by funding from Innovate UK, a government agency that supports organisations making new products and services. Interface Scotland enables the connection between businesses of all sizes, in all sectors with Scotland's world-leading academic expertise to help them grow.
For more information	**http://enviro.pet/**

DESIGN FOR RECYCLING

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: HIGH

Name of the practice

A system to divert organic waste and compostable packaging from landfills to composting facilities

Target plastic product	**Food Contact Primary Packaging**
Examples	**Tableware**
Application	**Food and Beverage Manufacturing / Brand owners** **Retailers** **Hospitality and hotel, restaurant, and catering (HORECA) sector**

Plastic materials/ Polymer types in the original product

Polypropylene (PP)
Polyethylene Terephthalate (PET)
High-density polyethylene (HDPE)
Polyvinyl Chloride (PVC)
Low-density polyethylene (LDPE) and linear low-density polyethylene (LLDPE)
Polystyrene (PS) and expandable PS (EPS)
Other: Polyethylene (PE), Acrylonitrile Butadiene Styrene (ABS), Polyamide (PA) or nylons, Polybutylene terephthalate (PBT), etc

Name and type of the substances of concern in the original product

- Plasticisers in PET (e.g., DPP, DEHA, DOA, DEP, diisobutylphthalate, and DBP)
- Antioxidants (e.g., arylamines)

Abstract

Compost Connect connects businesses using compostable single-use packaging to commercial composting facilities to divert compostable packaging and organic waste from landfill and transform these materials into high-value organic fertiliser compost. Compost Connect not only reduces the impact of waste in landfill but works to clean up the waste streams, and ensures inorganic materials, such as recyclables, are recovered and reused. Compost Connect has partnered with BioPak, the first manufacturer and distributor of compostable packaging in Australia and New Zealand, to provide this closed-loop solution. Compost Connect provides a composting service extending to more than 2,000 postal codes across Australia and New Zealand, in partnership with local waste management businesses. Customers can toss compostable packaging together with food scraps directly into an organic-waste bin for collection. BioPak claims that 660 tons of waste have been diverted from landfills because of the service.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Develop a clear policy framework for plastics with biodegradable and/or compostable properties, including harmonised rules for defining and labelling compostable and biodegradable plastics.
- Restrict or prevent solutions that increase the risk of littering or contamination of compost with plastics (including those that are compostable or biodegradable) from being marketed as biodegradable or compostable.

Technical enablers

- Collaboration of industry, municipalities/governments, and consumers to align material innovations with the appropriate infrastructure improvement and transform compostable materials from a niche initiative to a core pillar of a circular and sustainable economy.

A system to divert organic waste and compostable packaging from landfills to composting facilities

- Establish a harmonized labelling system to avoid confusing consumers.
- Awareness-raising campaigns and clear communication with consumers to improve their understanding of the labels used on plastics and ensure their correct disposal.

Market and financial enablers

- More investment in organics processing infrastructure if biobased biodegradable and compostable alternatives are to meet their full potentials, as well as building the necessary infrastructure and promoting private-public partnerships to ensure closed loop management.
- Use Green Public Procurement (GPP) to promote closed loop table-to-farm systems at local level (e.g., municipalities).

Challenges

Contamination with conventional plastics is an increasing challenge for compost quality. Replacing conventional plastics with certified compostable plastics for items that are often mixed with or attached to food waste, e.g., fruit stickers or tea bags, can help reduce contamination.

Opportunities/ Benefits

Although compostable plastics do not add nutrient value to compost, they have a role in supporting sustainable bio-waste management. Compostable packaging, for example, enables the recovery and recycling of food and packaging waste generated by the food service industry, diverting food waste way from the recycling stream for conventional recyclable materials. This is provided that the technical set-up of the local bio-waste management infrastructure guarantees effective collection and biodegradation of such plastics. By connecting packaging and food service businesses with the organic waste industry, Compost Connect is helping to grow access to organic recycling and instigate widespread change. Bio-waste from households and other sources is increasingly collected separately from other waste across Europe and the US. For example, separate collection or home-composting of bio-waste will be mandatory in all EU Member States from the end of 2023 onwards. Digesting or composting bio-waste in industrial digestion or composting plants results in compost or digestate that can be used as soil improver and fertiliser, as long as they comply with national/local quality requirements.

Replicability
Low, Medium, High

The practice can be easily replicated in similar economic, technological, and political settings.

HIGH

Geographical area of implementation

Oceania

Country

Australia | New Zealand

Contacts

Backed by the government and powered by Australia's leaders in sustainable food packaging BioPak, Compost Connect is a not-for-profit composting initiative that helps connect foodservice businesses to composting services and divert waste from landfill. Launched in May 2021, it has quickly grown to almost 400 members including cafes, restaurants, coffee roasters, schools, universities, offices and more. As a responsible business, BioPak could not continue to simply accept that their products were ending up in landfill when there was a more sustainable option available.
support@compostconnect.org

For more information

https://www.compostconnect.org/

Similar case studies

BioPak and Qantas case study: **https://drive.google.com/file/d/1Xuhz5q0SO7tb-dgsVEIYc1QjM1mKXsdn4/view**

DESIGN FOR RECYCLING

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: LOW

Name of the practice

A table-to-farm solution for single-use food ware

Target plastic product	**Food Contact Primary Packaging**
Examples	**Tableware (cutlery, plates, etc.)** **Food and beverage containers and cups**
Application	**Retailers** **Hospitality and hotel, restaurant, and catering (HORECA) sector**

Plastic materials/ Polymer types in the original product

Polypropylene (PP)
Polyethylene Terephthalate (PET)
High-density polyethylene (HDPE)
Polyvinyl Chloride (PVC)
Low-density polyethylene (LDPE) and linear low-density polyethylene (LLDPE)
Polystyrene (PS) and expandable PS (EPS)
Other: Polyethylene (PE), Acrylonitrile Butadiene Styrene (ABS), Polyamide (PA) or nylons, Polybutylene terephthalate (PBT), etc

Name and type of the substances of concern in the original product

- Plasticisers in PET (e.g., DPP, DEHA, DOA, DEP, diisobutylphthalate, and DBP)
- Antioxidants (e.g., arylamines)

Abstract

Bio24 is a table-to-farm solution that turns disposable dining food ware and food waste into compost. Enabling this is the proprietary plant-based material **NEUTRIA®** and the digestor that turns NEUTRIA® into farm-ready compost in just 24hrs. NEUTRIA® material is a bioactive polyester derived from plant-based sources. It breaks down rapidly upon deactivation in the Bio24 digestor. The Bio24 digestor comprises a catalytic degradation process that significantly reduces the composting time of the NEUTRIA® material – chemical free. Coupled with natural enzyme action, the NEUTRIA® material is reduced to compost in just 24hrs. After 24 hours in the digestor, food ware and food waste turn into nutrient-enriched, organic compost ready to pack and send to farms.

COMMERCIAL USE

State of implementation

- Develop a clear policy framework for biobased, biodegradable, and compostable plastics, including harmonised rules for defining and labelling biobased, biodegradable, and compostable plastics.

Legislative/ Policy enablers

- Restrict the use of solutions that increase the risk of littering or contamination of compost with plastics (including those that are compostable or biodegradable).

Technical enablers

- Collaboration of industry, municipalities/governments, and consumers to align material innovations with the appropriate infrastructure improvement and transform compostable materials from a niche initiative to a core pillar of a circular and sustainable economy.
- Establish a harmonized labelling system for biobased, biodegradable, and compostable plastics to avoid confusing consumers.
- Awareness-raising campaigns and clear communication with consumers to improve their understanding of the labels used on biobased, biodegradable, and compostable plastics and ensure their correct disposal.

Market and financial enablers

- More investment in processing infrastructure if biobased biodegradable and compostable alternatives are to meet their full potentials, as well as promote private-public partnerships to ensure closed loop management of these plastics.
- Use Green Public Procurement (GPP) to promote closed loop table-to-farm systems at local level (e.g., municipalities).

Challenges

High cost of biobased plastics and limited performance compared to conventional plastics are two major factors that hinder the growth of the bioplastics market. The plastics industry relies on legacy production facilities that depreciated long ago and turn-key processes that are safe for company boards to invest in while minimizing risk exposure. In addition, large-scale production of bioplastics comes with a host of technical challenges, from low reactor space-time yields to large variation in feedstock composition and structure. The result is an increase in by-products, which means added costs in separations, especially if one seeks drop-in replacements to conventional plastics. Biobased, biodegradable and compostable plastics often lack the economic push for commercialization given the low price of petroleum feedstocks and long-established industrial processes. In addition, compostable single-use food ware should be properly collected to avoid their dispersion in the environment or ending up in landfill, where they will not easily degrade. Even more important is to avoid that these plastics enter the commercial recycling stream as they can disrupt it. Finally, biobased plastics production often relies on crops that score poorly on environmental metrics such as ozone depletion, acidification, eutrophication, water use and food security. In terms of energy substitution, often there is no change in downstream production methods or product functionality. And biobased plastics may contain substances of concern as those found in conventional plastics.

Opportunities/ Benefits

Biobased, biodegradable and compostable plastics can bring advantages over conventional ones if designed for circularity, produced safely and from sustainably sourced feedstock, prioritising the efficient use of secondary biomass, and compliant with relevant standards. Using compostable plastic containers increases the capture rate of food waste provided that the technical set-up of the bio-waste management infrastructure guarantees effective collection, treatment, and biodegradation of such plastic products. Bio24 is an industry partnered programme that in principle ensures the waste from single-use food ware and food gets renewed, from table to farm. This way, consumers can continue to enjoy the conveniences of single-use food ware and businesses achieve zero-waste without costly operational changes.

Replicability
Low, Medium, High

The practice requires a high level of technological advancement, market preparedness, or specific economic/political conditions to be successfully replicated.

LOW

Geographical area of implementation

Asia

Country

Singapore

Contacts

TRIA is a venture-backed, sustainable, and innovative food ware company based in Singapore. Today, TRIA's products serve more than 200 million meals a year with clients consisting of brands such as KFC, 4Fingers and Soup Spoon.
https://triafoodware.com/about/ | **hello@triafoodware.com**

For more information

https://triafoodware.com/bio24/

DESIGN FOR RECYCLING

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: LOW

Name of the practice

A store drop-off recycling system for mono-material multilayer flexible packaging

Target plastic product	**Food Contact Primary Packaging**
Examples	**Multi-material multilayer pouches, flow wrappers, barrier film**
Application	**Food and Beverage Manufacturing / Brand owners Retailers**

Plastic materials/ Polymer types in the original product

Polyolefins PE and PP
HDPE, LDPE, LLDPE, OPP
Polyesters such as PET and PLA
Polyvinyl Chloride (PVC)
Polyamide (PA)
Ethylene vinyl alcohol (EVOH)
Ethylene-vinyl acetate (EVA)
Polyurethane (PUR)
Polyvinylidene chloride (PVDC)
Biobased polymer such as Polylactic acid (PLA)

Name and type of the substances of concern in the original product

- PFASs
- Phthalates
- NPEs/NPs

Abstract

RecycleReady Technology from **Dow Chemical Co.** allows to produce mono-material multilayer films with the same properties of multi-material multilayer materials and the added benefit of recyclability. Using linear, low-density resins, RecycleReady packaging is manufactured with an all-polyethylene structure (PE/PE). Technological advances allow for additional barrier properties. The PE/PE laminate is modified with copolymers, additives, and ethylene vinyl alcohol (EVOH) to control the oxygen and moisture transmission rates. RecycleReady Technology has been proven for low barrier applications like dry foods, frozen foods, and dry products (both edible and non-edible). Printing options for RecycleReady film are virtually the same as for conventional film. It can be printed flexographic or rotogravure; trapped or surface printed. Machining for RecycleReady film demands less energy than traditional packaging; it requires less heat, less time, and less pressure to create a seal. When brand owners and retailers request RecycleReady Technology from their converters, their final package structure can be submitted to the Sustainable Packaging Coalition (SPC) to qualify for the “How2Recycle” label. When approved for use, the “How2Recycle” label can be printed on the packaging, providing conspicuous evidence of its recyclability to consumers, as well as clear instructions regarding the recycling process – in this case, the “grocery store drop-off” system.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Develop and align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment and enable a circular plastic economy.
- Bans or restrictions on the manufacture, use, distribution, sale, or trade of SUPPs.
- Binding targets requiring that all plastic packaging placed on the market must be reusable or recyclable in a cost-effective manner by 2030 (e.g., EU New Circular Economy Action Plan).
- Binding material-specific targets and taxes, nudging producers towards recycling instead of disposal.
- Binding minimum targets (percent by weight) of all packaging waste to be recycled (e.g., EU Packaging Waste Directive 94/62/EC).
- Develop and implement product policies that focus on high quality design for recycling.
- Develop and implement policies that help grow secondary material and by-product markets.

Technical enablers

The treatment of flexible packaging materials, particularly the multi-material multilayer ones, depends on local capabilities, regulations, investments, and priorities. A packaging can only be considered recyclable in a country/market if there is a realistic chance that it will be collected, sorted into a material fraction where it is recycled into a new material/product at scale and for which there are viable end market applications. To increase recyclability, more integration and transparency amongst all actors in the packaging value chain is needed. This means joint efforts from various stakeholders regarding waste management actors, governments, packaging industry, research institutions, brand-owners, and consumers, towards a more harmonic system. It is also important to pass information about chemical ingredients along the local and global value chains to ensure products and materials are safely managed.

Market and financial enablers

- Market-based measures such as taxes, fees and incentives aligned with CE outcomes.
- Provide interdisciplinary research funds.
- Use Green Public Procurement (GPP) to grow circular sustainable products markets.

Challenges

Cost and minimums represent the greatest challenges to implement this innovative technology. The substitution of multi-material packaging by mono-material solutions is not sufficient to sort out the issue of multilayer packaging. Innovative recycling methods need to be developed and made available. But most importantly, design for recycling should be considered to reduce packaging complexity.

Opportunities/ Benefits

RecycleReady Technology for store drop-off recycling utilizes a set of IP-protected Dow products that offer a range of functional options and thus create an entire family of solutions for retailers and brand owners. The RecycleReady Technology provides comparable functional performance in stiffness and barrier protection, complete hermetic seals to avoid leaks, same end-use convenience, plus recyclability in communities with existing programs for PE film recycling (e.g., in-store drop-off in North America). In North America, many grocery stores, home centres, and department stores now offer containers for recycling a wide variety of films, wraps, and other plastic bags made from HDPE, LDPE and LLDPE, as well as packaging with the “How2Recycle” Store Drop-Off label.

A store drop-off recycling system for mono-material multilayer flexible packaging

Replicability Low, Medium, High	The practice requires a high level of technological advancement, market preparedness, or specific economic/political conditions to be successfully replicated.	**LOW**

Geographical area of implementation	North America
Country	USA
Contacts	The Dow Chemical Company is a US multinational corporation among the three largest chemical producers in the world. **https://www.dow.com/en-us.html**
For more information	**https://www.dow.com/en-us/brand/recycleready.html** **https://www.dow.com/content/dam/dcc/documents/en-us/mark-prod-info/768/768-39101-01-design-for-recyclability-overview.pdf** **https://www.dow.com/content/dam/dcc/documents/en-us/mark-prod-info/500/500-19801-01-a-flexible-and-recyclable-alternative-to-rigid-containers.pdf**
Similar case studies	Borealis Group - **https://www.borealisgroup.com/** - global

DESIGN FOR RECYCLING

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: MEDIUM

Name of the practice

Recyclable flexible packaging

Target plastic product	**Food Contact Packaging**
Examples	**Flexible packaging such as packets and wrappers**
Application	**Consumer Goods / Lifestyles** **Food and Beverage Manufacturing / Brand owners** **Retailers** **Hospitality and hotel, restaurant, and catering (HORECA) sector**

Plastic materials/ Polymer types in the original product

High barrier PET/PE
Nylon/PE
PET/metalized PET/PE
PET/Foil/PE
LDPE and LLDPE

Name and type of the substances of concern in the original product

- PFASs as grease-proofing agents
- NPEs/NPs as surfactants
- Phosphate antioxidants in food wraps
- Phthalates in plastic films
- Perchlorate as anti-static agent
- Bisphenols
- Contaminants: Heavy metals

Abstract

X-CYCLE is a range of recyclable flexible films developed by **A. Hatzopoulos S.A.** (Greece) that preserves the protective properties and functionality of conventional flexible films. The X-CYCLE solutions are designed for recycling through the PE/ PP/mixed polyolefins recycling streams, where available, according to the industry guidelines. The high-barrier, mono-material/homogeneous composites can replace conventional, non-recyclable laminates used for several sensitive products (coffee/ nuts, etc) with recycle-ready and lighter alternatives (with higher product-to-package ratio). Suitable for high-quality printing, good stiffness, hermetic sealing properties (even at lower temperatures), thus less energy consumption and reduced overall environmental impact.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Develop and align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment and enable a circular plastic economy.
- Bans or restrictions on the manufacture, use, distribution, sale, or trade of SUPPs.
- Binding minimum targets (percent by weight) of all packaging waste to be recycled (e.g., EU Packaging Waste Directive 94/62/EC)
- Binding targets requiring that all plastic packaging placed on the market must be reusable or recyclable in a cost-effective manner by 2030 (e.g., EU New Circular Economy Action Plan).
- Develop and implement product policies that focus on high quality design for recycling.

Technical enablers

The treatment of flexible packaging materials, particularly the multi-material multilayer ones, depends on local capabilities, regulations, investments, and priorities. A packaging can only be considered recyclable in a country/market if there is a realistic chance that it will be collected, sorted into a material fraction where it is recycled into a new material/product at scale and for which there are viable end market applications. To increase recyclability, more integration and transparency amongst all actors in the packaging value chain is needed. It is also important to pass information about chemical ingredients along the local and global value chains to ensure products and materials are safely managed.

Market and financial enablers

- Market-based measures such as taxes, fees and incentives aligned with CE outcomes.
- Use Green Public Procurement (GPP) to grow circular sustainable products markets.
- Provide interdisciplinary research funds.
- Innovation awards and challenges. The X-CYCLE packaging concept has received the Worldstar Packaging Award 2020 in the Packaging Materials category.
- Investments (through EPR or other systems) to advance the recyclability of film and flexible packaging and make progress towards recyclability targets.

Challenges

Recycling flexible multilayer packaging is technically and economically challenging: the process involves more steps than the traditional plastic recycling regimen as each layer has to be separated, analysed, identifies, and then recycled individually. Often most of the flexible multilayer packaging waste ends up in waste-to-energy facilities or landfills due to food contamination. With pricing for virgin resin consistently lower than recycled resin, the progress toward recycling flexible multilayer packaging cannot be made without important financial investment. Targeted initiatives such as the Australian REDcycle, which entailed partnerships with local supermarkets to collect and mechanically recycle mixed flexible packaging (including MMPP), reducing the leakage to the environment, have proved more challenging than expected and have failed. The development of recyclable flexible films/packaging requires high investments in R&D, technical capacities, and collaborations across the value chain. There are great collaborative initiatives in the works from forward-thinking groups. For example, in the USA, the Flexible Packaging Association has a strong focus on sustainable packaging and is working with several producers for packaging that is safe for the environment. The Sustainable Plastic Coalition, the Association of Postconsumer Plastic Recyclers (APPR) and The Flexible Film Recycling Group(FFRG) are also promoting and increasing public education and outreach on plastic film recycling. In the EU, CEFLEX is a collaborative initiative representing the entire value chain of flexible packaging. These initiatives are however mainly operating in developed countries.

Opportunities/ Benefits

The recyclability of the basic versions of the X-CYCLE films has been recently validated and independently certified by the German Institut Cyclos-HTP. X-CYCLE solutions can be applied on various existing packaging lines and formats (VFFS, HFFS, Doypack) and are suitable for packaging a broad range of consumer goods.

Replicability
Low, Medium, High

The practice requires certain specific requirements to be successfully replicated.

MEDIUM

Recyclable flexible packaging

Geographical area of implementation	Europe
Country	Greece
Contacts	Founded in 1931 in Greece, A. Hatzopoulos S.A. develops value-added flexible packaging solutions for the food and beverages, home-and personal care, cosmetics, and pharmaceuticals industries. It operates today on a worldwide level exporting 70 percent of its total sales to over 35 countries. **info@hatzopoulos.gr**
For more information	**https://hatzopoulos.gr/x-cycle-recyclable-packaging-films/**

DESIGN FOR RECYCLING

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: MEDIUM

Name of the practice

A recyclable fibre-based packaging

Target plastic product	**Food Contact Primary Packaging**
Examples	**Multilayer multilateral pouches**
Application	**Food and Beverage Manufacturing / Brand owners** **Retailers** **Hospitality and hotel, restaurant, and catering (HORECA) sector**

Plastic materials/ Polymer types in the original product

High barrier PET/PE
Nylon/PE
PET/metalized PET/PE
PET/ /PE

Name and type of the substances of concern in the original product

- PFASs as grease-proofing agents
- NPEs/NPs as surfactants
- Phosphate antioxidants in food wraps
- Phthalates in plastic films
- Perchlorate as anti-static agent
- Bisphenols
- Contaminants: Heavy metals

Abstract

Boardio® is a carton-based, cost-effective packaging solution with tailored low to high barrier protection. It mainly consists of renewable virgin fibres from sustainably managed forests (for the US market the fibres are also bleached). It includes a PE layer and a razor thin aluminium barrier, which is necessary to ensure gas tightness, product protection and shelf-life. At the same time, the packaging is designed for easy recycling in typical paper/carton board waste diversion programs. The Boardio® logistics have been optimized, with all components delivered flat to the customer. The Boardio® material reduces food waste, as well as the overall CO2/GHG impact.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Develop and align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment and enable a circular plastic economy.
- Bans or restrictions on the manufacture, use, distribution, sale, or trade of SUPPs.
- Binding minimum targets (percent by weight) of all packaging waste to be recycled (e.g., EU Packaging Waste Directive 94/62/EC)
- Binding targets requiring that all plastic packaging placed on the market must be reusable or recyclable in a cost-effective manner by 2030 (e.g., EU New Circular Economy Action Plan).
- Develop and implement product policies that focus on high quality design for recycling.

Technical enablers

- Promote integration and transparency amongst all actors in the packaging value chain, particularly on the content of new materials, to ensure products and materials are safely managed.
- Incorporate CE principles in higher education curricula, training programmes and apprenticeships.

Market and financial enablers

- Market-based measures such as taxes, fees and incentives aligned with CE outcomes.
- Use Green Public Procurement (GPP) to grow circular sustainable products markets.
- Provide interdisciplinary research funds.
- Innovation awards, prizes, challenges, and platforms, such as the World Economic Forum's Scale360° Playbook and UpLink.
- Investments (through EPR or other systems) to advance the recyclability of multi-material multilayer packaging (MMPPs) and make progress towards recyclability targets.

Challenges

A significant challenge for the alternative materials to MMPPs is to meet the performance requirements of oxygen and aroma barrier, where products like nylon and ethylene vinyl alcohol (EVOH) are typically used. One way of making those barrier structures recyclable is to reduce the amount of nylon and EVOH.

Opportunities/ Benefits

Flat delivery and an optimal use of material make Boardio® both environmentally sound and cost-efficient. Compared to glass jars, plastic tubs, and metal containers such as tin cans, which are delivered empty, the Boardio packaging reduces incoming goods by up to 95 percent simply by being delivered flat. Hence, not only the CO2 emissions and costs from transport by truck but also all the related handling and storage costs are reduced correspondingly. A fully utilized line, producing 30-40 million packs annually, can easily save the environment 500 tons of CO2 and save the producer several hundreds of work hours. A life cycle analysis shows Boardio® carbon emissions are 86 percent less than metal cans, and 78 percent less than moulded plastic canisters. In North America, the Western Michigan University (WMU) has performed tests confirming a high level of repulpability, with more than 80 percent fibre yield. Following the introduction in Canada by Club Coffee of the new AromaPakTM packaging, focus groups and home testing have revealed that 70 percent of consumers preferred AromaPakTM featuring Boardio® technology over traditional bags and cans. They believed this new packaging delivers a higher quality coffee experience than other packaging formats on the market today. An impressive 86 percent also expressed a willingness to switch to this new, innovative, and more sustainable pack format.

Replicability
Low, Medium, High

The practice requires certain specific requirements to be successfully replicated.

MEDIUM

Geographical area of implementation

North America | Europe

Contacts

AR Packaging is part of Graphic Packaging International and a leading provider of packaging solutions for food & consumer goods, beauty & cosmetics, confectionery, food service, tobacco, the pharmaceutical & medical industries and much, much more.
info@ar-packaging.com

For more information

https://www.ar-packaging.com/en/solutions/boardio/boardio-sustainability

Example of application: **https://clubcoffee.ca/innovation/aromapak-sustainable-products-solutions-systems/**

DESIGN FOR RECYCLING

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: HIGH

Name of the practice

Solid concentrated products in recyclable packaging

Target plastic product	**Food contact primary packaging**
Examples	**Tetra Pack cartons**
Application	**Food and Beverage Manufacturing / Brand owners Retailers**

Plastic materials/ Polymer types in the original product

Polyethylene (PE)
Aluminium
Cardboard
Biobased plastic cap

75 percent of the Tetra Pak carton is made from paperboard, 20 percent of polyethylene (PE) and 5 percent of aluminium

Abstract

The US start-up **JOI** has reimagined its product to change its packaging needs and improve the recyclability of the packaging. JOI makes concentrated nut paste for making nut milk and other food items at home. Shifting from a liquid product to a solid has changed the barrier requirements of the packaging, which can now be made to be recycled. It also allows more servings per container, reducing the overall amount of packaging needed. Joy's glass jars allow to save 85 percent of packaging waste.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Develop and align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment and enable a circular plastic economy.
- Bans or restrictions on the manufacture, use, distribution, sale, or trade of SUPPs.
- Binding waste reduction targets linked to effective sanctioning mechanisms for non-compliance.
- Binding minimum targets (percent by weight) of all packaging waste to be recycled (e.g., EU Packaging Waste Directive 94/62/EC)
- Binding targets requiring that all plastic packaging placed on the market must be reusable or recyclable in a cost-effective manner by 2030 (e.g., EU New Circular Economy Action Plan).
- Develop and implement product policies that focus on high quality design for recycling.
- Develop and implement awareness raising campaigns.

Technical enablers

- Promote integration and transparency amongst all actors in the packaging value chain, particularly on the content of new materials, to ensure products and materials are safely managed.
- Incorporate CE principles in higher education curricula, training programmes and apprenticeships.

Market and financial enablers

- Market-based measures such as taxes, fees and incentives aligned with CE outcomes.
- Well-designed EPR schemes, extended to both producers and retailers or distributors.
- Use Green Public Procurement (GPP) to grow circular sustainable products markets.
- Provide interdisciplinary research funds.
- Innovation awards, prizes, challenges, and platforms, such as the World Economic Forum's Scale360° Playbook and UpLink.

Challenges

JOI powder products are packaged in glass jars and in plastic pouches. Despite JOI claims that the pouches are safe for both industrial and home composting, it is known that compostable packaging do not easily break down as expected under home composting conditions. Moreover, if disposed of together with recyclable plastics, they can disrupt the commercial recycling streams.

Opportunities/ Benefits

Concentrated plant-based milk pastes have naturally long shelf lives without the use of preservatives or required refrigeration. YOI pastes and powders allow consumers to avoid gums, fillers, and food additives to bind or bulk the milk.

Replicability
Low, Medium, High

The practice can be easily replicated in similar economic, technological, and political settings.

HIGH

Geographical area of implementation

North America

Country

USA

Contacts

JOI is a US-based small business established in 2015.

For more information

https://addjoi.com/

DESIGN FOR RECYCLING

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: HIGH

Name of the practice

Recyclable Ocean Bound Plastic packaging

Target plastic product	**Primary packaging**
Application	**Consumer Goods / Lifestyles** **Food and Beverage Manufacturing / Brand owners** **Retailers** **Hospitality and hotel, restaurant, and catering (HORECA) sector**
Plastic materials/ Polymer types in the original product	High-Density Polyethylene (HDPE)

Abstract

Envision Plastics produces OceanBound Plastic (OBP) by using HDPE plastic waste from within 50 km of waterways and coastlines in areas that lack formal community-based recycling collection. As a result, there is a high likelihood that the plastic in these at-risk zones will enter the ocean. OBP collected from developing countries is shipped to the USA where it is used by Envision Plastics to produce film, as well as injection and blow moulding products, making it suitable for a wide range of packaging applications, including food contact applications. At the end-of-life, OBP can be recycled in the same channels and processes as any other HDPE product. Envision Plastics works with Qualified Partners in the interested coastal areas to professionalize the collection stream, collect the plastic, and manufacture it into usable products. Qualified Partners must satisfy several criteria before they can be considered a supplier for OBP source material, including being certified and undergo regular on-site inspections.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mainstream CE principles into national and international policies.
- Develop and align chemical legislation, restrictions, and bans to eliminate substances of concern to health and the environment and enable a circular plastic economy.
- Bans or restrictions on the manufacture, use, distribution, sale, or trade of SUPPs.
- Binding waste reduction targets linked to effective sanctioning mechanisms for non-compliance.
- Binding minimum targets (percent by weight) of all packaging waste to be recycled (e.g., EU Packaging Waste Directive 94/62/EC)
- Binding targets requiring that all plastic packaging placed on the market must be reusable or recyclable in a cost-effective manner by 2030 (e.g., EU New Circular Economy Action Plan).
- Mandatory minimum recycled content requirements for pre-consumer, post-industrial and pre-consumer recycled content to drive innovation and markets and fosters continual improvement through increasing requirements over time (e.g., the EU Single-use Plastic Directive that sets a specific target of incorporating 25 percent of recycled plastic in PET beverage bottles from 2025, and 30 percent in all plastic beverage bottles from 2030. UK is applying the same requirements). Ensure effective reporting and implement enforcement and penalties to incentivize compliance.

- Strong supply-side policies to increase the collection and processing of recyclables, such as the extended producer responsibility (EPR) and beverage container deposit return system (bottle bills).
- Develop and implement consumer education and awareness raising campaigns.

Technical enablers

Several initiatives have been established to support the production of OBP:

- NextWave Plastics is a consortium of multinational technology and consumer brands gathering to rapidly decrease the volume of plastic litter entering the ocean by developing the first global network of ocean-bound plastic supply chains.
- Ocean Bound Plastic certifications and labels were created by the NGO Zero Plastic Oceans to attest that OBP plastic waste is collected adequately and ethically, it is well managed once collected, and commercially recyclable OBP waste is traceable until the final recycled product.
- OceanCycle is a social enterprise also focused on preventing ocean plastic pollution and improving livelihoods in coastal communities through certification and direct social interventions.

Market and financial enablers

The concept of OBP is highly marketable and can attract consumers and investors. And investment is needed to help the sector grow, keep costs at competitive levels, improve infrastructure and logistics.

Volumes of OBP currently available remain small, and on average more expensive than conventional recyclates. While OBP products are expected to sell at a premium price, converters and traders are under pressure from brands that want them to supply recycled content at the lowest possible price. It is a financially challenging situation for recyclers. Ironically, however, the success of all ocean-bound plastics initiatives will be measured when there is no longer any OBP left to collect because the right waste management infrastructure is in place to prevent any plastic from getting anywhere near the coast in the first place.

Challenges

Collecting all OBP is a challenge that involves various actors and stakeholders, from waste pickers, recycling industries and waste treatment industries. If getting commercially recyclable OBP collected is relatively simple, when it comes to low or no value plastic it becomes harder. Concerns are also being raised about the safety of recycling ocean-bound plastic for use in food contact materials. Not only for the toxicity due to the polymers and their additives but also due to the toxic substances from ocean water, like PCBs, DDT, dioxins, and others, that might be absorbed by the OBP.

Opportunities/ Benefits

The US FDA has issued a Letter of Non-Objection (NOL) regarding the suitability of Envision's OceanBound Plastic when used at levels up to 100 percent in recycled HDPE packaging for all food types under Conditions of Use C-H. OBP is already collected in many developing countries across the globe. Through programs such as the OBP Certification Program, NextWave Plastics, and OceanCycle, new coastal communities can easily join and become trusted suppliers of OBP. In addition, Envision Plastics has made the recycling and shipping of OB material to the USA profitable for local communities.

Replicability
Low, Medium, High

The practice can be easily replicated in similar economic, technological, and political settings.

HIGH

Geographical area of implementation	North America
Country	USA
Contacts	Envision Plastics was established in 2001 in the USA. In June 2014, Envision was acquired by Consolidated Container Company and continues to operate as a distinct business within the CCC family to deliver innovative, sustainable, and reliable post-consumer resin solutions that meet and exceed the needs of retailers, consumers, and packaging customers.
For more information	**https://envisionplastics.com/oceanbound-plastic/**
Similar case studies	SABIC and PescaNova - **https://www.sabic.com/en/news/33462-sabic-certified-circular-pe-from-ocean-bound-plastic-used-in-pescanova-sea-food-packaging** - Saudi Arabia and Portugal EpTech - **https://www.eptech.co.nz/ocean-bound-plastic/** - New Zealand Lidl - **https://corporate.lidl.co.uk/media-centre/pressreleases/022020_ocean-boundplastic** - UK

DESIGN FOR RECYCLING

IMPLEMENTATION: COMMERCIAL USE

REPLICABILITY: HIGH

Name of the practice

Additive solutions to improve plastics mechanical recycling

Target plastic product	**Any packaging**
Application	**Recyclers, compounders, and converters**

Plastic materials/ Polymer types in the original product

Recycled HDPE, polyolefins, and mixed polymers
Recycled LDPE and LLDPE for incorporation into films and related flexible packaging applications
Recycled PP and polyolefin blends containing impurities
Reclaimed HDPE and PP blends for reuse in outdoor goods.
Polyolefin recyclates

Abstract

BASF's **IrgaCycle** line includes a range of different additive formulations that can help increase the percentage of recycled content in several end-use applications, including packaging. IrgaCycle line is tailored to enhance the quality of post-consumer and post-industrial polyolefin material for reuse in rigid, flexible, and moulding applications across various target industries.

State of implementation

COMMERCIAL USE

Legislative/ Policy enablers

- Mandatory minimum recycled content requirements for pre-consumer, post-industrial and pre-consumer recycled content to drive innovation and markets and fosters continual improvement through increasing requirements over time (e.g., the EU Single-use Plastic Directive that sets a specific target of incorporating 25 percent of recycled plastic in PET beverage bottles from 2025, and 30 percent in all plastic beverage bottles from 2030. UK is applying the same requirements). Ensure effective reporting and implement enforcement and penalties to incentivize compliance.
- Strong supply-side policies to increase the collection and processing of recyclables, such as the extended producer responsibility (EPR) and beverage container deposit return system (bottle bills).
- Voluntary corporate commitments for use of recycled content

Technical enablers

- Harmonized certification program for recycled content that benchmarks average content within a category of products or packaging.
- Increase packaging's recyclability while also using an optimal level of additives to reduce the overall additive content, and phenol-free solutions.

Market and financial enablers

- Use GPP policies to favour recycled content products.

Challenges

Major challenge for recycled plastics is mitigating polymers' quality deficiencies from thermal and mechanical stress during the recycling process. In addition, recycled plastics often contain impurities and polymer contaminants that accelerate polymer degradation, which change the material properties.

Opportunities/ Benefits

IrgaCycle enables recyclers, compounders, and converters to reach their environmental sustainability targets while mitigating quality deficiencies of polymers arising from thermal and mechanical stress during the recycling process. A specific advantage of these blends lies in their ready-to-use product forms, which are easy to apply in the recycling steps. The granulated non-dusting product form ensures safe and easy dosage during converting or compounding of reclaimed material. In addition to enabling plastic circularity, IrgaCycle bring value to plastic applications by improving durability, reducing waste, saving energy, and reducing emissions.

Replicability
Low, Medium, High

The practice can be easily replicated in similar economic, technological, and political settings.

HIGH

Geographical area of implementation

Global

Country

Germany

Contacts

BASF plastic additives is a leading supplier, manufacturer, and innovation partner of plastic additives. It is part of BASF's Performance Chemicals division. BASF Group is a German multinational chemical company and the largest chemical producer in the world.
www.basf.com.

For more information

https://www.basf.com/global/en/who-we-are/sustainability/whats-new/sustainability-news/2021/basf-introduces-irgacycle.html

PART 2 Insights from the Study

A. Public access to reliable and harmonized data on chemical substances associated to SUPPs

29. Out of the over 10,000 substances recently identified as associated with plastics, many are hardly studied and are not adequately regulated in many parts of the world[29].

30. There is substantial shortage of or lack of access to:

    a. information and data on the use of substances in plastics, on which substances are used in what application and in what quantities and at which levels they are present in finished plastic products;

    b. the properties, toxicity, and use patterns of these substances. No harmonized toxicological information, such as the Classification, Labelling and Packaging (CLP) hazard classification[30] is currently available for many substances that are associated with plastic packaging, even for substances for which hazards have been identified and characterized in academic studies.

31. This lack of publicly accessible information is prominent even for those products that are in direct contact with foods and therefore can be assumed to directly contribute to population-wide human exposure to substances of concern in plastics[31].

32. While commercial websites and companies could be or are in possession of potentially detailed chemicals-related information, they largely limit access to non-commercial, academic research purposes. This hampers public efforts to build complete national/regional chemical inventories.

33. Significant data gaps also exist for authoritative hazard information limiting the ability to perform accurate risk assessment (i.e., incorporating an exposure component). Yet hazard or risk assessments, conducted based on peer-reviewed literature and then made publicly available, could serve to inform, and guide substitution efforts[32].

34. Most of the publicly available information on substances used in plastic products is in the EU and the US. This is largely due to regulatory frameworks like the European Chemicals Agency's (ECHA) REACH (Registration, Evaluation, Authorisation, and Restriction of Chemicals) regulation in the European Union and the Toxic Substances Control Act (TSCA) in the United States.

35. Several projects have been initiated recently to address this need and improve the communication of information on substances in products along supply chains:

    a. The Proactive Alliance, an industry group, aims to develop a set of standards to support the sharing of information on chemicals in products across sectors.

    b. The non-profit Healthy Building Network's Pharos project, which provides resources to assess human and environmental health hazards of chemicals and building materials, plus tools to collaborate to find safer alternatives. The goal of this effort is to reduce the use of hazardous chemicals and improve the inherent safety of materials and products.

29 Wiesinger, H., Wang, Z. and Hellweg, S. (2021) "Deep Dive into Plastic Monomers, Additives, and Processing Aids," *Environmental Science & Technology*, 55(13), pp. 9339–9351. Available at: https://doi.org/10.1021/acs.est.1c00976.

30 The Classification, Labelling and Packaging (CLP) Regulation ((EC) No 1272/2008) aligns previous EU legislation with the Globally Harmonised System of Classification and Labelling of Chemicals (GHS), a United Nations system to identify hazardous chemicals and to inform users about these hazards. It also has links to the REACH legislation. The CLP Regulation entered into force on 20 January 2009 and progressively replaced the classification and labelling of Dangerous Substances (67/548/EEC) and Dangerous Preparations (1999/45/EC) Directives. Both directives were repealed on 1 June 2015.

31 Groh, K.J. et al. (2019) "Overview of known plastic packaging-associated chemicals and their hazards," *Science of the Total Environment*, 651, pp. 3253–3268. Available at: https://doi.org/10.1016/j.scitotenv.2018.10.015.

32 Ibid.

c. The Substances of Concern In Articles or Products Database (SCIP database) hosted by the European Chemicals Agency (ECHA), as part of the European Union (EU) Waste Framework Directive (WFD) (2008/98/EC), which stores safe-use information for substances of very high concern (SVHCs) present in articles placed on the market in the EU.

d. The Database on Migrating and Extractable Food Contact Chemicals (FCCmigex) systematically maps the scientific evidence of food contact chemicals (FCCs) that have been measured in migrates and extracts of food contact materials and articles. It was compiled by a team of researchers from the Food Packaging Forum together with colleagues from eight academic institutions. The scientists analysed 1,210 scientific studies that resulted from a systematic literature search and passed a two-phase screening process. In total, the database contains more than 3,000 FCCs and over 22,000 database entries.

e. The US Environment Protection Administration (EPA)'s Design for the Environment (DfE) Safer Choice helps consumers, businesses, and purchasers find products that perform and contain ingredients that are safer for human health and the environment. Safer Choice is an EPA Pollution Prevention (P2) program, which includes practices that reduce, eliminate, or prevent pollution at its source, such as using safer ingredients in products. These labels are voluntary: no company is required to subject its product(s) to Safer Choice or DfE assessment.

The scientists analysed 1,210 scientific studies that resulted from a systematic literature search and passed a two-phase screening process. In total, the database contains more than 3,000 FCCs and over 22,000 database entries.

36. However, the effective implementation of these initiatives is currently hindered by factors such as (claims of) complex supply chains, diverging interests, and technical capacities of actors within supply chains, and data storage and transfer issues.

37. Possible solutions to these issues include:

    a. An open and transparent centralized knowledge base of substances in products with inputs and support from all relevant stakeholders along the supply chains (e.g., chemical and material producers, product designers, retailers, and waste managers) could be established. This could be pursued building on existing public databases (e.g., PubChem, SciFinder, OECD eChemPortal, CAS Common Chemistry, and USEPA Comp-Tox Chemicals Dashboard) and industrial transparency initiatives (e.g., Global Automotive Declarable Substance List (GADSL), the HolyGrail project led by P&G). It can contribute to a better overview of relevant substances and related information and thus provide a basis for prioritization of future work, for example, based on production volumes and/or hazardous properties.

    b. The high costs associated with these initiatives might be co-funded through public-private partnerships, at global and regional, as a part of companies' corporate social responsibility and commitments to the human right to science.

    c. Information exchange standards across the existing major databases might be harmonized to allow easy retrieval and compilation of information at one central place.

    d. Finally, strong leadership through national and/or international governmental organizations (e.g., UNEP, OECD, ECHA) is needed for the setting up of this open and transparent centralized knowledge base of chemicals in products.

B. Legislation falling behind constantly evolving plastic manufacturing innovations

38. Current regulations, scientific and regulatory monitoring efforts, and industry initiatives seem to fall far behind the introduction of new substances in plastic manufacturing. A global sustainable management of substances is thus not achieved for several reasons, such as:
    a. not all substances of potential concern are listed under relevant international or regional regulations (e.g., Stockholm Convention);
    b. substance-by-substance regulations may not protect against regrettable substitutions;
    c. regional regulations might lead to shifting chemical pollution elsewhere;
    d. negative externalities (e.g., monitoring costs, potential clean-up costs, public health damages, and impaired ecosystem services) of substances throughout their life cycles are not fully addressed by current regulations;
    e. legislation often becomes outdated because risk assessment (RA) studies take time and are difficult to perform due to the lack of publicly available data and information on the substances associated with the products. In addition, not all data in the public domain are readily machine accessible and processable. For example, NIASs are not yet comprehensively understood, their identification remains challenging, not least because of a dearth of clarity on plastic compositions and conditions during production and use, and analytical difficulties of unequivocally identifying substances at low concentrations remain.

39. Possible solutions to these issues include:
    a. Increase the number of substances under regulatory scrutiny to cover all substances of potential concern.
    b. Focus on group-or class-based regulatory approaches to avoid substituting one hazardous substance with another hazardous one in the same group or class.
    c. Complement current regulation with market-based policy instruments (e.g., tradable use permits or a Pigouvian tax, where the raised governmental revenue is used to finance clean-up or chemical-related public health costs and helps to create financial incentives for avoiding the use of hazardous or unnecessary chemicals) to internalize externalities and incentivize true innovation and pioneers.
    d. Increase product transparency through company reporting on the polymers and additives used in the products and their concentrations, as well as hazard data of the substances used.

40. Overall, concerted efforts from industry, civil society organizations, the scientific community, regulatory agencies, and other policymakers are urgently needed to ensure sustainable chemicals management in the future.

C. Regulatory heterogeneity

41. Regulatory focus, approaches, and maturity vary considerably by region and diverge even further when viewed at the country or state level.

42. Established or aligned terminology is not in place globally, for example, the term recycling can have different meanings, leading to variable intensity of impact for the industry.

43. In more mature countries, some regulations focus on multiple categories, applications, end-products, and materials, while others focus on specific aspects, creating potential overlap with different regulations covering a similar scope. For example, the current European chemicals regulations mostly focus on single substances and/or certain industrial sectors (e.g., plastics for food-contact purposes, in toys, in electrical and electronic equipment, and in automotive applications), whereas current industrial circular economy initiatives focus primarily on the material level (e.g., using the same polymer for multilayer plastics to increase recyclability), with limited attention paid to the chemicals therein. In low-income countries, regulations are often in early stages of development, leading to uncertainty around undefined scopes, action plans, or targets.

44. This heterogeneity is making the fast-changing regulatory landscape complex to navigate on a worldwide basis. In addition, within the scope of this study, it has been observed that countries with stricter, well enforced and monitored regulations tend to have a higher number of innovative plastic waste prevention and minimisation practices in place.

45. Governments can and do play a critical role in spurring innovation, through regulations and by actively creating new markets through public-private partnerships, public procurements, direct investments, infrastructure, etc.

Governments can and do play a critical role in spurring innovation, through regulations and by actively creating new markets.

46. Possible solutions to these issues include:
    a. A legally binding instrument (under negotiation as of July 2024) to allow governments to tackle plastic pollution in a coordinated and comprehensive way, covering the whole lifecycle of plastics, making sure that in the coming decades a circular economy approach to the plastic value chain is implemented around the world[33].
    b. Foster cooperation among regulators from different fields and regions to ensure consistent measures and avoid shifting pollution to countries with less stringent regulations.
    c. To ensure industry actors comply with the evolving requirements, companies could stay up to date with or attuned to regulation developments (regulatory watch) by tracking changes in their focus markets and implement processes to address future requirements proactively as noncompliance could lead to the imposition of tax increases or penalties.

D. Regrettable "drop in" substitutions of substances of concern

47. While in some instances a substance of concern can be simply eliminated, in many cases these chemicals perform a key function in a product and a replacement chemical is necessary. Too often, companies replace the chemical of concern with one with the same structure and properties not yet subject to regulation.

48. To speed up the identification of substances that need regulatory action and to avoid regrettable substitutions, substances could be assessed and classified by looking at the groups formed according to structural and/or functional similarity rather than as single substances.

33 Resolution adopted by the United Nations Environment Assembly (UNEA) on 2 March 2022, 5/14. End plastic pollution: towards an international legally binding instrument. Available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/38525/k2200647_-_unep-ea-5-l-23-rev-1_-_advance.pdf?sequence=1&isAllowed=y

49 Possible solutions to these issues include:

a. Currently, tools are being developed allowing to weed out structurally similar chemicals with likely similar toxicity when searching for alternatives, for example, the SINimilarity tool developed by ChemSec, or The Commons Principles for Alternatives Assessment, developed by the Environmental Defense Fund (EDF) together with BizNGO with the support of over 100 representatives of business, universities, and NGOs in the US. Regulatory agencies are also increasingly applying grouping-based approaches to perform hazard and risk assessments for certain types of chemicals. According to ECHA, the grouping approach is believed to bring consistency and improve the coherence of regulatory work, make it faster to identify substances that need regulatory action as well as those for which no further action is needed at this stage, and to support informed substitution by industry[34].

b. In addition, the focus of toxicity testing may need to shift towards looking at the mixtures of chemicals present in a finished packaging article. This would allow evaluating the effects of unknown NIAS, and account for mixture toxicity of multiple substances.

E. Substitution of single-use products made of plastics with single-use products made of alternative materials

50. Substituting SUPPs with other single-use products made of a different material is not always the most environmentally friendly option. According to LCA studies, no single-use product is better than the other in all environmental impact categories[35]. Often the change simply produces a burden shift. From an environmental and health perspective, reusables are shown to be generally preferable to single-use products as in most cases, reuse helps reduce resource extraction, energy use, and waste generation by avoiding the manufacturing of new products from virgin materials, and even if recycling is available for single-use materials, the reduction in impacts achieved by using reusables is usually much higher. However, reusables only achieve their fullest potential if they do not include substances of concern, are reused as many times as possible, contain recycled content where possible, collection losses in the reverse logistics are minimized, and the additional logistics, transportation and washing cycles do not lead to higher environmental burden.

51. Possible solutions to these issues include applying a life cycle approach to identify trade-offs and prevent burden-shifting among value chain stages, when (re)designing a product.

F. Substitution of fossil-based with biobased plastics

52. The potential contribution of biobased plastics to a more circular plastic economy is still unclear. The evidence base is still developing in relation to these new types of plastic, particularly in terms of their environmental impacts in comparison to alternatives.

53. There are currently no policies or regulations that directly target raw materials for biobased plastics (besides hazardous chemical legislations such as REACH)[36]. There is no mandatory minimum biobased content, no global sustainability criteria that apply to biobased plastics, nor agreed certification scheme or label for a plastic product to be labelled as biobased. In 2021, the European Technical Committee for Standardisation for biobased products (CEN/TC 411) developed a set of standards for the biobased sector for measuring and reporting on biobased content in plastic products, sustainability aspects and terminology, but these are only voluntary standards.

34 *All news - ECHA* (2022). Available at: https://echa.europa.eu/-/group-assessment-of-bisphenols-identifies-need-for-restriction.
35 United Nations Environment Programme (2021) "Addressing Single-use Plastic Products Pollution Using a Life Cycle Approach." Nairobi. Available at: https://www.unep.org/resources/publication/addressing-single-use-plastic-products-pollution-using-life-cycle-approach
36 UNPRI (2021) "The plastics landscape: regulations, policies, and influencers." Available at: https://www.unpri.org/plastics/the-plastics-landscape-regulations-policies-and-influencers/4953.article.

54. Today, biobased plastics represent less than 1 percent of the global plastics production[37]. No biobased plastics is commercialized on a large scale, mainly due to: i) higher production costs than fossil-based ones; ii) a host of technical challenges, from low reactor space-time yields to large variation in feedstock composition and structure, leading to an increase in by-products, which means added costs in separations, especially if one seeks drop-in replacements to conventional plastics; iii) limited investments from the traditional plastics industry that tends to be conservative and risk averse[38].

55. In addition, studies have shown that biobased plastics are similar to conventional plastics when it comes to content of hazardous substances. This highlights the need to focus more on aspects of chemical safety when designing truly sustainable plastic alternatives[39].

56. Possible solutions to these issues include:

    a. International standards for biobased plastics could be defined.

    b. Government legislation could address risk and at the same time incentivise truly circular material innovations. For example, the Communication for an EU policy framework on biobased, biodegradable, and compostable plastics[40] brings clarifications on biobased, biodegradable, and compostable plastics and sets out the conditions to ensure that the overall environmental impact of their production and consumption is positive.

G. Substitution of conventional plastics with biodegradable and compostable plastics

57. Biodegradation is an important characteristic of plastics as it determines whether they will persist and accumulate in the environment. Both fossil-based and biobased plastics can be engineered to decompose at the end of their life by the conversion of all their organic constituents (polymers and organic additives) mainly into carbon dioxide and water, new microbial biomass, mineral salts and, in the absence of oxygen, methane. Compostable plastics are a subset of biodegradable plastics designed to biodegrade under controlled conditions, typically through industrial composting in special facilities for composting or anaerobic digestion.

58. The ability of a plastic to biodegrade, and how quickly that happens, it is not only inherent to the material properties, but it strongly depends on the environmental conditions it is exposed to. For example, industrially compostable plastics can biodegrade only under specific environmental conditions provided by a compatible biowaste collection and treatment system.

59. In addition, biodegradable plastics can release the additives used to produce them directly to the environment and do so quicker than conventional plastics[41].

60. European standards[42] exist for assessing the compostability of plastics in industrial composting plants and the biodegradability of mulch films in soil for use in agriculture. There is no international standard for assessing biodegradability in water, as the variable conditions in freshwater and marine environments make standardisation difficult[43].

37 European Bioplastics market data. Available at: https://www.european-bioplastics.org/market/.
38 Filiciotto, L. and Rothenberg, G. (2021) "Biodegradable Plastics: Standards, Policies, and Impacts," *Chemsuschem*, 14(1), pp. 56–72. Available at: https://doi.org/10.1002/cssc.202002044.
39 Zimmermann, L. et al. (2020) "Are bioplastics and plant-based materials safer than conventional plastics? In vitro toxicity and chemical composition," *Environment International*, 145, p. 106066. Available at: https://doi.org/10.1016/j.envint.2020.106066.
40 *Communication – EU policy framework on biobased, biodegradable, and compostable plastics* (2022). Available at: https://environment.ec.europa.eu/publications/communication-eu-policy-framework-biobased-biodegradable-and-compostable-plastics_en.
41 Qin, M. et al. (2021) "A review of biodegradable plastics to biodegradable microplastics: Another ecological threat to soil environments?," *Journal of Cleaner Production*, 312, p. 127816. Available at: https://doi.org/10.1016/j.jclepro.2021.127816.
42 European standard EN 13432:2000.
43 EEA Briefing no. 09/2020 "Biodegradable and compostable plastics challenges and opportunities." Available at: https://www.eea.europa.eu/publications/biodegradable-and-compostable-plastics

Continued support for research, innovation, and investment is needed to ensure plastics are safe and sustainable by design and that can biodegrade safely considering the possible transfer to other environments, biodegradation timeframes, and any negative long-term effects.

61. For all these reasons, the simple "drop-in" substitution of conventional plastics with biodegradable and/or compostable plastics does not represent a sustainable solution, particularly for SUPPs that are prone to be inappropriately disposed of or littered.

62. Possible solutions to these issues include:

    a. Continued support for research, innovation, and investment is needed to ensure plastics are safe and sustainable by design and that can biodegrade safely considering the possible transfer to other environments, biodegradation timeframes, and any negative long-term effects.

    b. Consistent and science-based testing for biodegradation of plastics in the open environment are essential to clarifying the concepts of biodegradability and compostability, while addressing the presence of toxic or adverse effects on the environment.

    c. International biodegradability and compostability standards could provide strategic guidance on the appropriate use of biodegradable and compostable plastics.

H. Substitution of multi-material multilayer materials with mono-material multilayer materials

63. The reduced weight and higher protection of multi-material multilayer plastic packaging (MMPP) make them particularly convenient as they reduce shipping costs and increase the shelf life of foods/products[44]. However, these materials consist of inextricable layers of different materials with different properties and melting points meaning they do not lend themselves to recycling. If recycled, the resulting plastic will be inferior in quality. In addition, collection and sorting is usually insufficient due to poor market value and/or lack of Extended Producer Responsibility (EPR) scheme support, as well as low value and yields due to presence of organics, ink, moisture, UV barriers and other polymers.

64. Mono-material multilayer plastic packaging has been developed by major petrochemical companies (e.g., the "RecycleReady" launched by the company Dow in the US, or the mono-material multilayer structure made of different PE layers by Borealis (Europe) in Europe, or the pouches for pet food made of PP structure coated with an ultra-thin barrier announced by Nestle and Amcor). However, the shift from multi- to mono-material multilayer plastic packaging could bring other burdens, such as decreased packaging quality, and product losses/food waste. For food-contact purposes, regulation and contamination factors might also hinder closed-loop mechanical recycling. Furthermore, alternatives to replace MMPP usually comprise mono-material layers coated with additives, which could probably increase contamination in conventional mechanical recycling, leading to a demand for additional recycling treatment steps.

44 Kaiser, K., Schmid, M. and Schlummer, M. (2017) "Recycling of Polymer-Based Multilayer Packaging: A Review," Recycling, 3(1), p. 1. Available at: https://doi.org/10.3390/recycling3010001.

I. Substitution of plastics with paper and paper-based material

65. Paper or cardboard packaging does not necessarily represent a more sustainable alternative to plastics. Various hazardous substances in printing inks, surfactants, bleaching agents, and the like, are incorporated in the paper during its manufacturing. These chemicals might then leach at any stage of the life cycle of the paper products. For these reasons, often recycled paper and paperboard do not fulfil the requirement for direct contact food packaging applications. In addition, paper can only be recycled maximum six to seven times without significant loss in quality.

66. Chemical coatings are used in conjunction with almost every packaging substrate: BPA with rigid plastic containers and metal cans, PFAS with flexible paper, and phthalates with soft plastics. Consequently, stakeholders across the packaging value chain, from raw-materials producers to converters and end users, are affected by chemical-substance regulations. Several packaging end users have taken swift action to phase out, or commit to phasing out, BPA, PFAS, and phthalates, as well as other substances of concern from their packaging. For example, over the past two years, many well-known retailers have implemented global chemical bans across their packaging portfolios, moves that will have a major impact on their packaging suppliers.

67. In particular, the continued use of PFAS in food packaging should be avoided particularly in plant fibre-based food packaging (e.g., moulded cardboard bowls), which could be seen as a regrettable substitution for single-use plastic products[45].

68. Legislation could be developed addressing the migration limits of hazardous substances into food from paper packaging, as well as the disposal techniques to be followed and usage of recycled paper for food packaging applications. Similar to plastics identification codes, a paper identification code depending on the material used, additives incorporated, number of recycling treatment could be developed[46].

Several packaging end users have taken swift action to phase out, or commit to phasing out, BPA, PFAS, and phthalates, as well as other substances of concern from their packaging. For example, over the past two years, many well-known retailers have implemented global chemical bans across their packaging portfolios, moves that will have a major impact on their packaging suppliers.

45 Schwartz-Narbonne, H. et al. (2023) "Per-and Polyfluoroalkyl Substances in Canadian Fast Food Packaging," *Environmental Science and Technology Letters* [Preprint]. Available at: https://doi.org/10.1021/acs.estlett.2c00926.

46 Deshwal, G.K., Panjagari, N.R. & Alam, T. (2019) "An overview of paper and paper based food packaging materials: health safety and environmental concerns." *J Food Sci Technol* 56, 4391–4403 (2019). https://doi.org/10.1007/s13197-019-03950-z

PART 3 Guides, Guidelines and other Resources to safely minimize and prevent plastic waste

This section outlines the available guides, guidelines and other resources identified on the topic of plastic waste prevention and minimization.

What for	What	Owner	Description	Link
NEW BUSINESS MODELS	**The Circular Design Guide**	The Ellen MacArthur Foundation and IDEO	The guide provides insights on the theory of the circular economy, and guidance for designers to understand, define, make, and release circular innovations.	**https://www.circulardesignguide.com/**
NEW BUSINESS MODELS	**The Circular Business Model**	The Ellen MacArthur Foundation and IDEO	A Business Model canvas that guides organisations in rethinking their business model.	**https://www.circulardesignguide.com/post/circular-business-model-canvas**
NEW BUSINESS MODELS	**Circular Economy an introduction**	TU Delft and co-created with the Ellen MacArthur Foundation and the Leiden-Delft-Erasmus Centre for Sustainability.	An online course that explains the Circular Economy: how businesses can create value by reusing and recycling products, how designers can come up with amazingly clever solutions, and how you can contribute to make the Circular Economy happen.	**https://online-learning.tudelft.nl/courses/circular-economy-design-and-technology/**
NEW BUSINESS MODELS	**Circular Design Product Assessment**	TU Delft	An online course that helps design professionals such as product architects and industrial design engineers to make their products more circular.	**https://online-learning.tudelft.nl/courses/circular-product-design-assessment/**
NEW BUSINESS MODELS	**The Upstream innovation**	The Ellen MacArthur Foundation and IDEO	The Upstream Innovation guide and case studies that help harness the power of upstream innovation in packaging as a root-cause solution to plastic waste.	**https://plastics.ellenmacarthurfoundation.org/upstream**
NEW BUSINESS MODELS	**Guidance for Selecting Alternatives to Single-use Plastics**	The Government of Canada	To help businesses and organisations transition away from these products, the Government of Canada has developed this guidance document outlining important considerations to take into account when selecting alternative products or systems that prevent plastic pollution and help the transition to a circular economy. It was published in the wake of the publication of the Single-use Plastics Prohibition Regulations.	**https://www.canada.ca/en/environment-climate-change/services/managing-reducing-waste/consultations/proposed-single-use-plastics-prohibition-regulations-consultation-document.html**
SAFE AND CIRCULAR MATERIAL SELECTION	**The Safe & Material Choices Smart Material choice**	The Ellen MacArthur Foundation and IDEO	An online platform that provides specific indications on how to choose safe materials by exploring the impacts of material choices at each phase of the product's life cycle (during production, the use phase, waste management, and when bringing materials back into the system again).	**https://www.circulardesignguide.com/safe-circular**
SAFE AND CIRCULAR MATERIAL SELECTION	**Smart Material choice**	The Ellen MacArthur Foundation and IDEO	Simple steps to help make better choices about what materials go into the products as well as their impact on the wider system.	**https://www.circulardesignguide.com/post/materials**
DESIGN FOR OPTIMISED RESOURCE USE	**The management guidelines of the "Round Table for the Eco Design of Plastic Packaging"**	Round Table EcoDesign of Plastic Packaging	The Round Table EcoDesign of Plastic Packaging provides management guidelines, a toolbox, and practical examples to eco-design plastic packaging.	**https://ecodesign-packaging.org/en/**

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What for	What	Owner	Description	Link
DESIGN FOR OPTIMISED RESOURCE USE	**Unwrapped**	Zero Waste Europe	A set of studies that provide recommendations on how to reduce overpackaging and successful case studies.	**https://zerowasteeurope.eu/library/unwrapped/**
SUBSTITUTION OF HAZARDOUS SUBSTANCES	**A Chemicals Perspective on Designing with Sustainable Plastics: Goals, Considerations and Trade-offs**	OECD	A simple guide to enable the creation of inherently sustainable plastic products by integrating sustainable chemistry thinking in the design process. The study focuses on the chemical's perspective of the material selection process when plastic is the material of choice.	**https://www.oecd.org/publications/a-chemicals-perspective-on-designing-with-sustainable-plastics-f2ba8ff3-en.htm**
SUBSTITUTION OF HAZARDOUS SUBSTANCES	**OECD Substitution and Alternatives Assessment Toolbox (SAAT)**	OECD	A compilation of resources relevant to chemical substitution and alternatives assessments.	**http://www.oecdsaatoolbox.org/**
SUBSTITUTION OF HAZARDOUS SUBSTANCES	**The Six Classes**	The Green Science Policy Institute	A program designed to reduce the use of harmful chemicals in consumer and other products. It focuses on entire classes or groups of chemicals of concern, rather than phasing out problematic chemicals one at a time.	**https://www.sixclasses.org/**
SUBSTITUTION OF HAZARDOUS SUBSTANCES	**ChemFORWARD's cloud-based tool**	ChemForward	The website pools together data from some of the best-known chemicals assessment methodologies. A colour-coded letter grade rolls up information from the United Nations' Globally Harmonized System of Classification, Cradle to Cradle (on material health) and the EPA SaferChoice Safer Chemical Ingredients List. That results in offering users more than 50 pieces of interpretation and over 20 human and environmental endpoints, such as around neurotoxicity or aquatic toxicity, for each chemical.	**https://www.chemforward.org/**
SUBSTITUTION OF HAZARDOUS SUBSTANCES	**The Safer Choice**	U.S. EPA Pollution Prevention (P2) program	A program that helps consumers, businesses, and purchasers find products that perform and contain ingredients that are safer for human health and the environment. It certifies safer products based on stringent requirements for chemical ingredients that meet the Safer Choice criteria. There are now more than 2000 certified products for a wide range of applications: household and facility cleaning, and automotive and outdoor. The label means that products have been verified by a trusted U.S. government agency and that they contain only safer chemical ingredients. The Safer Choice Programme also maintains the Safer Chemical Ingredients List (SCIL) of more than 900 chemicals, which constantly evolves and expands.	**https://www.epa.gov/saferchoice**
SUBSTITUTION OF HAZARDOUS SUBSTANCES	**The Sustainability Method Selection Tool**	The Dutch National Institute for Public Health and the Environment through its Centre for Safety of Substances and Products	A tool to help, amongst other things, evaluate how sustainable a substitution option may be. The centre also includes discussions and research on biobased products as potential alternatives to hazardous chemicals taking a full life cycle approach.	**http://www.sustainabilitymethod.com/**

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What for	What	Owner	Description	Link
SUBSTITUTION OF HAZARDOUS SUBSTANCES	**The Guide on Sustainable Chemicals**	The German Environment Agency (Umweltbundesamt -UBA)	A guide that describes criteria which can be used for a first assessment of the sustainability of substances and mixtures.	**https://www.umweltbundesamt.de/sites/default/files/medien/479/publikationen/161221_uba_fb_chemikalien_engl_bf.pdf**
SUBSTITUTION OF HAZARDOUS SUBSTANCES	**SubSelect**	The German Environment Agency (Umweltbundesamt -UBA)	An online tool that guides manufacturers, formulators or end users of substances and mixtures on how to gather information on hazard, mobility, resource, and CO2-emission aspects and prioritise substitution needs or compare alternatives.	**https://www.umweltbundesamt.de/en/document/subselect-guide-for-the-selection-of-sustainable**
SUBSTITUTION OF HAZARDOUS SUBSTANCES	**The International Sustainable Chemistry Collaborative Centre (ISC3)**	The ISC3 is an international organisation hosted by GIZ (the Deutsche Gesellschaft für Internationale Zusammenarbeit) on behalf of the German Federal Ministry for the Environment and the German Environment Agency.	A centre aimed to support transformation toward sustainable chemistry by providing a platform where all players from policy, civil society, industry, and academia can come together to exchange and develop innovative solutions.	**https://www.isc3.org/en/home.html**
SUBSTITUTION OF HAZARDOUS SUBSTANCES	**The International Union of Pure and Applied Chemistry (IUPAC)'s Interdivisional Committee on Green Chemistry for Sustainable Development**	The International Union of Pure and Applied Chemistry (IUPAC)	To promote exchange of information in relation to green and sustainable chemistry.	**https://iupac.org/**
SUBSTITUTION OF HAZARDOUS SUBSTANCES	**The SubSportPlus portal**	IUPAC	A portal that offers information supporting efforts in substituting hazardous substances and assisting to find your way to safer alternatives. Case studies database included.	**https://www.subsportplus.eu/subsportplus/EN/Home/Home_node.html**
SUBSTITUTION OF HAZARDOUS SUBSTANCES	**The UNEP-MAP SCP/RAC has also released several publications that can guide designers in identifying safer alternatives to most common additives.**			**http://www.cprac.org/sites/default/files/otherfiles/the_business_case_for_tackling_plastic_packaging.pdf**
SUBSTITUTION OF HAZARDOUS SUBSTANCES	**The MarketPlace**	ChemSec	A free of charge business to business website where buyers and sellers of alternatives to hazardous chemicals can interact.	**https://marketplace.chemsec.org/**
SUBSTITUTION OF HAZARDOUS SUBSTANCES	**Substitution to Safer Chemicals - European Information Sharing Network**	The European Chemicals Agency (ECHA)	A LinkedIn group to discuss and share information and experiences in substitution to safer chemicals at European and at individual Member States level.	**https://www.linkedin.com/groups/13554908/**
SUBSTITUTION OF HAZARDOUS SUBSTANCES	**Practical Methodological Guide for Assessing Substitution Solutions**	The French Ministry for Ecology and Solidary Transition	A guide based on a wide set of criteria (hazard, risk, performance, risk/benefit, feasibility, socio-economic aspects) to go beyond comparative hazard assessment and integrate risk/exposure. It also provides guidance for addressing uncertainties and data gaps. The guide is easily accessible to small and medium sized enterprises (SMEs) and non-specialists.	**https://substitution.ineris.fr/fr/guide-methodologique-pratique-devaluation-solutions-substitution**

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What for	What	Owner	Description	Link
DESIGN FOR RECYCLING	**Designing for a Circular Economic (D4ACE)**	CEFLEX Consortium (Circular Economic for Flexible Packaging)	Guidelines aimed to help current systems recycle flexible packaging.	**https://guidelines.ceflex.eu/guidelines/**
DESIGN FOR RECYCLING	**RecyClass Platform**	Plastics Recyclers Europe (PRE)	An autonomous platform which allows for a value chain cooperation and exchange of best practices, allowing for testing of packaging compatibility with existing plastic waste streams by assessing compositions of packaging.	**https://recyclass.eu/**
DESIGN FOR RECYCLING	**Plastic Packaging Recyclability by design guidelines**	RECOUP	Guidelines that provide details on how to recycle plastic packaging, including sustainable alternatives for some of the issues encountered with the various polymers and packaging types.	**https://www.recoup.org/p/130/recyclability-by-design**
DESIGN FOR RECYCLING	**PackScore**	The British Plastics Federation (BPF) and supported by RECOUP	Online tool for brands, retailers, and designers to use at the earliest stages of packaging design, for them to assess whether the packaging can be easily recycled. This allows the users to adjust features of the packaging design to improve recyclability.	**www.PackScore.co.uk**
DESIGN FOR RECYCLING	**The ECR Guideline for Recyclable Packaging Design**	ECR Community, the World Packaging Organisation (WPO) and FH Campus University of Applied Sciences, Austria	Guideline design packaging for recycling is applicable to all primary, secondary, and tertiary packaging, as well as food, near-food, and non-food packaging, provided that product-specific regulations of the packaging system are observed.	**https://www.worldpackaging.org/Uploads/2021-09/ResourcePDF37_1630863760.pdf**
DESIGN FOR RECYCLING	**Guidelines for the recyclable design of packaging**	FH Campus Wien www.fh-campuswien.ac.at Circular Analytics	This guideline aims to provide recommendations for the recyclable design of packaging and addresses all actors along the entire value chain. The recommendations mainly refer to household packaging. For commercial packaging (volume > 5 L), they can also be applied to check minimum requirements. However, it should be noted that different, further sorting steps can be used for commercial packaging, so that the recyclability must be checked in each individual case by means of sorting tests.	**https://www.fh-campuswien.ac.at/fileadmin/redakteure/Forschung/FH-Campus-Wien_Circular-Packaging-Design-Guideline_V04_EN.pdf**
DESIGN FOR REUSABILITY	**The eCircular tool**	Ecomatters	As part of the EIT Climate-KIC founded eCircular project, Ecomatters and the involved project partners developed a tool for designing reusable products and packaging. To create this tool, we have conducted literature research and expanded our knowledge with additional insights through reaching out to experts in sustainable product and packaging design, circular design, and eco-design; as well as start-up companies developing new propositions around reusability. From these interviews we gathered valuable, first-hand insights on how reusability can be implemented in practice, what the lessons are, and which hurdles entrepreneurs have to overcome. The tool aims to help entrepreneurs and SMEs to expand their insights and embark on a journey of reusability.	**https://www.ecomatters.nl/services/climate-energy/ecircular-tool/**

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What for	What	Owner	Description	Link
SUBSTITUTION OF HAZARDOUS SUBSTANCES	**UP Scorecard (v0.2)**	The UP Scorecard is being further developed and managed by the Single-Use Material Decelerator (SUM'D), which is a passionate and dedicated team of leading food service companies, NGOs, and technical experts.	The UP Scorecard is a science-based online free-to-use tool to help users select food ware and food packaging that is safe and environmentally sustainable. The UP-Scorecard measures commonly used food ware and food packaging materials with a single yardstick to offer the first-ever, free, and comprehensive tool for making sustainable purchasing decisions for these products based on the latest available science. Scores are provided for plastic pollution, chemicals of concern, climate, water use, sustainable sourcing, and recoverability. Developed through an unprecedented collaboration of leading food service companies, NGOs and technical experts, the UP Scorecard provides an authoritative resource for businesses as well as for environmental and human health advocates.	**https://upscorecard.org/**
DESIGN FOR RECYCLING	**Recyclable flexible packaging Handbook**	Hatzopoulos S.A. is an international supplier of advanced flexible packaging solutions based in Greece.	The Handbook has been designed to provide detailed information regarding all packaging design choices that impact the quality and quantity of the recycled materials produced. Giving practical advice and presenting real, shelf-ready examples, we help you redesign the next generation of your flexible packaging, improving its environmental impact while preserving its functionality and performance.	**https://hatzopoulos.gr/recyclable-packaging-handbook/**
DESIGN FOR RECYCLED CONTENT	**Designing for a Circular Economic (D4ACE)**	CEFLEX Consortium (Circular Economic for Flexible Packaging)	Guidelines aimed to help current systems recycle flexible packaging.	**https://guidelines.ceflex.eu/guidelines/**
DESIGN SAFE AND CIRCULAR MATERIALS	**Safe and sustainable by design chemicals**	ChemSec	A guide to transition into an economy where chemicals, materials and their use in products are safe and sustainable. It starts with the design phase and goes on with the whole life cycle: production, use, and end-of-life.	**https://chemsec.org/app/uploads/2021/06/ChemSec-Safe-and-Sustainable-by-Design-Chemicals-2021-06-29.pdf**
DESIGN FOR REUSABILITY	**The Future of Reusable Consumption Models report**	World Economic Forum	The objective of this report is to give leaders in business, government, civil society, and multilateral organizations a clear picture of an alternative plastic waste-reduction model, one that goes beyond the recycling of waste to its reuse –with the eventual result that a discarded item is no longer seen as "waste", but rather as a still-useful object about to enter a new phase of value generation. The second part of the report is a diagnostic aid for companies and communities seeking to establish a reuse system, as a facilitator of informed dialogue within and among stakeholder organizations, and as a tool for measuring potential outcomes.	**https://www3.weforum.org/docs/WEF_IR_Future_of_Reusable_Consumption_2021.pdf**
DESIGN FOR RECOVERY	**The Essentials of Sustainable Packaging online training program**	The Sustainable Packaging Coalition	The Sustainable Packaging Coalition created the Essentials of Sustainable Packaging training program to educate professionals about the top subjects in sustainable packaging, such as: Designing for recovery, Bioplastics, Compostable packaging, Material health, Ocean plastic pollution.	**https://sustainablepackaging.org/projects/esp/**

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DESIGN SAFE AND CIRCULAR MATERIALS	**The Plastic Additive Optimization Tool**	The Plastic Additive Optimization Tool has been jointly developed as an output of the Safe + Circular Materials Collaborative, a partnership between ChemFOWARD and the Sustainable Packaging Coalition (SPC).	The Plastic Additive Optimization Tool enables users to check the chemical hazard profile of over 1100 different additives used in plastics.	**https://www.chemforward.org/news/chemforward-and-spc-offer-plastic-producers-free-access-to-chemical-additive-safety-toolnbsp**
DESIGN SAFE AND CIRCULAR MATERIALS	**Database on Migrating and Extractable Food Contact Chemicals (FCCmigex)**	Food Packaging Forum together with colleagues from eight academic institutions	The novel Database on Migrating and Extractable Food Contact Chemicals (FCCmigex) systematically maps the scientific evidence of food contact chemicals (FCCs) that have been measured in migrates and extracts of food contact materials and articles.	**https://www.foodpackagingforum.org/fccmigex**
SUBSTITUTION OF HAZARDOUS SUBSTANCES	**Chemicals associated with Plastic Packaging (CPPdb)**	Food Packaging Forum	Database of Chemicals associated with Plastic Packaging (CPPdb) is presented. CPPdb contains chemicals used in manufacturing and/or present in final articles. 906 chemicals identified as likely; 3377 chemicals as possibly associated. Hazard data: CLP classifications, EDC, PBT, vPvB identifications explored. Data gaps concerning both the use and toxicity of numerous substances identified.	**https://www.sciencedirect.com/science/article/pii/S0048969718338828?via%3Dihub**
DESIGN FOR CIRCULAR ECONOMY	**The Sustainability Guide**	The Sustainability Guide, launched in 2017 and developed within EcoDesign Circle, an EU-funded three-year project with the aim to increase the capacity of SMEs and design centres in the field of eco-design.	The Sustainability Guide provides inspiration and knowledge by gathering information, methods, and good examples of how to use design to achieve a sustainable and circular business as well as social development.	**https://www.https://sustainabilityguide.eu/fccmigex**
DESIGN FOR RECYCLING	**Recyclable flexible packaging Handbook**	Hatzopoulos S.A. is an international supplier of advanced flexible packaging solutions based in Greece.	The Handbook has been designed to provide detailed information regarding all packaging design choices that impact the quality and quantity of the recycled materials produced. Giving practical advice and presenting real, shelf-ready examples, we help you redesign the next generation of your flexible packaging, improving its environmental impact while preserving its functionality and performance.	**https://hatzopoulos.gr/recyclable-packaging-handbook/**
SUBSTITUTION OF HAZARDOUS SUBSTANCES	**The OECD Substitution and Alternatives Assessment Toolbox (SAAToolbox)**	OECD	The OECD Substitution and Alternatives Assessment Toolbox (SAAT) — a compilation of resources relevant to chemical substitution and alternatives assessments.	**http://www.oecdsaatoolbox.org/**
SUBSTITUTION OF HAZARDOUS SUBSTANCES	**The Repository of Analyses of Alternatives**	The European Chemicals Agency (ECHA)	A publicly accessible database that compiles various assessments of potential substitutes for hazardous chemicals.	**https://echa.europa.eu/**
SUBSTITUTION OF HAZARDOUS SUBSTANCES	**The Substitution to Safer Chemicals website**	The European Chemicals Agency (ECHA)	A platform that provides resources and guidance to help industries transition away from hazardous chemicals towards safer alternatives.	**https://echa.europa.eu/**

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What for	What	Owner	Description	Link
SUBSTITUTION OF HAZARDOUS SUBSTANCES	**The Transitioning to Safer Chemicals Toolkit**	U.S. OSHA	By using this toolkit, businesses can improve worker well-being through eliminating or reducing hazardous chemicals, while creating other benefits.	**https://www.osha.gov/safer-chemicals**
SUBSTITUTION OF HAZARDOUS SUBSTANCES	**Toxics Reduction Program - Reference Tool for Assessing Safer Chemical Alternatives**	Canada		**http://dr6j45jk9xcmk.cloudfront.net/documents/1190/18-safer-chemical-alternatives-en.pdf**
DESIGN FOR RECYCLING	**Circular Design Guide for Packaging that focuses on recyclability. Read more and download the guide here.**	Stora Enso	Stora Enso's Circular Design Guidelines introduce our circular design principles which are being integrated into their own innovation and product management. One of the biggest things going for us is our raw material: we are lucky to be working with trees that grow back.	**https://info.storaenso.com/signup-circular-design-guide?_gl=1*1wz2k2j*_ga*MTE5NDkyMTYzMS4xNjU1Njg5MzMz*_ga_VGEMW7TFN1*MTY1NTY4OTMzMy4xLjEuMTY1NTY5MDE4Ny41MA..**

Annex 1 – Main substances of concern addressed by the Study

Intentionally Added Substances (IAS) and short NIAS

Per- and Polyfluorinated alkyl substances (PFASs)

- Per-and polyfluorinated alkyl substances (PFASs) are a large class of thousands of synthetic chemicals with a wide range of different physical and chemical properties. They can be gases, liquids, or solid high-molecular weight polymers. PFASs contain carbon-fluorine bonds, which are one of the strongest chemical bonds in organic chemistry. They can be sub-grouped based on their structure: for example, some PFASs are described as long-chain, others as short-chain molecules.

- PFASs are widely used as they have unique desirable properties, e.g., they are stable under intense heat. Many of them also have surfactant properties and function as water and grease repellents. PAFSs may be used as grease-proofing agents in paper/paperboard food packaging (e.g., fast-food wrappers, microwave popcorn bags, take-out paperboard containers, and pet food bags) to prevent oil and grease from foods from leaking through the packaging.

- PFASs are released into the environment through industrial manufacturing and through the use and disposal of PFAS-containing products. Humans can be exposed to them every day at home, in their workplace and through the environment, for example, from the food they eat (e.g., fish and seafood, meat and meat products, eggs, milk and dairy products) and drinking water[47].

- Because of their persistent character, PFASs accumulate in the human body and in the environment without being degraded. PFASs have been frequently observed to contaminate groundwater, surface water, and soil. Cleaning up polluted sites is technically difficult and costly. Recent studies have associated a variety of PFAS substances with an array of health problems including endocrine disruption and children developmental harm[48].

- Two widely used members of this class are perfluoro octane sulfonate (PFOS) and perfluoro octanoic acid (PFOA). PFOS and PFOA do not follow the pattern of a classic Persistent Organic Pollutant (POP): they do not accumulate in fatty tissues but instead bind to proteins. They therefore accumulate mainly in organs such as the liver, kidney, brain, and spleen. As these two substances have come under regulatory pressure, the industry has shifted to other PFAS with similar properties.

- Several studies have documented the widespread use of PFAS in food packaging, with specific compounds used changing over time - from PFOS precursors to substances based on 6:2 fluorotelomer alcohol (FTOH). PFAS can migrate from food packaging into food depending on the type of material, contact time, temperature, and PFAS chain length. The presence of polymeric PFAS, notably side-chain fluorinated polymers, in food packaging materials is indeed another concern. Although these PFAS polymers are likely less mobile and bio-accessible than nonpolymeric PFAS, they contain nonpolymeric PFAS impurities and can produce lower molecular weight breakdown products such as FTOHs. As polymers, these substances are not subject to the same regulatory scrutiny as monomers, and neither are their impurities and breakdown products[49].

- The negative health and environmental consequences of PFAS used in food packaging have led to legislative changes in many countries around the world.

47 *Per- and polyfluoroalkyl substances (PFASs) - ECHA* Available at: https://echa.europa.eu/hot-topics/perfluoroalkyl-chemicals-pfas.
48 *Biomonitoring Summary | CDC* Available at: https://www.cdc.gov/biomonitoring/PFAS_BiomonitoringSummary.html.
49 Schwartz-Narbonne, H. et al. (2023) "Per-and Polyfluoroalkyl Substances in Canadian Fast Food Packaging," *Environmental Science and Technology Letters* [Preprint]. Available at: https://doi.org/10.1021/acs.estlett.2c00926.

- Since 2009, PFOS and its derivatives have been included in the international Stockholm Convention to eliminate their use. In addition, the Stockholm Convention regulates the global elimination of PFOA, its salts and PFOA-related compounds. In June 2022, Parties to the Stockholm Convention decided to include PFHxS, its salts and related compounds in the Convention, for global elimination without specific exemptions. This global ban entered into force in December 2023. Long-chain perfluorinated carboxylic acids (C9-21 PFCAs) are being considered for inclusion in the Stockholm Convention and consequent global elimination.

- In the EU, the Chemicals Strategy for Sustainability[50] places PFAS policy front and centre and the European Commission has committed to phasing out all PFASs, allowing their use only where they are proven to be irreplaceable and essential to society. To date, the following actions have been taken:
  - Under the POPs Regulation[51], PFOA has been banned since 4 July 2020, while the PFOS has already been restricted for more than 10 years.
  - A number of PFASs are on the Candidate List of substances of very high concern (SVHC) of the EU Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), for example PFOA, perfluorinated carboxylic acids (C9-14 PFCAs) and PFHxS. Based on their persistence, mobility, and toxicity, which were considered to pose a threat to human health and wildlife when exposed through the environment (including through drinking water), the following groups of PFASs were identified as SVHCs (in June 2019, January 2020, and January 2023):
    - 2,3,3,3-tetrafluoro-2-(heptafluoropropoxy)propionic acid, its salts, and its acyl halides (HFPO-DA), a short-chain PFAS substitute for PFOA in fluoropolymer production, was the first substance added to the Candidate List. Its ammonium salt is commonly known as GenX. [General Court judgment];
    - perfluorobutane sulfonic acid (PFBS) and its salts, a replacement of PFOS; and
    - perfluoroheptanoic acid (PFHpA) and its salts.

    These PFASs were identified as of equivalent concern to carcinogens, mutagens and reprotoxicants (CMRs) and persistent, bioaccumulative and toxic/very persistent and very bioaccumulative (PBTs/vPvBs) chemicals.
  - Per fluorinated carboxylic acids (C9-14 PFCAs), their salts and precursors have been restricted in the EU/EEA since February 2023 following a decision taken by the European Commission on a proposal by the German and Swedish authorities.
  - Individual EU Member States have proposed tighter restrictions (e.g., The Netherlands, Germany, Norway, Denmark, and Sweden submitted a restriction proposal to cover a wide range of PFAS uses to ECHA in January 2023) and ECHA's scientific committees are evaluating these proposals (under review as of July 2024).
  - Several additional PFASs are on the list for evaluation over the coming years (Community rolling action plan[52]) or have already been evaluated. The evaluation aims to clarify initial concerns on the potential risk to human health or the environment that manufacturing or using these substances could pose.
  - The recast of the Drinking Water Directive, which took effect on 12 January 2021, includes a limit of 0.5 µg/l for all PFAS. This is in line with a grouping approach for all PFASs.

50 European Commission (2020) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Chemicals Strategy for Sustainability Towards a Toxic-Free Environment. Available at: https://circabc.europa.eu/ui/group/8ee3c69a-bccb-4f22-89ca-277e35de7c63/library/dd074f3d-0cc9-4df2-b056-dabcacfc99b6/details?download=true

51 Regulation (EU) No 2019/1021 of the European Parliament and of the Council of 20 June 2019 on persistent organic pollutants. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32019R1021. Available at: https://echa.europa.eu/pops-legislation

52 European Commission (2022) Staff Working Document Restrictions Roadmap under the Chemicals Strategy for Sustainability. Available at: https://ec.europa.eu/transparency/documents-register/detail?ref=SWD(2022)128&lang=en

- In September 2020, the European Food Safety Authority (EFSA) set a new safety threshold for the main perfluoroalkyl substances that accumulate in the body: perfluorooctanoic acid (PFOA), perfluorooctane sulfonate (PFOS), perfluorononanoic acid (PFNA), perfluorohexane sulfonic acid (PFHxS). The threshold – a group tolerable weekly intake (TWI) of 4.4 nanograms per kilogram of body weight per week – is part of a scientific opinion on the risks to people's health from the presence of these substances in food. EFSA's scientific advice will support risk managers in their decisions on how best to protect consumers from exposure to PFASs through food.
- Under the CLP Regulation[53], a few PFASs already have a harmonised classification and labelling. These include:
  - perfluorooctanoic acid (PFOA).
  - ammonium pentadecafluorooctanoate (APFO).
  - perfluorononan-1-oic acid (PFNA) and its sodium and ammonium salts.
  - nonadecafluorodecanoic acid (PFDA) and its sodium and ammonium salts; and
  - perfluoroheptanoic acid (PFHpA).
- An informal coordination group of several EU countries, ECHA and the European Commission has, since 2014, screened data on PFASs contained in ECHA's registration database and coordinated group-based regulatory work. Despite an efficient approach compared to regulating substance by substance, work has only been able to cover the PFAS groups of highest urgency due to the very large number of PFAS. Assessing and, where relevant, managing risks subgroup by subgroup would require a considerable amount of time. Therefore, ECHA acknowledges that a holistic group approach to regulatory assessment and risk management needs to be explored.

- In 2020, Denmark banned PFAS-containing cardboard and paper used in food packaging.
- In the US, the Food and Drug Administration (FDA) has authorized specific PFAS for use in specific food contact applications. In 2016, the FDA banned manufacturers from using long-chained PFAS in food packaging[54]. After finding that a short-chain member of the PFAS family also lingered in humans after eating food contaminated with the compound, 6:2 FTOH, the FDA and manufacturers announced that they would phase out use of that compound as a food container coating. In 2021, an PFAS Strategic Roadmap was announced by the Environment Protection Agency (EPA) setting timelines by which EPA plans to take specific actions to safeguard communities from PFAS contamination. As of 2022, 11 states in the United States have passed regulations banning the use of PFAS in food packaging.
- In 2020, three U.S. manufacturers agreed to voluntarily phase out sales of food packaging products containing 6:2 FTOH by 2023, and McDonald's and Restaurant Brands International have committed to removing all PFAS from consumer packaging materials by 2025.
- In Canada, PFOS, PFOA, and long-chain perfluoroalkyl carboxylic acids (PFCAs) as well as their salts and precursors are prohibited from manufacture, use, sale, or import under the Prohibition of Certain Toxic Substances Regulations, 2012, with a limited number of exemptions. However, the Government of Canada published draft Regulations in 2022 to remove or phase-out most of these exemptions. PFOS, PFOA and LC-PFCAs, their salts and precursors are defined in the Regulations by their chemical structures rather than by individual identifiers such as Chemical Abstracts Service Registry Numbers (CAS RNs). A non-exhaustive list of CAS RNs that represent substances

53 Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006. Available at: https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A32008R1272

54 Food and Drug Administration (2016) "FDA Removes Approval for the Use of PFCs in Food Packaging Based on the Abandonment." Available at: https://www.fda.gov/food/cfsan-constituent-updates/fda-removes-approval-use-pfcs-food-packaging-based-abandonment.

that are listed to the Regulations is made available through the Canadian Environmental Protection Act Registry. Although multiple CAS RNs are listed for these substances, it is not an exhaustive list of all the substances that could be included. They are provided as a guide to assist with understanding the intent of the Regulations. Canada does not specifically publish a list of PFAS that are restricted or that can be used in food packaging and materials.

- Most PFAS substances remain unregulated in most of the countries in Africa, Asia, and the Middle East[55]. In China, the production, transportation, application, imports, and exports of PFOS, its salts and PFOSF, is banned except for specific exemptions and acceptable use[56].
- Due to the complexity and negative characteristics of PFAS, there is increasing interest in regulating PFAS as a class rather than as individual substances.

Bisphenols

- Bisphenols are a group of chemical compounds with two hydroxyphenyl functionalities, all closely related.
- Bisphenol A (BPA) is one of the most commonly produced synthetic chemicals worldwide[57]. BPA is mainly used as a monomer for polycarbonate plastics (65 percent of the volume used) and epoxy resins (30 percent of the volume used). Polycarbonate plastics are used in the production of (reusable) food containers and bottles, whereas epoxy resins act as a protective lining in food and beverage packaging. BPA can also be used as an antioxidant or as a plasticiser in other polymers (PP, PE, and PVC). As BPA has come under pressure from regulators, companies have moved to using other similar bisphenols, such as bisphenol S (BPS), bisphenol F (BPF) and bisphenol HPF (BHPF) due to their similar structure ("drop in" substitutions).
- Although BPA does not accumulate in the body, it is still a great health concern as humans and the environment are constantly exposed to it. It is ubiquitous within the environment, and it is estimated that > 90 percent of people have detectable levels of BPA in their urine[58]. BPA is an environmental health concern due to its widespread exposure as well as its potential toxicity. BPA is an endocrine disruptor that acts as an oestrogen mimic. Evidence suggests that BPA affects circulating hormone levels, cardiovascular health, obesity, reproductive health in both males and females, hormone-driven cancers, and neurobehavioral development in children[59]. General exposure to BPA at low levels comes from eating food or drinking water stored in containers that have BPA.
- In the EU, BPA has been restricted as a substance on its own and in mixtures intended for consumer use in the EU since March 2018. Its use in thermal paper has been restricted since January 2020. However, companies have commonly used bisphenol S (BPS) to replace BPA in thermal paper which is a concern as it is also suspected to affect human reproductive and hormonal systems. To avoid similar situations where one hazardous bisphenol is replaced with another that may be equally hazardous, ECHA and the Member States have assessed the regulatory needs of 148 bisphenols as a group. Uses of the assessed bisphenols range from intermediates to thermal paper, inks, coatings, adhesives, and textiles. To protect people and the environment, the assessment found that 34 bisphenols need to be

55 IPEN (2019) "PFAS pollution across the middle east and Asia." Available at: https://ipen.org/sites/default/files/documents/pfas_pollution_across_the_middle_east_and_asia.pdf
56 OECD Chemical Safety Portal on perfluorinated chemicals. Available at: https://www.oecd.org/chemicalsafety/portal-perfluorinated-chemicals/countryinformation/china.htm
57 The global bisphenol A (BPA) market attained a value of about USD 10.92 billion in 2020. Aided by the increased demand in the automotive industry, the market is projected to further grow at a CAGR of 7.8 percent between 2021 and 2026 to reach a value of USD 30.62 billion by 2026.
58 Venisse, N. et al. (2014) "Reliable quantification of bisphenol A and its chlorinated derivatives in human urine using UPLC–MS/MS method," *Talanta*, 125, pp. 284–292. Available at: https://doi.org/10.1016/j.talanta.2014.02.064.
59 Zhang, H. (2022) "BPA replacement linked to increased cardiovascular disease," *EHN*, 22 February. Available at: https://www.ehn.org/bpa-replacement-2656483035.html.

restricted as they may interfere with hormonal systems and affect reproduction. This number may change as more information is generated for these and other bisphenols that were lacking data. Three bisphenols (BPA, bisphenol B (BPB) and 2,2-bis(4'-hydroxyphenyl)-4-methylpentane) have already been identified as substances of very high concern (SVHCs). SVHC identification or harmonised classification and labelling is proposed for further bisphenols where sufficient information on hazards is already available. However, for many group members, more data needs to be generated before potential endocrine-disrupting and reprotoxic properties can be confirmed. German authorities are already preparing a proposal to restrict the use of BPA and other bisphenols with endocrine-disrupting properties for the environment[60]. Once it is more clear which bisphenols the German proposal will cover, ECHA will consider any further needs for regulatory action on bisphenols. Coordination is also needed with the planned restriction of PFASs as bisphenol AF and its eight salts are also defined as PFASs. In addition, the French and Swedish authorities have proposed to restrict over 1 000 skin sensitising chemicals in clothing, footwear, and other articles with a similar skin contact. BPA and other bisphenols, which have been identified as skin sensitisers, would be included in this restriction[61].

- BPA can be used in materials that come into contact with food in the EU. However, only a limited amount (0.05 mg/kg) is allowed to leach from the material into food. BPA has been banned in infant feeding bottles across the EU since June 2011 and in plastic bottles and packaging containing food for babies and children under three years since September 2018. The European Food Safety Authority (EFSA) is re-evaluating the risks to public health related to BPA in foodstuffs and plans to finalise the updated assessment in 2022.
- The U.S. Food and Drug Administration still considers BPA "safe at the current levels occurring in foods", except for baby bottles, cups, and infant formula packaging.
- Several countries in Asia (e.g., Malaysia, China, and Indonesia) have restricted the use of BPA in baby bottles.
- An increase in industrial productions and food packaging across Africa has resulted in increased utilization of BPA-containing products with a concomitant increase in environmental bioaccumulation and human exposure. However, the utilization of BPA-containing products is still unregulated across Africa[62].

Phthalates

- Ortho-phthalates, often referred to as phthalates, are chemicals used as additives (plasticizer) in high concentrations in plastic products to make the material soft and less brittle. Polyvinyl chloride (PVC), used in several single-use packaging applications such as labels of plastic bottles, transparent packaging boxes and trays[63], can contain 10 to 60 percent phthalates by weight[64]. PVC is particularly used because of its low price, durability, and scratch resistance. Di(2-ethylhexyl) phthalate (DEHP) is commonly added to flexible packaging films. Some phthalates may be used in food packaging or other minor food contact uses[65] such as components of adhesives, lubricants, and sealants. For example, meat packaging and the sealing of screw caps can contain phthalates. Consumption of highly processed and prepared foods contribute to human exposure of legacy ortho-phthalates[66].

60 *Submitted restrictions under consideration - ECHA* (no date). Available at: https://echa.europa.eu/restrictions-under-consideration/-/substance-rev/71401/term.
61 *Bisphenols - ECHA* (no date). Available at: https://www.echa.europa.eu/hot-topics/bisphenols.
62 Rotimi, O.A. et al. (2021) "Bisphenol A in Africa: A review of environmental and biological levels," *Science of the Total Environment*, 764, p. 142854. Available at: https://doi.org/10.1016/j.scitotenv.2020.142854.
63 Transparent PVC is hard to be distinguished from transparent PET, which is also used in many of these single-use applications. Identification is partly supported by the printed recycling code, where 1 stands for PET and 3 for PVC.
64 *Plastic's toxic additives and the circular economy | IPEN* (no date). Available at: https://ipen.org/documents/plastics-toxic-additives-and-circular-economy.
65 *Phthalates in food* (no date). Available at: https://www.edf.org/health/phthalates-food.
66 Edwards, L. et al. (2022) "Phthalate and novel plasticizer concentrations in food items from U.S. fast food chains: a preliminary analysis," *Journal of Exposure Science and Environmental Epidemiology*, 32(3), pp. 366–373. Available at: https://doi.org/10.1038/s41370-021-00392-8.

- Phthalates can easily leach into the environment during manufacturing, use, and mostly through the disposal of plastic waste in landfills[67]. They have been found in a wide range of environments.
- Despite the short half-lives in tissues, phthalates have been identified as endocrine-disrupting chemicals (EDCs) which interfere with normal hormonal actions. Chronic exposure to phthalates will adversely influence the endocrine system and functioning of multiple organs, which has negative long-term impacts on the success of pregnancy, child growth and development, and reproductive systems in both young children and adolescents[68]. Several *ortho-phthalates*, for example DEHP, *dibutyl phthalate* (DBP), *diisobutyl phthalate* (DIBP) and *benzyl butyl phthalate* (BBP), are classified as toxic to reproduction (Repr. 1B). This means that they are presumed to damage fertility or the unborn baby and interfere with our hormonal system. In addition, DBP and BBP are classified as very toxic to aquatic life (aquatic acute 1) and BBP also as very toxic to aquatic life with long lasting effects (aquatic chronic 1)[69].
- Despite their hazardousness, phthalate plasticizers are the cheapest plasticizers available in the market and are thus preferred by many small and medium scale industries over other plasticizers[70].
- The EU restricts several phthalates that are considered dangerous for human health under the REACH Regulation, the Toy Safety and RoHS Directives, the EU Food Contact Materials Framework Regulation, and other regulations. These restrictions can be based on concentration by weight, or on specific migration limits, especially in food contact materials. Main actions are:
  - the Candidate List of substances of very high concern (SVHC) contains several ortho-phthalates that are harmful for reproduction. Among those, five ortho-phthalates are identified as substances of very high concern also due to their endocrine disrupting properties - DIBP, DBP, BBP, DEHP, dicyclohexyl phthalate (DCHP) for human health, and DEHP and DCHP also for the environment. Producers and importers of articles must notify ECHA if their article contains a substance on the Candidate List within six months after the substance has been included in the list[71].
  - the REACH Authorisation List contains 14 phthalates. After a given date the use of these phthalates will be prohibited unless the European Commission authorises the company to continue its use. When applying for authorisation the company needs to demonstrate that the use of the substance is controlled, that there are no suitable alternatives and the benefits of continued use exceed the risks.
  - In November 2021, the Commission added endocrine disrupting properties to DEHP, DBP, BBP and DIBP, which were originally added to the list for being toxic to reproduction[72]. The update of hazard properties to cover hormonal effects means that companies will need to apply for REACH authorisation for some uses that were previously exempted. These include, for example:
    - uses of DEHP, for example in food contact materials, medical devices, and immediate packaging of medicinal products (due to the hazards to the environment), and
    - uses of BBP and DBP in immediate packaging of medicinal products.
    - Phthalates that are classified as toxic to reproduction (Repr. 1B) are restricted on their own and in mixtures that are intended for consumer use (e.g., children's swimming aids, flooring, coated fabrics, and paper). The restrictions also regulate the import of articles containing these phthalates.

67 *Di(2-Ethylhexyl)Phthalate (DEHP) | ToxFAQsTM | ATSDR* (no date). Available at: https://wwwn.cdc.gov/TSP/ToxFAQs/ToxFAQsDetails.aspx?faqid=377&toxid=65.
68 *Plastic's toxic additives and the circular economy | IPEN* (2020). Available at: https://ipen.org/documents/plastics-toxic-additives-and-circular-economy.
69 *Phthalates - ECHA* (no date). Available at: https://echa.europa.eu/hot-topics/phthalates.
70 Mo, C. (2023) "Phthalate Regulations in the European Union: An Overview." Available at: https://www.compliancegate.com/phthalate-regulations-european-union/#Are_Phthalates_banned_in_the_European_Union.
71 *Phthalates - ECHA* (no date c). Available at: https://echa.europa.eu/hot-topics/phthalates.
72 Ibid.

- The Regulation (EC)10/2011[73] covers plastic materials and articles intended to come into contact with food. The regulation allows the use of several phthalates that are generally considered dangerous for human health, for some categories of product. For example:
  i. DBP and DEHP are allowed as plasticizers in repeated use food contact materials for non-fatty foods.
  ii. BBP, DIDP, and DINP are allowed as plasticizers in repeated use food contact materials, and in single-use food contact materials for non-fatty foods, with the exceptions of infant formulae and follow-on formulae.

– The European Food Safety Authority (EFSA) assessed DBP, BBP, DEHP, DINP and DIDP in food contact materials in 2005 and again in 2019, considering new scientific evidence. The latest review introduced a tolerable daily intake level for the group of DBP, BBP, DEHP and DINP considering combined exposure to these phthalates. It was set on a temporary basis due to limitations and uncertainties identified in the assessment. The exposure to DBP, BBP, DEHP, DINP from food was found to be seven times below group safe level – while for DIDP the dietary exposure is 1 500 times below its safe level[74]. To follow up on the 2019 review, the European Commission has requested EFSA to conduct preparatory work ahead of the re-evaluation of the risks to public health from plasticisers such as phthalates used in food contact materials. It is concerning, indeed, that several phthalates that have been proven hazardous to human health are still allowed to be used in plastic food contact materials, including BBP, DBP and DEHP. This is since chemicals in food contact materials are regulated under a different legislation than REACH.
– Since 1999, the use of six phthalates, DINP, DEHP, DBP, *di-"isodecyl" phthalate* (DIDP), *dioctyl phthalate* (DNOP) and BBP, in children's toys was prohibited under a temporary ban. In 2007, a permanent ban started to apply. This ban also broadened the scope to include childcare products that small children can put in their mouths. In January 2018, the restriction was further expanded to include DIBP. Since July 2011, all phthalates classified as reprotoxic have generally been prohibited in toys and components of toys.
– The restriction of hazardous substances in the electrical and electronic equipment (RoHS) directive prohibits BBP, DBP, DEHP and DIBP in most electronic and electrical equipment since 22 July 2019. Products containing these chemicals are not allowed to be sold on the EU market. However, the restriction does not apply to products such as medical devices and control instruments that have been placed on the market before 22 July 2021.
– Since 5 Jan 2021, the Waste Framework Directive requires manufacturers, importers and distributors of products containing substances of very high concern to notify about these products to ECHA's SCIP database. Products containing phthalates that are on the REACH Candidate List must be notified.
– Finally, the SCIP database contains information about products that contain certain phthalates. This is expected to help, for example, waste treatment operators in their daily work and will, in turn, contribute to circular economy. Old plastic items can indeed contain some of the phthalates that are no longer allowed to be used. This creates a challenge for circular economy as these phthalates first need to be detected and removed before the material can safely be recycled or reused. With more information available on hazardous chemicals, consumers can make more informed choices when buying products. Companies are also encouraged to use the information in SCIP database when considering how to replace such harmful substances.

73 Commission Regulation (EU) No 10/2011 of 14 January 2011 on plastic materials and articles intended to come into contact with food. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32011R0010
74 *Phthalates - ECHA* (no date c). Available at: https://echa.europa.eu/hot-topics/phthalates.

  - Several member states of the European Union have also implemented national phthalates legislations that go beyond the EU legislation. In Denmark, for example, under the Statutory Order No. 947 of 20 June 2020 , instead of indicating the six original phthalates regulated by entry 51 and 52 of Annex XVII to REACH Regulation (EC) No 1907/2006, all restricted phthalates under these two entries are now excluded from it. This Order applies to toys intended for use by children under 3 years of age and childcare articles that are expected to be put in the mouth of children under 3 years of age, excluding food contact articles. Except the excluded phthalates, all other phthalates are prohibited to be present in the regulated products in concentration exceeding 500 mg/kg. Depending on the level of risk posed, economic operators may be required to stop selling or recall the problematic products from end users. The authority may also notify on the EU rapid alert system – "Safety Gate" (previously known as "RAPEX") of the non-compliance so other EU countries can take preventive measures[75].

- In the US, the FDA allows nine phthalates in the production of food contact polymers (eight for use as plasticizers and one for use as a monomer). In 2021, the FDA was sued by eight environmental and human health organizations for failing to ban phthalate chemicals from food and beverage packaging, despite years of research proving the danger to human and environmental health[76,77]. The FDA is generally aware of updated toxicological and use information on phthalates that is publicly available. Nevertheless, it recognises that stakeholders may have access to information that is not always made public. For these reasons, the FDA issued a request for information about the current specific food contact uses, use levels, dietary exposure, and safety data for the remaining phthalates still authorized as plasticizers for use in food contact applications. The request for information[78] does not include the phthalate authorized for use as a monomer since any exposure resulting from this use is expected to be negligible. On September 26, 2022, the FDA has reopened the comment period for the notice in response to a request from stakeholders to extend the comment period to allow additional time for interested parties to develop and submit data, other information, and comments for this request for information[79]. If, in the future, a manufacturer wants to use any of the revoked phthalates for use in food contact applications, the FDA expects the manufacturer to submit either a food additive petition or a food contact substance notification to the agency because these intended uses were previously authorized under the FDA food additive authorities[80].

- China is the largest consumer of phthalates in the world. Since 2017, phthalates are no longer allowed in plastic food packaging in China. Restrictions on other types of plastic packaging (i.e., non-food) are also being considered. Furthermore, in the recent five-year plan from the Chinese government, a need to replace phthalate plasticisers with new, preferably biobased, alternatives were identified. On March 14th, 2022, China Working Group on Pollution Prevention Standards for Electrical and Electronic Products of the Ministry of Industry and Information Technology (MIIT) organized the meeting for deepening the management of restricted use of hazardous substances in electrical and electronic products by planning to include four phthalates (DEHP (CAS: 117-81-7), BBP (CAS: 85-68-7), DBP (CAS: 84-74-2), DIBP (CAS: 84-69-5)) to the list of hazardous substances of "Measures for the administration of restricted use of harmful substances in electrical and electronic products" (China RoHS) and further strengthen the China RoHS supervision and management mechanism[81].

75 *BEK nr 947 af 20/06/2020, Ministeriet for Fødevarer, Landbrug og Fiskeri* (no date). Available at: https://www.retsinformation.dk/eli/lta/2020/947.
76 CNS MEDIA (2021a) "Safety first: Phthalate chemicals present human health threats beyond regulatory "safe" limits, study finds." Available at: https://www.packaginginsights.com/news/safety-first-phthalate-chemicals-present-human-health-threats-beyond-regulatory-safe-limits-study-finds.html.
77 CNS MEDIA (2021b) "FDA sued over "deadly" inaction on phthalate plasticizers in F&B packaging." Available at: https://www.packaginginsights.com/news/fda-sued-over-deadly-inaction-on-phthalate-plasticizers-in-fb-packaging.html.
78 NutritionPhthalates in Food Packaging and Food Contact Applications. Available at: https://www.fda.gov/food/food-ingredients-packaging/phthalates-food-packaging-and-food-contact-applications#Evaluation.
79 Ibid.
80 Nutrition U.S. Food and Drug Administration, 26 September. Available at: https://www.fda.gov/food/food-ingredients-packaging/phthalates-food-packaging-and-food-contact-applications.
81 Rheinland, T. (2022) "China Proposes to Add Phthalates to the National RoHS Regula." Available at: https://www.tuv.com/regulations-and-standards/en/china-proposes-to-add-phthalates-to-the-national-rohs-regulation.html.

- Despite the extensive production and use of phthalates in Asian countries, limited information is available about the current situation of human exposure in this region, and thus identification of further research needs is warranted.
- Limited information on regulations addressing phthalates in plastic packaging is available for countries in Latin America and Africa.

Nonylphenols

- Nonylphenol ethoxylates (NPEs) are non-ionic surfactants, a functional class of chemicals that provide increased surface activity and reduce the surface tension of water, allowing easier spreading, wetting, and better mixing of liquids. NPEs are considered workhorse surfactants given their cost-effectiveness and high performance in multiple applications and consumer products. NPEs are part of the broader category of surfactants known as alkylphenol ethoxylates (APEs)[82]. NPEs are used for many applications such as paints, pesticides, detergents, and personal care products (80 percent of total consumption) and as phosphate antioxidants for rubber and plastics, and miscellaneous uses, including lube oil additives (10 percent of total consumption each)[83].
- NPEs degrade to more toxic chemicals, including nonylphenols NP, which are persistent, moderately bio accumulative, and extremely toxic to aquatic organisms. NPEs/NPs also may also threaten the health of the developing foetus and young children. NPEs, though less toxic than NP, are also highly toxic to aquatic organisms, and in the environment degrade to more environmentally persistent NP. NP has also been detected in human breast milk, blood, and urine and is associated with reproductive and developmental effects in rodents[84].
- Since the discovery in 1940, NPEs production has increased exponentially: the nonylphenol ethoxylates market was valued at USD 515.20 million in 2021 and is expected to grow at a CAGR of 7.80 percent during the forecast period of 2022 to 2029[85]. NPEs are rarely listed as an ingredient on a product label, though widely used in many household products.
- There is great variability in the structure of non-ionic surfactants. The simplest substitution for NPEs is to use other APEs. For example, the US Safer Chemical Ingredient List (SCIL) lists almost 200 non-NPE safer surfactants[86]. Some surfactants may substitute for specific applications only, for instance, silicon surfactants are used in production of polyurethane foam while naphthalene condensates are used in photo finishing solutions. In other cases, NPE can be replaced with a surfactant blend of alternative non-ionic or a blend that includes anionic or amphoteric surfactants. Market acceptance of these alternatives depends on several factors including cost and performance in the intended use. Many of these alternatives are less persistent and break down to chemicals that are less toxic than NP and may be deemed safer substitutes for NPEs by the regulators.
- In the EU, NP/NPEs are included in the Annex XVII of the REACH Regulation[87]. This regulation stipulates that nonylphenols and their ethoxylates shall not be placed on the market, or used, as substances or in mixtures in concentrations equal to or greater than 0,1 percent by weight for specific purposes[88].

82 *Nonylphenol and Nonylphenol Ethoxylates* (2016). Available at: https://chemsafetypro.com/Topics/Restriction/REACH_annex_XVII_Nonylphenol_and_Nonylphenol_Ethoxylates.html.
83 *Nonylphenol (NP) and Nonylphenol Ethoxylates (NPEs) Fact Sheet | US EPA* (2022). Available at: https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/nonylphenol-np-and-nonylphenol-ethoxylates-npes-fact.
84 *Ibid.*
85 *Nonylphenol Ethoxylates Market Players, Size, Share, Report, Value, & Forecast Trends By 2029* (2021). Available at: https://www.databridgemarketresearch.com/reports/global-nonylphenol-ethoxylates-market.
86 *Nonylphenol (NP) and Nonylphenol Ethoxylates (NPEs) Fact Sheet | US EPA* (2022). Available at: https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/nonylphenol-np-and-nonylphenol-ethoxylates-npes-fact.
87 *Regulatory information | Alkylphenol ethoxylates substitution* (no date). Available at: https://substitution-apeo.ineris.fr/en/regulatory-information.
88 Ibid.

- Since February 2021, a more restrictive regulation applies to nonylphenol ethoxylates present in textile articles that can reasonably be expected to be washed in water during their normal lifecycle.
- 4-nonylphenol ethoxylated, branched and linear, 4-nonylphenol, branched and linear, 4-(1,1,3,3-tetramethylbutyl)phenol, ethoxylated and 4-(1,1,3,3-tetramethylbutyl)phenol have been identified by the Member State Committee as SVHC (Substance of Very High Concern) because of their endocrine disrupting properties for the environment.
- 4-nonylphenol, branched and linear, ethoxylated and 4-(1,1,3,3-tetramethylbutyl)phenol, ethoxylated are included in the Authorisation List of the Annex XIV of REACH. This annex lists substances for which authorization is necessary to place them on the EU market (concerning uses covered by the REACH Regulation).
- On 09 November 2021, the European Commission has granted eleven authorizations for industrial and medical uses of 4-(1,1,3,3-tetramethylbutyl)phenol, ethoxylated (4-tert-OPnEO) : siliconisation of glass containers, viral inactivation of biological proteins in the manufacture of biopharmaceutical substances. The review dates for these authorisations range, depending on the uses concerned, from 04 January 2026 to 04 January 2033.
- Octylphenols and nonylphenols are on the list of priority substances of the Water Framework Directive. The Directive stipulates that discharges, emissions and losses of these substances must stop no later than 2021.
- Nonylphenol is included in the list of substances to be monitored in drinking water due to its endocrine disrupting properties and the risk it poses to human health (European Directive 2020/2184). According to the decision approved by the European Commission on 19 January 2022, if nonylphenol is detected at concentrations above the guideline value of 300 ng/l, the State shall ensure that certain measures are taken, for example: appropriate prevention, mitigation or monitoring measures in catchment areas for abstraction points, measures to require water suppliers to check whether treatment is adequate to achieve the guideline value or, if necessary, to improve treatment. The deadline for transposition of the directive was 12 January 2023.
- The European Union prohibited Nonylphenols in cosmetics via the European Regulation n°1223/2009.
- Neither nonylphenols, nor octylphénols, nor their ethoxylates are on the list of monomers, other starting substances, macromolecules obtained from microbial fermentation, additives and polymer production aids authorized by the Commission Regulation (EU) N°10/2011 of 14 January 2011 relating to plastic materials and articles intended to come into contact with food.

- In the US, the Environmental Protection Agency (EPA) proposed a Significant New Use Rule (SNUR) in 2014. The rule would require manufacturers to provide at least 90-day notice to EPA before commencing or resuming any significant new use of the 15 NP/NPEs that are no longer used in commerce. This would give EPA the opportunity to evaluate the intended use and, if warranted, take action to prohibit or limit the activity before it occurs. When finalized, the SNUR provides EPA the opportunity to review and evaluate any intended new or resumed uses of these chemicals and, if necessary, take action to limit those uses. NP and NPEs have also been added to the list of chemicals included in the Toxic Substances Control Act that "present or may present an unreasonable risk of injury to health or the environment" and the Toxics Release Inventory list.

- The EPA also provides indications to consumers to avoid products with NP/NPEs by looking for products with EPA's Design for the Environment (DfE) Safer Product Label[89]. The label on a product is proof that EPA scientists have evaluated every ingredient in the product to ensure it meets stringent human health and environmental criteria.

89 *Learn About Design for the Environment (DfE) Certification | US EPA* (2022). Available at: https://www.epa.gov/pesticide-labels/learn-about-design-environment-dfe-certification.

- On December 30, 2022, China's Ministry of Ecology and Environment issued the 2023 List of Key Controlled New Pollutants, as part of the Action Plan on Controlling New Pollutants announced by the State Council in May 2022. The management measures include bans, restrictions, and discharge restrictions on the pollutants. The 2023 list contains 14 key controlled new pollutants along with pollutant-specific environmental risk management measures, which include bans and restrictions on their production, processing, use, import and export as well as discharge reduction rules. According to the final list[90], the use of nonylphenols is banned in cosmetics under the Safety and Technical Standards for Cosmetics, as additives in agrochemicals and to produce nonylphenol ethoxylates. The ban came into effect March 1, 2023.

- No regulations are in place in India to restrict or phase out the use of NPEs in detergents and other consumer products to prevent the release of nonylphenol into the environment, especially water bodies, nor water quality criteria and standards[91].

Perchlorate

- Perchlorate is an anti-static additive used in plastic intended to use for dry food and in food handling equipment. Its presence is not recorded at all, but as by-product of bleach and packaging, it was reported to be found in organic, conventional, and bulk foods alike[92]. Some experts reckon that actively avoiding perchlorate exposure is difficult since it enters food when it's still upstream from becoming a retail product, in large-scale storage and facility cleaning. Buying organic foods in bulk or bringing your own (BYO) container will not spare consumers from the exposure to perchlorate. Food contamination is thus widespread; especially problematic is the increase of perchlorate levels in baby food dry cereal.

- Reported health effects of perchlorate include the disruption of the thyroid gland's normal function and reduction production of the thyroid hormone needed for healthy foetal and child brain development[93,94].

- In the EU, sodium perchlorate is authorized as an additive in plastic FCMs (Regulation (EU) 10/2011), with a specific migration limit (SML) of 0.05 mg/kg food. However, safety authorities in Germany have also previously called for the reduction of perchlorate levels in food[95].

- In the US, the Food and Drug Administration (FDA), approved perchlorate for use in food packaging and food processing equipment. However, objections were filed in May 2017 by multiple non-governmental organizations, and a response has not yet been issued[96]. In the US, the safety of perchlorate is currently under review by the FDA.

Ethyl and methyl glycol, toluene, and n-methyl-pyrrolidone (NMP)

- These solvents, often used in printing inks, leave residues in packaging, and represent a reproductive or development risk. Toluene has been targeted by several retailers, such as Amazon and Rite-Aid, for removal from personal care and beauty products. Toluene and NMP have been targeted for removal in other product categories as well.

90 http://www.gov.cn/zhengce/2022-12/30/content_5734728.htm
91 *Toxics Link | For a Toxics-Free World* (no date). Available at: https://toxicslink.org/
92 Cernansky, R. (2020) "The Dangerous Food Additive That's Not on the Label." Available at: https://civileats.com/2019/03/19/the-dangerous-food-additive-thats-not-on-the-label/.
93 *Perchlorate in food* (no date). Available at: https://www.edf.org/health/perchlorate-food.
94 Groh, K. (2022a) "Health effects of perchlorate exposure." *Food Packaging Forum*. Available at: https://www.foodpackagingforum.org/news/health-effects-of-perchlorate-exposure.
95 Groh, K. (2022b) "Reducing perchlorate in food." *Food Packaging Forum*. Available at: https://www.foodpackagingforum.org/news/reducing-perchlorate-in-food.
96 Boucher, J. (2022) "NGO awaits response on perchlorate." *Food Packaging Forum*. Available at: https://www.foodpackagingforum.org/news/ngo-awaits-response-on-perchlorate.

Non-intentionally Added Substances (NIAS)

The high complexity of plastic products, in particular plastic packaging, makes it extremely challenging to know all chemicals, chemical reactions, and by-products formed during the manufacturing, use, and disposal of these products and eventually their migration to the food. The composition of certain plastic packaging is often not known by the manufacturers, let alone the consumers. However, paying attention to non-intentionally added substances (NIAS) is important, particularly when evaluating the potential health effects of increasing levels of recycled content in plastic products[97]. Awareness of contamination may be an incentive to modify the manufacturing or recycling processes, substitution of hazardous additives, or even reconsideration of the likely contaminated plastic types for use in packaging applications.

In many countries, there is no current legislation regarding NIAS. While for commonly investigated IAS, there is risk assessment data available for prior research or via accredited methods, for NIAS there is rarely relevant data and an absence of industry-wide harmonized methodology to deal with them[98].

Several studies determining NIAS were carried out for the following food contact materials (FCMs): polyurethane adhesives (PU), polyethylene terephthalate (PET), polyester coatings, polypropylene materials (PP), multilayers materials, plastic films, polyvinyl chloride (PVC), recycled materials, high-density polyethylene (HDPE) and low-density polyethylene (LDPE)[99]. The findings allowed to identify the following points:

- It is estimated that most of the FCMs contain NIAS and most of the substances that migrate from plastic food packaging are unknown.
- Substances used to manufacture FCMs may disappear, and it may be mainly reaction products that turn up in the migrates (antioxidants, side reaction products and oligomers).
- NIAS could be present in the materials in deficient concentrations and still be a risk for human health.
- There are only a few references outside Europe and the United States regarding NIAS in food contact materials, although other territories closely follow European and American legislation.
- Biobased and composite plastics are currently being developed as an attempt to replace conventional plastics, however, to avoid regrettable substitutions studies on the safety of these materials and migration of compounds to food are needed to evaluate these alternative materials for hazardous compounds and NIAS and establish legislation for these specific new materials. The knowledge gap about the chemical safety of biopolymers/biobased plastics is problematic because human exposure to chemicals from these plant-based materials will increase with their increasing application.

Heavy metals, such as Lead (Pb), Cadmium (Cd), Mercury (Hg), and Chromium (Cr)

- Heavy metals are elements and metalloids that occur in nature having high density or atomic weight. Metals may remain in plastics as catalytic or reaction residues, with a well-documented example being catalytic Antimony (Sb) contaminating polyethylene terephthalate. However, the principal primary source of metals in plastics is functional additives, as insoluble inorganic compounds, partially soluble organic compounds, or organometallic liquids or salts. Metal-based additives have a wide range of functions in plastics as, for example, biocides, antimicrobial agents, lubricants, and flame retardants. However, their principal uses are as inert fillers, pigments for colour, and stabilizers. Fillers increase the stiffness and hardness of plastic and often reduce the cost of the product as they are generally cheaper than the base polymer. As heat stabilizers, metal-based compounds have found extensive use in the versatile, and widely used thermoplastic, polyvinyl chloride (PVC)[100].

97 Groh, K.J. et al. (2019) "Overview of known plastic packaging-associated chemicals and their hazards," *Science of the Total Environment*, 651, pp. 3253–3268. Available at: https://doi.org/10.1016/j.scitotenv.2018.10.015.
98 Ibid.
99 Kato, L.A. and Conte-Junior, C.A. (2021) "Safety of Plastic Food Packaging: The Challenges about Non-Intentionally Added Substances (NIAS) Discovery, Identification and Risk Assessment," *Polymers*, 13(13), p. 2077. Available at: https://doi.org/10.3390/polym13132077.
100 Turner, A. and Filella, M. (2021) "Hazardous metal additives in plastics and their environmental impacts," *Environment International*, 156, p. 106622. Available at: https://doi.org/10.1016/j.envint.2021.106622.

- Heavy metals are generally deemed to be hazardous even in low concentrations. Their concentrations in final plastic products depend on the type of polymer, the nature of the additive and the desired effect (e.g., opacity, depth of shade, thickness of article), but can often represent an important percentage of total weight. The toxicity of the heavy metals may depend on factors such as the dose, chemical species, and route of exposure[101]. Long-term exposure to Pb may cause developmental and neuro-behavioural problems in foetuses, young infants, and children, exposure to Hg may cause kidney failure, cognitive impairment, and injury to the central nervous system, exposure Cd may result in damage to the kidneys, bones, and lungs, as well as renal dysfunction and cancers of the breast and prostate, while bioaccumulation of Cr may cause lung cancers and DNA damage, as well as skin, renal, reproductive and neurological disorders[102].
- Concerns about the migration of hazardous metals from plastic products resulted in regulations and voluntary commitments that restricted the use, concentration, or mobility of certain metals in consumer and industrial plastics[103].
- The EU enacted several regulations and directives that restrict or ban certain heavy metals in consumer products, including:
  - The Substances of very high concern (SVHC) Candidate List[104] contains several heavy metals, such as Pb, Cd and Cr and their compounds.
  - The European Chemicals Agency (ECHA) requires importers and manufacturers of products containing SVHC in concentrations exceeding 0.1% w/w to:
    a. Notify ECHA of the substance's presence in their product by registering and entering the information into the SCIP (Substances of Concern In articles as such or in complex objects (Products)) database.
    b. Notify consumers upon request.

    Companies importing and manufacturing over 1 ton per year of SVHCs must also register those substances with ECHA.
  - The Regulation (EC) No 1907/2006 concerning the REACH Regulation prohibits companies from manufacturing, importing, or selling articles containing substances listed in Annex XVII[105] that exceed permitted limits. Below are several heavy metals, their restrictions, and to what products they apply:
    a. Lead and its compounds are restricted to a maximum of 0.05% by weight in products such as jewellery articles (e.g., bracelets, rings) as well as articles and accessible parts thereof that children might place in their mouths.
    b. Nickel and its compounds are restricted to less than 0.2 µg/cm^2/week for body-piercing objects (e.g., earrings) and 0.5 µg/cm^2/week for long-term wearable articles directly contacting the skin (e.g., anklets).
    c. Cadmium and its compounds are restricted to a maximum of 0.01% by weight in plastic materials (e.g., PVC, polystyrene) and metal items (e.g., piercing jewellery).
    d. Chromium VI compounds are restricted to 2 mg/kg (or 0.0002% by weight) for hydrated cement and cement-containing mixtures, and 3 mg/kg (or 0.0003% by weight) for leather articles and products containing leather parts in contact with the skin (e.g., watch strap).

101 Kurasaki, M. et al. (2022) "Effects of Metals on Human Health and Ecosystem," *The Handbook of Environmental Chemistry*, pp. 81–119. Available at: https://doi.org/10.1007/698_2021_825.
102 Shen, Y. (2023) "Heavy Metals Regulations in the European Union: An Overview." Available at: https://www.compliancegate.com/heavy-metal-regulations-european-union/#Are_heavy_metals_banned_in_the_European_Union.
103 Turner, A. and Filella, M. (2021) "Hazardous metal additives in plastics and their environmental impacts," *Environment International*, 156, p. 106622. Available at: https://doi.org/10.1016/j.envint.2021.106622.
104 The Substances of Very High Concern (SVHC) Candidate List is a list managed by the European Chemicals Agency (ECHA) under the REACH regulation. It includes chemicals that may have serious impacts on human health or the environment.
105 Mo, C. (2023) "REACH Annex XVII Substances List: An Overview." Available at: https://www.compliancegate.com/reach-annex-xvii-substances-list/.

e. Mercury is prohibited in some measuring devices (e.g., barometers, and thermometers).

- The Restriction of Hazardous Substances (RoHS) Directive restricts the usage of certain hazardous substances (including heavy metals) in electrical and electronic equipment (EEE) to protect animals, human health, and the environment. Annex I of the RoHS Directive provides several categories of covered EEE products.
- Annex II of the directive provides maximum concentration values for four heavy metals: Cd < 0.01%; Cr VI < 0.1%; Pb < 0.1%; Hg < 0.1%[106].
- The Toy Safety (TS) Directive and its amendments[107,108] lay down criteria that toys must meet before being marketed in the EU. For materials that can be 'scraped off', including plastics, concentration limits on the migration of eighteen species of sixteen metals in 0.07 M HCl at 37 °C for 2 h are stipulated. In contrast, the Restriction of Hazardous Substances (RoHS) Directive[109,110,111], that includes electronic and electrical plastic housings and insulation, and the End-of-Life Vehicles (ELV) Directive[112,113], that encompasses plastic components of vehicles, set total concentration limits for four metals (1000 mg kg−1 for Cr(VI), Hg, and Pb, and 100 mg kg−1 for Cd).
- The Packaging and Packaging Waste (PPW) Directive 94/62/EC[114] is also restricted to these metals but sets a combined total concentration limit of 100 mg kg−1, while the Directive relating to plastics intended to come into contact with foodstuffs (CFS)[115] stipulates different but substantially lower total concentration limits for five metals.
- In the latest amendment of Regulation EU 10/2011, (Regulation (EU) 2020/1245), a new Table 1 lists substances that must only be used in accordance with compositional requirement in Chapter II or may only be present as impurity subject to restrictions specified in the table. Table 1 consolidates metals in point 1 of Annex II, a list of permitted salts of authorized acids, phenols, and alcohols from Article 6.3(a), and newly includes specific migration limits for certain metals. Plastic materials and articles shall not release in quantities exceeding specific migration limits for the following metals: Antimony, Arsenic, Cadmium, Chromium, Europium, Gadolinium, Lanthanum, Lead, Mercury, and Terbium[116].
- An amendment to a Council Directive dealing with marketing and usage of dangerous substances[117] now specifically restricts the employment of di-and tri-substituted organotin compounds to 1000 mg kg−1 by weight of Tin (Sn) in plastics, and is particularly relevant to PVC[118].
- In addition, due to more specific health and sustainability concerns about the production, use and disposal of PVC, European producers and stakeholders have enacted a series of voluntary measures that allowed to slowly phase out the intentional introduction of Cd-and Pb-based stabilizers in the EU through a series of charters, like "Vinyl 2010".

106 Shen, Y. (2023) "Heavy Metals Regulations in the European Union: An Overview." Available at: https://www.compliancegate.com/heavy-metal-regulations-european-union/#Are_heavy_metals_banned_in_the_European_Union.
107 European Parliament and Council of the EU, 2009. Directive 2009/48/EC of the European Parliament and of the Council of 18 June 2009 on the safety of toys. Off. J. Eur. Union L170/1.
108 Council of the European Union, 2017. Council Directive (EU) 2017/738 of 27 March 2017 amending, for the purpose of adapting to technical progress, Annex II to Directive 2009/48/EC of the European Parliament and of the Council on the safety of toys, as regards lead. Off. J. Eur. Union L110/6.
109 European Parliament and Council, 2003. Directive 2002/95/EC of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment. Official Journal of the European Union L37/19
110 European Parliament and Council, 2011. Directive 2011/65/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment (recast). Off. J. Eur. Union L174/88.
111 Commission Delegated Directive, 2015. EU Directive 2015/863 amending Annex II to Directive 2011/65/EU of the European Parliament and of the Council as regards the list of restricted substances. Off. J. Eur. Union L137/10.
112 European Parliament and of the Council, 2000. Directive 2000/53/EC of 18 September 2000 on end-of-life vehicles. Off. J. Eur. Communities L269/34.
113 Commission Directive, 2017. EU Directive 2017/2096 amending Annex II to Directive 2000/53/EC of the European Parliament and of the Council on end-of-life vehicles. Off. J. Eur. Union L299/24.
114 European Parliament and Council of the EU, 1994. Directive 94/62/EC of 20 December 1994 on packaging and packaging waste. Off. J. Eur. Union L365.
115 Commission Directive, 2002. EC Directive 2002/72/EC of 6 August 2002 relating to plastic materials and articles intended to come into contact with foodstuffs. Off. J. Eur. Communities L220/18.
116 Commission Regulation (EU) 2020/1245 of 2 September 2020 amending and correcting Regulation (EU) No 10/2011 on plastic materials and articles intended to come into contact with food. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32020R1245.
117 Council Directive, 1976. Directive 76/769/EEC of 27 July 1976 on the approximation of the laws, regulations and administrative provisions of the Member States relating to restrictions on the marketing and use of certain dangerous substances and preparations. Off. J. Eur. Communities L262/201.
118 Commission Decision, 2009. Directive 2009/425/EC amending Council Directive 76/769/EEC as regards restrictions on the marketing and use of organostannic compounds for the purpose of adapting its Annex I to technical progress. Official Journal of the European Union L138/11.

- Based on the above, at least in Europe, hazardous metal-based additives are no longer intentionally incorporated into contemporary plastics. However, hazardous metal-based additives have been detected in societal circulation and widely contaminate plastics lost in nature. Recent research suggests that such additives are still illegally employed in certain consumer goods available in the EU (but not necessarily manufactured there) and that historical, industrial plastics containing hazardous metals have been used to manufacture consumer goods with the intention of being environmentally positive. In addition, because of the durability of many plastics, historical products still in circulation (like toys) or employed for construction or plumbing (such as PVC window frames and piping) may contain high levels of restricted metals[119].

- More broadly, the recycling of plastics - especially poorly managed or dismantled electronic plastics coming both from within and outside of the EU - has introduced traces of restricted additives into a wider range of contemporary products in both the consumer and industrial sectors[120]. From a health perspective, this is particularly problematic for food-contact plastics or toys designed for young children.

- There appear indeed to be important loopholes that enable plastics defined as hazardous in one sector to be recycled into new (compliant or otherwise) goods in another sector that evade regulation or where regulation is less clear[121]. For example, inefficiently sorted waste from electrical and electronic equipment (WEEE) has the potential to introduce restricted and hazardous substances into the recyclate, including brominated flame retardants (BFRs), Sb, a flame-retardant synergist, and the heavy metals, Cd, Cr, Pb, and Mercury (Hg)[122]. For example, the occurrence of Cd, Cr, Pb, Sb, Nickel (Ni) and Cobalt (Co) has been reported in the take-out food containers widely used in China[123]. Most of the popular take-out food containers use cheap, highly heterogeneous, and coloured materials, often recycled in informal sectors.

- This holds particularly true for black plastic products, which constitute about 15 percent of the domestic plastic waste stream and of which the majority is single-use packaging and trays for food made of polyethylene (PE), polypropylene (PP), polystyrene (PS), and acrylonitrile-butadiene-styrene (ABS) plastic polymers[124]. Black plastics is not only hard to recycle, owing to the low sensitivity of black pigments to near infrared radiation used in conventional plastic sorting facilities, but there is mounting evidence that the demand for black plastics in consumer products is partly met by sourcing material from the plastic housings of end-of-life WEEE. Published and unpublished measurements of restricted substances (including Br as a proxy for BFRs) in food packaging, plastic electrical and electronic equipment (EEE) and non-EEE plastic products confirm the linear economy of plastic food packaging and demonstrate a complex quasi-circular economy for WEEE plastic that results in significant and widespread contamination of black consumer goods ranging from thermos cups and cutlery to tool handles and grips, and from toys and games to spectacle frames and jewellery. In addition, a compilation of data on black plastic litter collected from beaches of southwest England further reveals the contamination of consumer goods and blended plastic WEEE recyclate, exemplifying the pervasiveness of the problem[125].

119 Turner, A. and Filella, M. (2021) "Hazardous metal additives in plastics and their environmental impacts," *Environment International*, 156, p. 106622. Available at: https://doi.org/10.1016/j.envint.2021.106622.
120 Ibid.
121 Turner, A. (2018a). "Concentrations and migratabilities of hazardous elements in second-hand children's plastic toys." *Environ. Sci. Technol.* 52, 3110–3116. Available at: https://pubs.acs.org/doi/10.1021/acs.est.7b04685
122 Turner, A. (2018b) "Black plastics: Linear and circular economies, hazardous additives and marine pollution," *Environment International*, 117, pp. 308–318. Available at: https://doi.org/10.1016/j.envint.2018.04.036.
123 Han, Y. et al. (2021) "Occurrence, potential release and health risks of heavy metals in popular take-out food containers from China," *Environmental Research*, 206, p. 112265. Available at: https://doi.org/10.1016/j.envres.2021.112265.
124 Turner, A. (2018) "Black plastics: Linear and circular economies, hazardous additives and marine pollution," *Environment International*, 117, pp. 308–318. Available at: https://doi.org/10.1016/j.envint.2018.04.036.
125 Ibid.

- In the US, the Consumer Product Safety Improvement Act (CPSIA) covers safety requirements for toys and other children's products, such as substance limitation, testing, and labelling requirements. Heavy metals might also be restricted. For instance, the amount of lead contained in the products should be lower than 0.01 percent by weight.
  - 21 Code of Federal Regulations set out the requirements for the sale of food, drugs, cosmetics, and FCM, including food-contact plastics such as plastic food packaging and kitchen utensils. These Code include substances restrictions, including several hazardous metals.
  - The Toxic Substances Control Act (TSCA) regulates the manufacture and sale of certain toxic chemicals to protect the public from potential harm. The act covers a wide range of topics such as water treatment chemicals, substances registration, and the restriction of certain substances in consumer products.
  - The California Proposition 65 regulates substances that can cause health issues to consumers, for example, cancer or reproductive issues. It defines the No Significant Risk Level (NSRL) as the daily intake level that might lead to at most the 0.001 percent risk of cancer.
  - The Food and Drug Administration (FSA) is involved when industry collects used polymeric materials (usually food containers) and proposes to recycle these materials to make new food containers. FDA's main safety concerns with the use of PCR plastic materials in food-contact articles are: 1) that contaminants from the PCR material may appear in the final food-contact product made from the recycled material, 2) that PCR material may not be regulated for food-contact use may be incorporated into food-contact article, and 3) that adjuvants in the PCR plastic may not comply with the regulations for food-contact use. To address these concerns, FDA considers each proposed use of recycled plastic on a case-by-case basis and issues informal advice as to whether the recycling process is expected to produce PCR plastic of suitable purity for food-contact applications. FDA has prepared a document entitled Guidance for Industry - Use of Recycled Plastics in Food Packaging: Chemistry Considerations that will assist manufacturers of food packaging in evaluating processes for PCR plastic into food packaging.
  - Finally, many States adopted some of the substance limitations set by the EU Restriction of Hazardous Substances (RoHS) Directive.
- As online food delivery is undergoing explosive growth, particularly in China where there are several millions orders per day, the demand for take-out food containers is also growing. However, little is still known about the potential metal release from the containers and the associated health risks remains poorly understood.
- In 2022, the Ministry of Ecology and Environment of China released its "opinions on strengthening regulations on heavy metal pollution". The opinions require the designation of key regulated areas, substances, and industries as well as classification-based discharge management of heavy metals while setting targets for 2025 and 2035. Heavy metal pollutant discharge is planned to be managed through the designation of key regulated substances, total discharge limits and the pollutant discharge permit system. The key regulated substances are lead, mercury, cadmium, chromium, arsenic, thallium, and antimony, with total discharge limits imposed on five of them, namely lead, mercury, cadmium, chromium, and arsenic. The key regulated industries are: the mining and processing of certain non-ferrous metals (copper, lead, zinc, nickel, cobalt, tin, antinomy, and mercury), the smelting of these non-ferrous metals, lead-acid battery manufacturing, electroplating,

126 Cheng, V. (2023) "Plastic Product Regulations and Safety Standards in the United States." Available at: https://www.compliancegate.com/plastic-product-regulations-united-states/.
127 Turner, A. and Filella, M. (2021) "Hazardous metal additives in plastics and their environmental impacts," *Environment International*, 156, p. 106622. Available at: https://doi.org/10.1016/j.envint.2021.106622.

the manufacturing of certain chemical raw materials and chemical products ([poly]vinyl chloride production by calcium carbide method, chromium salt production and inorganic lead compound production from industrial solid waste) and leather processing. While the key regulated areas are designated based on heavy metal discharge intensity, the necessity of environmental improvement and environmental risk regulation. In each local government, key regulated substances and industries that are not listed in the ministry's opinions are specified in accordance with their targets for ecological environment improvement and heavy metal pollution intensity. The main targets are:

- By 2025, to reduce the discharge of the key heavy metal pollutants in the key industries by five percent starting from 2020 and to enhance green development in the industries, as well as improving the heavy metal environmental management capacity of the industries.
- By 2035, develop a system and a long-term framework for heavy metal pollution control and manage the environmental risks of heavy metals comprehensively and effectively.

The environmental management records of the pollutant permit, self-monitoring data and implementation reports of companies, will become important reference materials for pollutant discharge management by 2025[128].

128 *China strengthens regulations on heavy metal pollution | Enviliance ASIA* (no date). Available at: https://enviliance.com/regions/east-asia/cn/report_5674.

Annex 2 - Attributes used to describe the design practices

Objective of the practice	• Safe and waste-free practices • Safe and circular materials • Substitution of hazardous substances, when plastic is the material of choice • Design for reusability, when plastic is the material of choice • Design for recycling, when plastic is the material of choice
Name of the practice	If available, name of the practice or design.
Target plastic product	• Single-use plastic products (SUPPs) • Primary plastic packaging • Secondary plastic packaging • Tertiary plastic packaging
Application	What the product is used for, in which sector/industry.
Plastic materials/ Polymer types	• Thermoplastic types of polypropylene (PP) • Low-and linear low-density polyethylene (LDPE and LLDPE) • Polyvinyl chloride (PVC) • High-density polyethylene, (HDPE) • Polyethylene terephthalate (PET) • Polystyrene (PS), and expandable PS • Other
Name of the main additive(s) of concern	If available, the name and type of the substances of concern substituted or minimised.
Abstract	A brief outline of the practice.
State of implementation	**Pilot:** An initial small-scale implementation that is used to prove the viability of a project idea. **Start-up:** Practices in the early stages of development. **Commercial use:** Practices that have reached a certain scale and maturity, based on various indicators, such as number of end-users, number of participating businesses, number of countries reached.
Critical enablers	Legislative, technical, market and financial factors that should be in place for the practice to be successful.
Challenges/ Opportunities	Major challenges faced or expected in implementing the practice, as well as key opportunities.

Replicability	What makes the practice potentially replicable in comparable sectors, market conditions and policy contexts: • **High** - The practice can be easily replicated in similar economic, technological, and political settings. • **Medium** - The practice requires certain specific requirements to be successfully replicated. • **Low** - The practice requires a high level of technological advancement, market preparedness, or specific economic/political conditions to be successfully replicated.
Geographical area of implementation	Geographical area where the practice is currently implemented.
Contact	Contacts and country of the organisation(s) owning or promoting the practice.
For more information	Official website(s).
Similar case studies	When similar examples, from different countries, are to be found, only one will be described in detail. A short list of other cases (names, website) will be made available.
Comments	Any relevant information that might not be captured by the attributes listed above.

Glossary

Additives[129] are substances mixed with a base polymer during manufacturing to improve processability and modify the physical or chemical properties of the final plastic material. Basic polymer is incorporated into a formulary *(plastic compound)* with different additives, which are chemical compounds added to improve the performance (e.g., during shaping of the polymer, through injection moulding, extrusion, blow moulding, vacuum moulding, etc.), functionality and ageing properties of the polymer.

Additives may be present in a polymer:

- As *substances by themselves*, so they do not react covalently with polymer molecules, but instead they interact via weaker noncovalent bonds or may have reacted in the polymer matrix. These weakly-bound additives can leach into the environment during the normal use of plastic materials containing them, but especially during the degradation of plastics after improper disposal. Major emission originates from wear-and-tear and pulverisation.
- As *reactive additives* that may have reacted in the polymer matrix. These substances are inert and do not leak into the environment unless they are not fully polymerised during production.

Depending on their chemical structure, non-reactive additives may be toxic because of their persistence and bio accumulative properties, thereby posing a threat to living organisms. In addition, they may degrade into smaller and likely toxic persistent and bio-accumulative molecules. Substances used as monomers, intermediates or catalysts in plastic manufacturing are not considered to be additives.

Backhaul refers to the transport of the reusable packaging, after being used, back to retailer and/or producer which will clean, sanitize, repair, and reinsert it in the production line to be reused.

Barrier films are films that have been designed to be impervious to gas migration.

Beverage or food container is a vessel for transporting and drinking beverages, or for transporting and eating food. A large portion of beverage and food containers belongs to the category of single-use packaging.

Biobased plastics[130] are plastics derived fully or partially from plant materials, such as cellulose, potato or corn starch, sugar cane, maize, and soy, instead of petroleum or natural gas. Biobased plastic can be engineered to be biodegradable or compostable, but not all biobased plastics are biodegradable. They can be designed to be structurally identical to fossil-based plastics, in which case they can last in the environment for the same period.

Blockchain[131] is a distributed database that is shared among the nodes of a computer network. In this way, a blockchain is the foundation for immutable ledgers, or records of transactions that cannot be altered, deleted, or destroyed.

Circular Economy (CE)[132] can be defined as a systems approach to industrial processes and economic activity that enables used resources to maintain their highest value for as long as possible. Key considerations in implementing a CE are reducing and rethinking resource use, and pursuing longevity, renewability, reusability, reparability, replaceability and upgradability for resources and products that are used.

Circular business models (CBMs)[133] are usually classified in the following way:

- Retain product ownership (RPO) (or access and performance model or product-service system): where users can access and use the product without owning it.
- Product life extension (PLE) (or long-life model and encourage sufficiency): the focus is on long-lasting and durable products as a key competitive differentiator and a strong rationale for premium pricing, often associated to maintenance/repair services to support users' ability and willingness to keep the product in use as long as possible.
- Extending product value: whereby the manufacturer reuses or remanufactures old products through take-back programmes.
- Design for recycling (DfR) (or extending resource value): when waste is turned into useful raw material allowing a decrease or replacement of virgin material altogether.
- Industrial symbiosis: it refers to physical proximity and collaboration between companies.

Circular Business Models often overlap and complement each other, thus forming 'hybrid' CBMs.

Circular design[134] can be defined as a design based on lifecycle approach covering the whole internal process consisting of R&D, design, and circular business model development. Another commonly used term is eco-design although eco-design often aims for more environmentally friendly design within the current linear system, and it excludes circular business model development.

129 Wagner, S. and Schlummer, M. (2020) "Legacy additives in a circular economy of plastics: Current dilemma, policy analysis, and emerging countermeasures," *Resources Conservation and Recycling*, 158, p. 104800. Available at: https://doi.org/10.1016/j.resconrec.2020.104800.
130 *Biodegradable and compostable plastics — challenges and opportunities* (2020). Available at: https://www.eea.europa.eu/publications/biodegradable-and-compostable-plastics.
131 *What is blockchain?* (2022). Available at: https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-is-blockchain.
132 The Global Assessments Unit of the United Nations Environment Programme – Glossary. Available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/36833/RBMLCEG.pdf
133 Bocken, N. et al. (2016) "Product design and business model strategies for a circular economy," *Journal of Industrial and Production Engineering*, 33(5), pp. 308–320. Available at: https://doi.org/10.1080/21681015.2016.1172124.
134 The Ellen MacArthur Foundation *Design and the circular economy*. Available at: https://archive.ellenmacarthurfoundation.org/explore/circular-design

Design for resource optimisation[135] is designing products and services that require minimal resource use from the start to allow for circularity and longevity.

Design for recycling (DfR)[136] is design focused on the end of life of the product to ensure the value is maintained throughout the closed loop, without negatively impacting on the product/packaging's aesthetics, cost, or practicality. It is aimed to maximise the recyclable components in the structures, avoid hazardous materials or non-recyclables, reduce complexity, among other efforts. The final product should be fit for correct handling in a sorting process and for material recovery by means of recycling. The term recyclable packaging/product refers to a system that enables industrial-scale recycling.

Endocrine disrupter[137] is an exogenous substance or mixture that alters function(s) of the endocrine system and consequently causes adverse health effects in an intact organism, or its progeny, or (sub)populations.

Expanded Polystyrene[138] (EPS) is a white foam plastic material produced from solid beads of polystyrene. It is primarily used as a packaging and insulating material. It is a closed-cell, rigid foam material produced from:

- Styrene – which forms the cellular structure.
- Pentane – which is used as a blowing agent that facilitates the formation of foam.

Both styrene and pentane are hydrocarbon compounds and are obtained from petroleum and natural gas by-products. EPS is very lightweight with very low thermal conductivity, low moisture absorption, and excellent cushioning properties. Although EPS is 100 percent recyclable, it poses a significant environmental challenge, because the material is voluminous, non-biodegradable, and lightweight. There is, to date, no meaningful recycling of EPS due to high food contamination rates and a very weak market to clean, handle and process the material. In addition, since 1970 researchers have been studying the migration of styrene from packaging into food and uptake by animals. Studies have shown that styrene monomer migration into food products not only can have an impact on the sensory quality, but it can also lead to toxicologic and carcinogenic health effects[139].

Flexible packaging[140] includes films and laminates, which allow for the transport of higher volumes of product and less materials needed for production. This has been a revolutionary movement for brands to adopt to save on energy costs and reduce capital spent on materials. Flexible film is typically defined as any plastic less than 10 millimetres thick.

Food contact chemicals (FCCs)[141] are chemicals that are intentionally used and non-intentionally present in food contact materials (FCMs). FCMs can be defined as materials that come into contact with food and beverages during food processing, packaging, transport, storage, cooking, or serving. Different types of FCMs, for example, plastics, paper, glass, metal, adhesives, or printing inks, can be used, solely or in combination, to produce FCAs. A typical FCA is food packaging, such as bottles or wraps. However, food service items (e.g., cutlery) as well as food processing equipment (e.g., conveyor belts) or transport vessels also constitute a significant proportion of FCAs overall.

Monomer, under the REACH Regulation EC No 1907/2006, is defined as a substance which is capable of forming covalent bonds with a sequence of additional like or unlike molecules under the conditions of the relevant polymerforming reaction used for the particular process (Article 3(6)). In other words, it is a substance which, via the polymerisation reaction, is converted into a repeating unit of the polymer sequence. Substances exclusively involved in the catalysis, initiation or termination of the polymer reaction are not monomers. Any substance used as a monomer in the manufacturing of a polymer is therefore by definition an intermediate.

Mono-material multilayer plastic packaging[142] is packaging made from one polymer that is chemically modified to reveal slightly distinct functionalities, usually polyethylene (PE) resins, including both low-density and high-density materials. Differentiation of molecular characteristics allows modification of physical, mechanical and barrier properties. However, this type of packaging usually has limited properties, such as limited barrier performance or seal-ability properties; and may be unable to meet packaging requirements. On the other hand, considering that mono-materials are more homogeneous, conventional recycling systems can usually absorb their flows. Examples include retail grocery bags, bread bags, produce bags, newspaper sleeves, bubble wrap, PE based film mailers, air pillows and case wrap. Polypropylene (PP) is also used for packaging in similar applications.

Multi-material multilayer materials plastic packaging (MMPP)[143] is a packaging that consist of more than one layer of distinct materials where the components are layered to form flexible packaging (pouches, bags, shrink films, other pliable products) or rigid ones (trays, cups, containers, other rigid plastic sheets). This type of packaging is widely applied in the Fast-Moving Consumer Goods (FMCG) industry, in items with a relatively low-cost price and with a relatively short lifespan, like beverages, food, and toiletries. Flexible packaging often

135 Schumann, B. (2019) "Design for Optimised Resource Use - EcoDesign." Available at: https://ecodesign-packaging.org/en/guidelines/strategies/design-for-optimised-resource-use/.
136 Ibid.
137 *Endocrine disrupting chemicals* – United Nations Environment Programme. Available at: https://www.unep.org/explore-topics/chemicals-waste/what-we-do/emerging-issues/endocrine-disrupting-chemicals.
138 *Expanded Polystyrene (EPS Foam): Uses, Structure & Properties*. Available at: https://omnexus.specialchem.com/selection-guide/expanded-polystyrene-eps-foam-insulation.
139 Dawson, P.A., Seydim, A.C. and Hirt, D.E. (2020) "Styrene Monomer Migration from Expanded Polystyrene Into Food Acids and Ethanol," *Journal of Food Research*, 9(3), p. 39. Available at: https://doi.org/10.5539/jfr.v9n3p39.
140 *What Are the Different Types of Flexible Packaging and Films?* (2021). Available at: https://www.labelprofi.com/news/ID/209/What-Are-the-Different-Types-of-Flexible-Packaging-and-Films.
141 Groh, K.J. et al. (2021) "Overview of intentionally used food contact chemicals and their hazards," *Environment International*, 150, p. 106225. Available at: https://doi.org/10.1016/j.envint.2020.106225.
142 De Mello Soares, C.T. et al. (2022) "Recycling of multi-material multilayer plastic packaging: Current trends and future scenarios," *Resources Conservation and Recycling*, 176, p. 105905. Available at: https://doi.org/10.1016/j.resconrec.2021.105905.
143 De Mello Soares, C.T. et al. (2022) "Recycling of multi-material multilayer plastic packaging: Current trends and future scenarios," *Resources Conservation and Recycling*, 176, p. 105905. Available at: https://doi.org/10.1016/j.resconrec.2021.105905.

includes pouches, sleeves, sachets, and bags. Packaging for fresh food products may consist of four to seven layers of different components. A wide range of substances with different physical and chemical characteristics form multi-material multilayers, connected to functionalities and packaging performance needs. Various polymers are applied, such as polyolefins (PE and PP) and chemical variants (HDPE, LDPE, LLDPE, OPP), or polyesters such as PET and PLA. The layers within a flexible package can be aluminium foil or paper in addition to plastic. They are usually developed by co-extrusion or lamination techniques. High-speed equipment requirements for packaging production can also include specifications of rigidity, pliability, and heat resistance, being fundamental for a flawless packaging engineering. PE layers are applied to prevent leakage, while aluminium protects drinks from light and oxygen and is therefore most often used in products intended to provide a relatively long shelf-life. Laminated films made of aluminium and plastic are another example for multi-material multilayers. They are typically used in the form of pouches, tubes, and bags for the storage of a diverse range of foods and beverages. Industrial processes for recycling laminated packaging are not yet broadly available. Beverage cartons are more widely used packaging material for which recycling procedures have been developed and implemented.

Plastic packaging[144] usually consists of single polymers (e.g., polyethylene terephthalate (PET), polypropylene (PP), high (HDPE) and low (LDPE) density polyethylene, polystyrene (PS), and polyvinylchloride (PVC)), or multilayer plastic products, which are combinations of layers of several types of plastic or other materials. Plastic packaging often contains additives to enhance certain characteristics or functionalities, along with other components, such as adhesives or coatings. Further, packaging can contain residues from substances used during manufacturing, such as solvents, along with non-intentionally added substances (NIAS), such as impurities, oligomers, or degradation products.

Primary Packaging is the packaging that most closely touches a product, often referred to as "retail packaging." Its primary objective is to protect the product and inform or attract a customer.

Secondary Packaging is the packaging used to ship products already in primary packaging. Its main goals are to protect products and provide branding during shipping. It's also used as display packaging in retail locations such as grocery stores.

Tertiary Packaging is the packaging used most often by warehouses to ship secondary packaging. Its main goal is to properly protect shipments during their time in transit. Typically, it is not seen by consumers.

All three types of packaging can overlap.

Polymer[145] is a substance consisting of molecules characterised by the sequence of one or more types of monomer unit. A polymer can also contain additives necessary to preserve the stability of the polymer and impurities deriving from the manufacturing process. Stabilisers include, for example, heat stabilisers, antioxidants (both useful during extrusion) and light stabilisers (e.g., for preservation during use). Impurities are unintended constituents of the polymer such as catalysts residues. The quantities of a monomer substance which do not react during the polymerisation reaction and remain in the composition of a polymer are referred to as "unreacted monomers". Unreacted monomers in a polymer are also constituents of that polymer. Substances may also be added to improve the performance of the polymer for the purpose of adjusting or improving the appearance and/or the physico-chemical properties of the polymeric material. Examples of such substances include pigments, lubricants, thickeners, antistatic agents, antifogging agents, nucleating agents, and flame retardants. When a polymeric material contains such substances, it should be considered as a mixture or an article, as the case may be.

Material Recovery Facility (MRF) is a plant that separates and prepares single-stream recycling materials to be sold to end buyers.

Non-intentionally added substance (NIAS)[146] means "an impurity in the substances used or a reaction intermediate formed during the production process or a decomposition or reaction product". Most NIAS are regularly detected when using high sensitivity analytical techniques, although the chemical structure of unknown compounds is often difficult to establish by conventional tools.

Post-consumer Resin (PCR) is recycled resin produced from material that was used for its intended purpose. PCR is typically derived from materials that are collected in residential and commercial recycling programs.

Post-industrial Resin (PIR) is recycled resin produced from a by-product of manufacturing that was never used for its intended purpose, such as scrap in the manufacturing process.

Recyclable plastics, according to **The Association of Plastics Recyclers** (APR) and **Plastics Recyclers Europe** (PRE) in 2018, must meet the following four conditions:

- The product must be made of plastic that is collected for recycling, has market value, and/or is supported by a legislatively mandated program.
- The product can be processed and reclaimed/recycled with commercial recycling processes.
- The product must be sorted and aggregated into d efined streams for recycling processes.
- The recycled plastic becomes a raw material that is used in the production of new products.

Plastic recycling[147] encompasses a variety of methods aimed at reusing and repurposing plastic materials, each differing in complexity, cost, and environmental impact. These include:

144 The Ellen MacArthur Foundation. *The New Plastics Economy: Rethinking the future of plastics.* Available at: https://ellenmacarthurfoundation.org/the-new-plastics-economy-rethinking-the-future-of-plastics.
145 ECHA *How to register non-polymer*. https://echa.europa.eu/documents/10162/23221373/example_how_to_register_non-polymer_en.pdf/0b2f82af-42a0-05b6-7d24-63d03e435a18
146 Commission Regulation (EU) No 10/2011 of 14 January 2011 on plastic materials and articles intended to come into contact with food Text with EEA relevance. Available at: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32011R0010
147 World Economic Forum. (2020) "Plastics, the Circular Economy and Global Trade." Available at: https://www.weforum.org/whitepapers/plastics-the-circular-economy-and-global-trade.

Primary (closed-loop) recycling – Plastic materials are applied in new products without changing their physical and chemical states. It is an affordable means of recycling but cannot be maintained over a prolonged period due to wear and tear.

Secondary (mechanical) recycling – Plastics are physically reduced to smaller fragments, then thermally processed to recreate plastic products. Mechanically recycled plastics may contain both recycled and virgin plastics depending on the level of quality desired for the product. The presence of contaminants in plastic waste during mechanical processing can drastically reduce the quality of recycled plastic products.

Feedstock (chemical) recycling – A range of chemical reactions such as thermal cracking can be used to alter thermoplastics at the molecular level, breaking down polymers into smaller units called monomers and oligomers. These smaller molecules can then be fed back into the production cycle to create new polymers. Chemical recycling requires economies of scale due to costs; it cannot be applied to all thermoplastics and the environmental impact is still under debate. The method can be a potential solution to address the challenges related to so-called "substances of concern for recycling".

Quaternary recycling – Plastics are incinerated for energy generation, but the process has harmful ecological effects. For example, it releases carbon dioxide. Some in the field do not consider the process to be actual recycling. Thermosets such as silicone and polyurethane cannot be thermally remoulded once they have been cured in a heated catalytic environment. They can, however, undergo chemical recycling like thermoplastics.

Reusable packaging[148] is a packaging conceived, designed, and placed on the market to accomplish within its life cycle multiple trips or rotations by being refilled or reused for the same purpose for which it was conceived. They can be classified as follows:

- Reusable packaging that can be refilled by consumers, businesses provide only the refill.
  - Zero waste shops and Bring Your Own (BYO) initiatives.
  - Refillable parent packaging
- Take-back systems where businesses own the packaging and ensure (directly or outsourcing) the return, inspection, washing/sanitation, tracking, and refill of the packaging.
- Returnable packaging, with or without financial incentive (deposit return)
- Returnable Transport Packaging (RTP) systems (B2B, B2C, e-commerce)

Single-use beverage cups[149] are a widely used packaging system for take-away drinks.

Single-use plastic products are products made wholly or partly from plastic and that are not conceived, designed, or placed on the market to accomplish, within their lifespan, multiple trips, or rotations by being returned to a producer for refill or reused for the same purpose for which they were conceived (EU 2019/904). Often also referred to as disposable plastic products.

Shrink film or shrink wrap is a packaging material made of polymer-based plastic. The film is heated to a specific temperature to make it shrink around the product being packaged. A heat gun or heat tunnel is used in applying the desired amount of heat to the film.

Substance[150] is a chemical element and its compounds in the natural state or the result of a manufacturing process. In a manufacturing process, a chemical reaction is usually needed to form a substance.

Substitution refers to "the replacement or reduction of hazardous substances in products or processes by less hazardous or non-hazardous substances, or by achieving an equivalent functionality via technological or organisational measures", according to the REACH Regulation EC No 1907/2006. This is important as substitution does not need to be narrowly confined to switching to alternative substances but can be achieved by technological or organisational measures.

Stretch film or stretch wrap is an elastic polymer-based plastic film used to wrap pallets of products for shipping. Stretch wrap elasticity ensures that the items are bound very tightly and well protected. Shrink film is heated to create an extra layer of protection for the package. Stretch film enlarges to wrap pallets of pre-packaged goods for extra protection during transportation. Shrink film does not stretch and cannot be used as a stretch film. Stretch film does not shrink, and it cannot be sent through a heat tunnel or used with a heat gun.

Take-back programmes for reuse, remanufacturing and finally for recycling require reverse logistics, facilities for disassembly and designing and setting up a system for remanufacturing. These operations can be performed either through by the company itself or through setting up partnerships.

148 McKinsey (2022) "Reusable packaging: Key enablers for scaling." Available at: https://www.mckinsey.com/industries/paper-forest-products-and-packaging/our-insights/reusable-packaging-key-enablers-for-scaling.
149 Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (2020) "Material choices for environment-friendly packaging design. Analysis of existing Life Cycle Assessment (LCA) studies." Available at: https://greentechknowledgehub.de/sites/default/files/2021-10/Material_choices_211020.pdf
150 ECHA *What is a substance?* Available at: https://echa.europa.eu/support/substance-identification/what-is-a-substance.