Barriers and opportunities for circularity in plastics

Defining circularity for plastics

Photo by James Wakibia

Final report WP1

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Executive Summary

The current, predominantly linear approach to the plastics economy results in inefficient resource use, unnecessary waste and unprecedented pollution. This approach creates multiple social, economic, and environmental problems that characterise the global plastic pollution crisis. Multiple reports set out the case for a transition to a circular plastics economy, in which materials are retained in the economy for as long as possible to minimise waste and pollution. However, the specific approach to delivering operational plastics circularity is often undefined and unclear. Given the urgency of finding a systemic approach to reducing plastic pollution, it is critical to define circularity for plastics. This report therefore aims to identify an evidence-based definition and accompanying set of principles for the circularity of plastics.

The review to find and evaluate definitions and principles of a circular economy and discuss what they mean for plastics was undertaken in four parts. A desk-based review was conducted by searching the academic and practitioner literature using Boolean searches across multiple databases to identify literature that specifically defined circularity and identified principles of a circular economy. Remote structured interviews were conducted with 6 experts and actors in the plastics and circular economy field. The definitions and principles, and interview transcripts were text-coded to identify the core elements and components of each definition and set of principles. The final step was to convene a workshop with the Defra project team to discuss the definitions and principles identified and to consider which, with respect to plastics, should be used throughout the project

A definition for plastics circularity serves as a foundational framework to evaluate whether a specific activity, material, product, or system aligns with the circular economy. This definition functions as a set of criteria or benchmarks that must be met for something to be considered circular. If a material, product or process fails to meet the criteria in the definition, it cannot be classified as circular. In the database, 204 entries for definitions or principles were identified. Of all the entries there were 185 definitions, 59 sets of principles, and 49 entries with both. Of the 49 with both a definition and an accompanying set of principles, none was specific to plastics.

The most frequently identified core elements of definitions of circularity (in general) were removing or reducing waste, keeping resources or materials in use, minimising or preventing pollution, maintaining the value of materials or resources, and product or material design. The most common core elements of the 19 definitions specific to plastics circularity were removing or reducing waste, maintaining the value of materials or resources, keeping resources or materials in use, and minimising or preventing pollution. All interviewees highlighted the need to recirculate products or materials to retain their highest value, while half of all interviewees added that this needs to be for as long as possible. Other core elements of a definition of plastics circularity prevalent in the interviews were prioritising processes according to the zero waste hierarchy, the need to cover the entire life cycle of plastics, and decoupling economic activity from resource use.

Based on the literature review, expert discussions and interviews, the following suite of core elements were identified as essential to a definition for the circularity of plastics:

- Decouples economic activity from resource use or extraction
- Covers the full life cycle of plastics
- Follows the zero waste hierarchy
- Maintains the value of materials by keeping them in use as long as possible
- Removes or reduces waste
- Balances environmental integrity and social sustainability with economic value

Further analysis was undertaken of examples of definitions and a series of potential definitions were developed. While the definition offers a high-level understanding and determines whether or not a material, product or system is circular, a set of principles provides practical guidelines that operationalize the core concept and act as "guard rails," guiding actions and decisions in alignment with the overarching goals of circularity. Of the 60 sets of principles, all were for general materials. Definitions that were original comprised 32, while 28 were based on other definitions, neither of which had any that were plastics specific. Based on the text coding of the literature review and associated count of the principles, the most frequently cited were those of the Ellen MacArthur Foundation, namely: design out waste and pollution; circulate products and materials at highest value; and protect, regenerate or restore nature. The Rs of reuse, recycle, reduce, refill, repair and remanufacture followed next as the most common principles upon which a circular economy is based. Essential principles identified by the interviewees were varied, but the most commonly highlighted principles were the need to minimise waste and pollution, including that associated with greenhouse gas emissions; the need for protection of jobs and/or economic prosperity; and the need to ensure the health, safety and human rights across the entire value chain. The 'Rs' which include reuse, recycling, refill, repair, redesign, remanufacture, and others, were excluded since these do not guide decision making, but rather act as vehicles through which circularity can be delivered. Based on the literature review, expert discussions and interviews, the following five principles were identified as essential to guiding decisions on the circularity of plastics.

Any activity in line with plastics circularity must:

- Protect, restore or regenerate nature
- Ensure inclusive outcomes, quality job creation, fair and safe working conditions and that human rights are upheld
- Minimise pollution, including emissions and chemical leakages from plastics production, processing and disposal
- Transition away from the production of virgin materials, in line with the zero waste hierarchy
- Uphold dynamic safeguarding

All of the principles apply and are relevant to every material in the plastics economy. Any decision, policy, activity or process related to plastics should conform to all of these principles. The principles follow no hierarchy, and should all be considered equally. Measurable principles allow for the tracking of progress which fosters a culture of accountability and transparency. As such, a series of possible metrics or measurable targets for each principle is presented.

In adopting a set of definitions and principles for plastics circularity, several limitations were evident. First, definitions and principles in the literature and applied in practice are highly varied. Second, terms such as 'plastics', 'lifecycle', and others related to circular economy are often defined and applied inconsistently across various studies and practices. This inconsistency can lead to misunderstandings and hinder the development of cohesive approaches to circularity. Third, this research was restricted to open access literature, or that which is available behind paywalls to academic institutions, which may not encompass all available or relevant information on the topic. Finally, limiting research to English-language sources excludes a significant body of work in other languages, potentially overlooking valuable insights, case studies, and approaches adopted in non-English speaking regions.

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Acronyms

Defra	Department of Environment, Food and Rural Affairs
EMF	Ellen MacArthur Foundation
GPPC	Global Plastics Policy Centre
M&E	Monitoring and Evaluation
NGOs	Non-governmental Organisations
UNEP	United Nations Environment Programme
UoP	University of Portsmouth
WEF	World Economic Forum
WP	Work Package

Introduction

1.1 Context

The current, predominantly linear approach to the plastics economy results in inefficient resource use, unnecessary waste and unprecedented pollution. This approach creates multiple social, economic, and environmental problems that characterise the global plastic pollution crisis. Estimates suggest that current national and private sector policies will only slow the increase in plastic pollution by 7% per year against business as usual by 2040 (Lau 2020). Therefore, alternative approaches to organising the plastics economy are needed. Multiple reports set out the case for a transition to a circular plastics economy, in which materials are retained in the economy for as long as possible to minimise waste and pollution (EMF 2017, OECD 2022, UNEP 2023). Several countries, including the Netherlands, France and Italy in Europe, have adopted varying circular economy policies (King and Locock 2022) although guided by similar thinking at the EU level. The transition to plastic circularity within planetary boundaries is a key topic in the negotiations for an international legally binding instrument to end plastic pollution (the 'Global Plastics Treaty'). However, the specific approach to delivering operational plastics circularity is often undefined and unclear.

The practical meaning of circularity and the principles that guide circular approaches are rarely defined, making the role of circularity in reducing plastic pollution challenging to implement (Suraez et al., 2019; Nobre & Tavares 2021) Many interpretations of circularity exist, emphasising different scales, material flows, inclusions and exclusions, life cycle stages (Figure 1), and definitions. Given the urgency of finding a systemic approach to reducing plastic pollution, it is critical to define circularity for plastics (King & Locock 2022). There is a wealth of literature and reports on the circular economy, and an abundance of definitions and principles to define this topic, and sometimes, the varying definitions and principles can conflict with one another, or generate inconsistencies that make it difficult to apply a circular approach at local, national or even international scales.

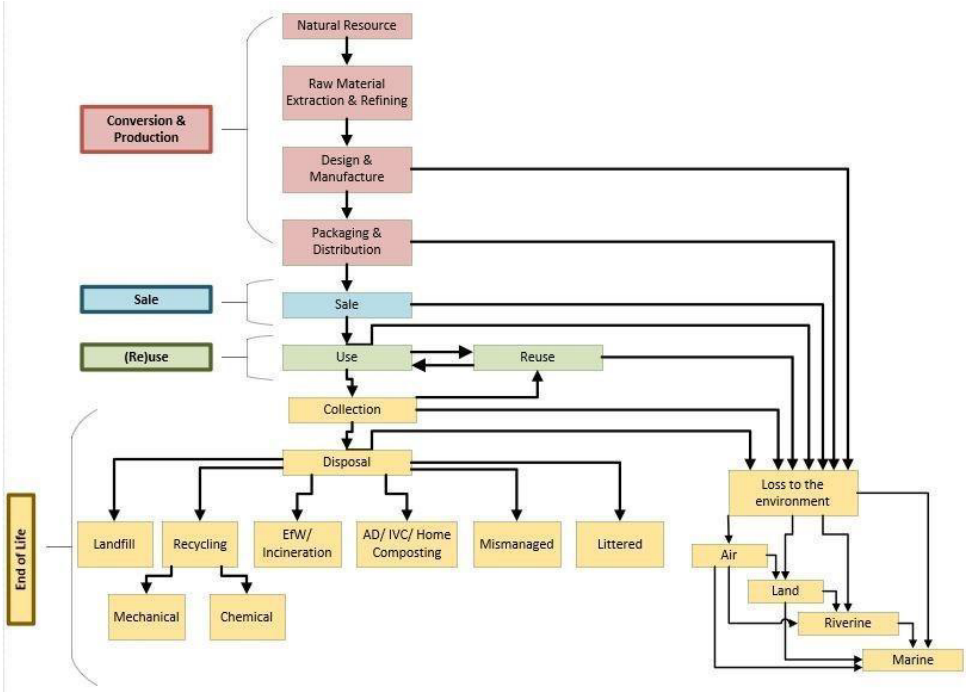

Figure 1. Flow diagram to represent each of the stages in the life cycle of plastic. Source: Defra

1.2 Objective

The objective of this study is to identify an evidence-based definition and accompanying set of principles for the circularity of plastics.

This report is structured into four main parts following the introduction. First the approach to synthesising and analysing definitions and principles, and exploring barriers and opportunities to plastics circularity, including for 9 different material types is presented in section 2. The findings and interpretations thereof are presented in section 3 for definitions and principles, and section 4 for circularity in practice. Finally, section 5 presents the limitations of this research, as well as future considerations and research priorities.

2. Methods

2.1 Definitions and principles

The review to find and evaluate definitions and principles of a circular economy and discuss what they mean for plastics was undertaken in four parts.

Literature review

A desk-based review was conducted by searching the academic and practitioner literature using Boolean searches across multiple databases to ensure full coverage. In particular, sources were sought that specifically define circularity and identify principles of a circular economy. Material from organisations that advocate for a circular economy, including the UNEP International Resource Panel, the Ellen MacArthur Foundation, and the European Environment Agency were also identified and reviewed. The following set of search engines were used:

- Google
- Google Scholar
- Scopus
- Science Direct

In each of the search engines, the following terms were consistently used either alone or in combination with the words 'definition' and 'principles', or other relevant words.

- Circularity
- plastic(s) circularity
- circular economy
- plastic(s) circulation
- material circularity

Only high quality evidence sources were used such as peer-reviewed academic articles, official reports by organisations and/or their websites, or policy briefs. Any other sources such as unofficial websites, student theses, blogs, or non-peer reviewed articles were excluded.

Interviews

Remote structured interviews were conducted with 6 actors in the plastics and circular economy field. The interviews were undertaken to provide expert insights into already adopted definitions and principles of plastics circularity, as well as to identify what experts consider to be the key components of a definition and/or set of principles to ensure an holistic, practical and clear approach to identifying circular economy practices. Interviewees remain anonymous to protect confidentiality. The interview questions are presented in Annex 2. The breakdown of interviewees was:

- 2 industry/producer representatives
- 1 academic specialising in materials and plastics circularity
- 2 circular economy focused organisations

- 1 innovation organisation directly involved in national circular initiatives

Text coding and analysis
The definitions and principles identified from the literature review were directly copied from source, and catalogued into an Excel database (Annex 1). The database included information on the year, originality (and the original source(s) or references if based on another), material type, and quality of evidence. The original text was then text coded to identify the core elements and components of each definition and set of principles. The interview transcripts were also text coded according to definitions cited or presented, core elements of definitions, key principles, as well as barriers and opportunities to plastics circularity and examples of circularity in practice (to be used for WP 2).

Analyses of the text coded database were run in Excel to identify patterns and recurring themes in the data. The original definitions of plastics circularity and patterns therein were evaluated to identify any conflicts or trade-offs for plastics and to consider the potential benefits and challenges of using the circular economy approach for plastics suggested by the original authors.

Workshop with Defra team
The final element of WP1 was to convene a workshop with the Defra project team to discuss the definitions and principles identified and to consider which, with respect to plastics, should be used throughout the project. Ahead of the workshop, a form was sent to all participants to identify what the effects of adopting the proposed definition core elements and principles would have on their area of work, and what life cycle stages would be affected. The workshop brought together all of the synthesised information and data and resulted in the identification of a core set of components in the definitions and principles, specific to plastics, that would be taken forward in this work.

3. Defining circularity for plastics: findings and interpretation

A total of 204 circularity definitions or principles were identified and entered into the database. There were 185 definitions and 59 sets of principles. There were 49 entries with both. Of the 49 with both a definition and an accompanying set of principles, none were specific to plastics.

It is recognised that the roots of the circular economy concept are often linked to the ideas of economists like Kenneth E. Boulding, who in his 1966 work "The Economics of the Coming Spaceship Earth" introduced the idea of a closed system of economy versus an open one. The earliest definition in the database is from 1994, referring to the need for ‘closed cycles’ of materials such as steel, energy and chemicals, to reduce disturbances on the natural environment and increase economic outputs, but does not refer to plastics specifically. The first use of the word ‘circular’ in the database of definitions and principles appears in 2008. The first plastics specific circularity definition appears in 2017, with the publication of the WEF, Ellen Mac Arthur, and McKinsey & Company’s “The New Plastics Economy — Rethinking the future of plastics”. This was one of the first major reports to bring the issue of plastic waste into the circular economy discourse, emphasising the need for a systemic shift in how plastic products are designed, used, and recycled. Since 2016, there has been a significant increase in the number of definitions and principles associated with the circular economy (Figure 2). The increase in new definitions started in 2016, with a marked increase in definitions relating to plastics as shown in Figure 2b. This continued rise in definitions and the emergence of plastics specific definitions suggests there is not a set consensus on either the definition of the circular economy or that of the circular economy in relation to plastics.

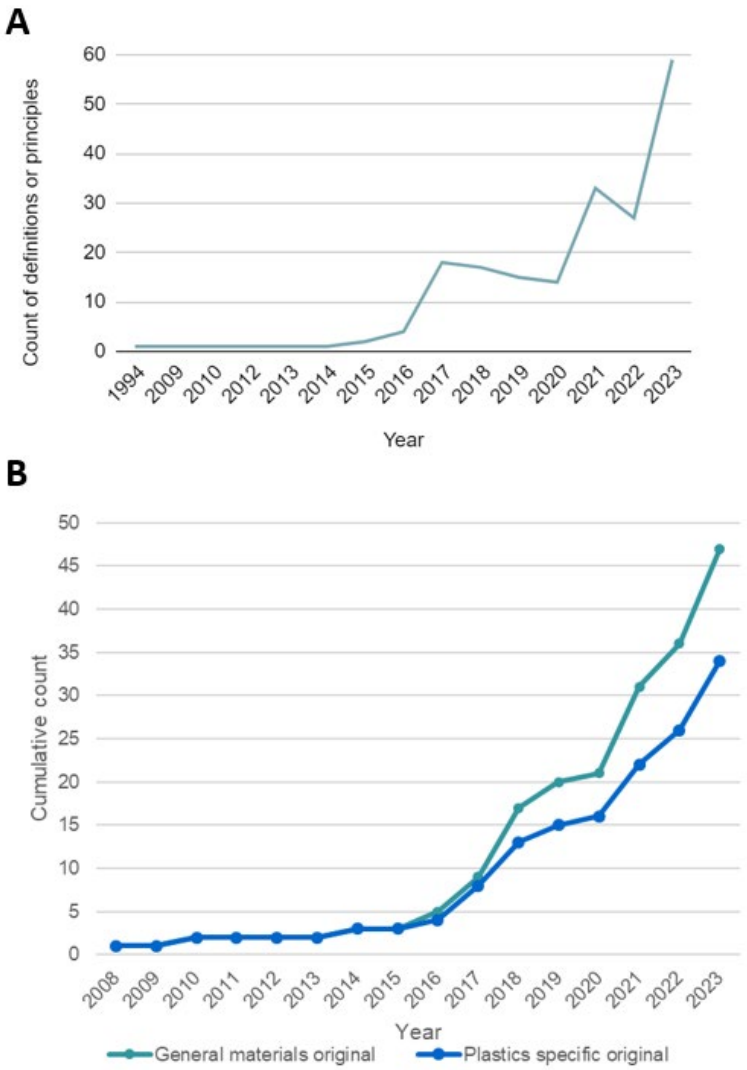

Figure 2. A. *Count of entries for definitions and principles over time.* ***B.*** *Cumulative count of original definitions for general materials and those specific to plastics*

There are a number of core circularity thought pieces and pioneers, such as the “Economics of natural resources and the environment” (Pearce and Turner, 1989) which discusses the relationship between economic activity and environmental impact, including resource depletion and pollution and "Cradle to Cradle: Remaking the Way We Make Things" (McDonough and Braungart, 2002), where circularity is defined through the concept of designing products and systems that emulate nature's processes where there is no waste. Books such as these have driven much of the circular economy thinking, and upon which the EMF bases their work, however have not been included in this study since they are not open access or accessible generally to academic institutions (see limitations in section 5).

3.1 Definitions

Box 1. *Purpose of a definition for plastics circularity*

A definition for plastics circularity serves as a foundational framework to evaluate whether a specific activity, material, product, or system aligns with the circular economy. This definition functions as a set of criteria or benchmarks that must be met for something to be considered circular. **If a material, product or process fails to meet the criteria in the definition, it cannot be classified as circular.** By setting clear, comprehensive standards, a circularity definition guides decisions and practices across industries, helping to drive genuine progress towards a more sustainable and regenerative approach to plastics use and management.

3.1.1 Patterns in definitions data

Of the 185 definitions, 165 (89%) were for general materials, and 20 (11%) were plastics specific (Figure 3A). There were 113 (61%) original definitions, of which 9 were plastics specific, while 72 (39%) were derived from other definitions, of which 11 (6%) were plastics specific (Figure 3B).

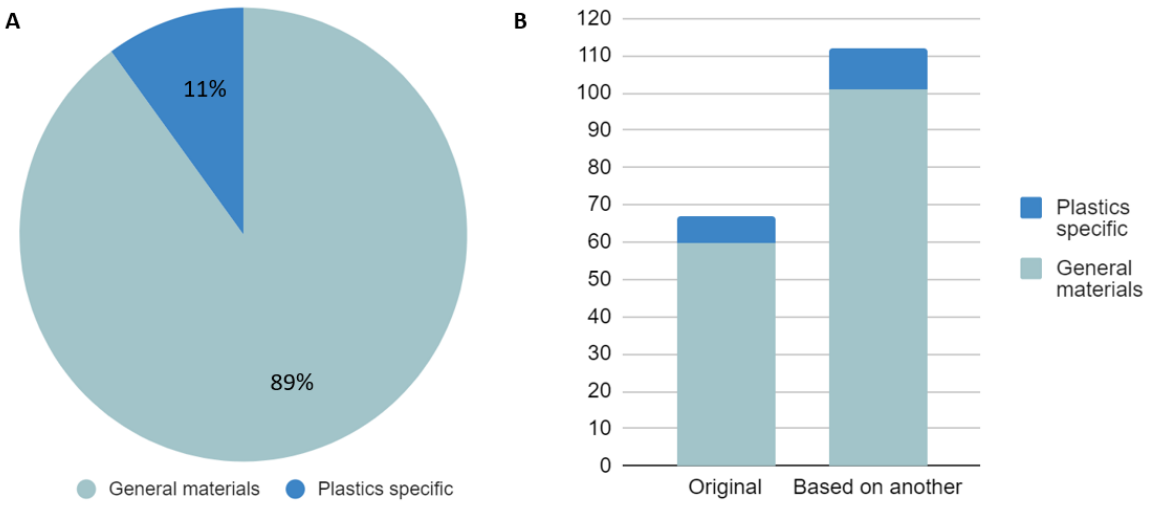

Figure 3. A. *Percentage of definitions that applied to general materials, or plastics specifically.* ***B.*** *Number of original definitions and those based on others, by material (plastics or general).*

In terms of the sources of definitions, 80% were identified from peer reviewed academic articles, 10% from official reports, 9% from official websites, and 1% from policy briefs.

Table 1. *Number of definitions from each source type, specific for plastics specific definitions.*

Source type	All definitions	Plastics specific
Peer reviewed journal	148	14
Official report	19	4
Official website	16	2
Policy brief	2	0

When coding for core elements of all definitions, the most frequently identified (Table 2) were removing or reducing waste (50%), keeping resources or materials in use (40%), recycling (38%), reuse (37%), minimising or preventing pollution (33%), maintaining value of materials or resources (32%), and

product or material design (21%). The most common core elements of the 19 definitions specific to plastics identified were removing or reducing waste (58%), recycling (42%), maintaining value of materials or resources (37%), keeping resources or materials in use (26%), reuse (26%), and minimising or preventing pollution (26%).

Table 2. *Number of times core elements appeared in definitions, including plastics specific definitions*

Core element	Count in all definitions (n=185)	%	Count in plastics specific definitions (n=20)	%
removing or reducing waste	92	49.7%	11	55.0%
keeps resources or materials in use / renewable resources	77	41.6%	6	30.0%
recycling	671	38.4%	9	45.0%
reuse	69	37.3%	5	25.0%
minimises or prevents pollution	6 2	33.5%	5	25.0%
maintaining value of materials or resources	59	31.9%	8	40.0%
product or material design	40	21.6%	2	10.0%
decouples economic activity from resource use / extraction	33	17.8%	2	10.0%
restorative or regenerative	32	17.3%	5	25.0%
covers full life cycle	32	17.3%	2	10.0%
refill or repair	20	10.8%	2	10.0%
end of life management / waste management	18	9.8%	1	5.0%
recovery and collection	15	8.2%	3	15.0%
eliminates chemicals or toxicity	6	3.3%	0	0.0%
zero waste	3	1.6%	0	0.0%

When evaluating the coded text from the interviews, the core elements identified as necessary for a definition of plastics circularity by each participant were identified (Table 3). All of the interviewees (n=6) highlighted the need to recirculate products or materials to retain their highest value, and half added that this needs to be for as long as possible. Four interviewees made reference to prioritising processes according to the zero waste hierarchy. Half of the interviewees mentioned the need to cover the entire life cycle of plastics, and four indicated the importance of reducing the reliance of economic activity on new resource extraction (decoupling economic activity from resource use). Others were mentioned by only one or two interviewees and can be identified in Table 3 or Annex 3 in more detail.

Table 3. *Essential definition components according to expert interviews*

Participant number	Core definition elements identified	Definition suggested or adopted in their practice
P1	• Resource or material efficiency • Maintaining value of materials or resources • Covers full life cycle • Returning the materials back to the economy • Dematerialise consumption (decoupling) • Follow zero waste hierarchy	The goal of the circular economy is to use plastics as efficiently and for as long as possible and then recover them. That's why the entire life cycle of a plastic is considered from the very beginning: from raw material extraction to production, processing and use to recycling.
P2	• Covers full life cycle • Decouple economic growth from resource dependence • 5 Rs - Reduce, Re-design, Reuse, Repair, Recycle need to be ranked - not equal • Maintain the value of materials over time • Eco-design of products	The circular economy is the sustainable management of materials through a closed-loop system that maximises their reuse and maintains their value. This approach encompasses the entire lifecycle, from production to disposal, aiming to minimise waste, reduce reliance on new resources, and create economic and environmental benefits.
P3	• Materials should kept in circulation through processes maintenance • Reuse should be prioritised over recycling, refurbishing, composting etc. • Account for the entire life cycles • Account for import/export of materials and products • Clarify that plastic is not only packaging, but a variety of products that span from agriculture to construction • Creating eco-designed products	None, they use EMF's definition.
P4	• Keeping products and materials in use (at their highest value) for as long as possible • Designing products and materials to be cycled back into the economy in order to eliminate waste • Reduce reliance on resources to protect natural environment • Design for reuse, redistribution, disassembly or finally, recycling	A circular economy describes an economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes… with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations
P5	• Restorative and regenerative by design • Social equity and prosperity • Recirculation of the value of products and materials • Fair trade • Prioritises environmental sustainability • Decouples growth from resource extraction	None
P6	• Minimises resources use • Maintains resources in circulation for as long as possible without losing integrity • Reduces energy consumption • Should account for climate impacts, and as such deprioritise incineration • Minimises pollution • Optimises the economy	None

Evaluation of these core elements, in consultation with the experts interviewed and the Defra project team, led to 'restorative and regenerative of nature', and 'minimises or prevents pollution' being excluded from further analysis, as these act more as principles to guide decision making around circularity (see section 3.2 on principles). Further, the 'Rs' which include reuse, recycling, refill, repair, redesign, remanufacture, and others, were excluded since these do not define a material, product or system which is circular, but rather identifies vehicles through which circularity can be delivered.

Instead, all of these Rs sit within the zero waste hierarchy (Figure 4), and can be referenced as such accordingly to ensure that discussions and strategies in the circular economy are grounded in a framework that is not limited to isolated actions or short-term solutions, or that 'lower' hierarchy Rs, such as recycling or residuals (waste) management, are not adopted as a priority solution over the higher hierarchy Rs such as redesign or reuse.

Based on the literature review, the workshop with Defra, and interviews, the following suite of core elements have been identified as essential to a definition of the circularity of plastics:

- Decouples economic activity from resource use or extraction
- Covers the full life cycle of plastics
- Follows the zero waste hierarchy
- Maintains the value of materials by keeping them in use as long as possible
- Removes or reduces waste
- Balances environmental integrity and social sustainability with economic value

Decouples economic activity from resource use or extraction

Decoupling in this sense asserts that achieving true circularity in plastics necessitates a fundamental shift away from reliance on new resource extraction (Parrique et al., 2019) and promoting the idea of 'reduce' in resource use. This speaks to disassociating the product or service from the natural resource (IRP, 2021), or prioritising the function of the product or service, rather than the material itself, to sustain economic activity while reducing environmental impact. Fundamentally, circularity cannot be achieved without this decoupling (EMF, 2017). Without decoupling, the continual reliance on extracting new resources perpetuates a linear model of consumption, which is antithetical to the concept of circularity. Furthermore, without decoupling, there is little incentive to innovate, as the focus remains on producing new items rather than rethinking how to make the best use of existing materials.

Covers the full life cycle of plastics

Incorporating the full life cycle of plastic ensures a comprehensive approach to managing plastics from resource extraction and production to end-of-life, including recycling and disposal. A life cycle approach aims to ensure that every stage of a plastic material or product's life contributes to a more efficient system which produces less waste and pollution (including greenhouse gas emissions). This core element had low representation in the database, which is likely since the vast majority of definitions were not specific to plastics. However, Life Cycle Analysis (LCA) has been suggested generally as the tool to ensure that circular economy approaches adopted meet the expectations of the benefits. This would enable analysis of the impact at different stages within the product lifecycle and identification of potential synergies between the stages (Sassanelli et al., 2019; Peña et al., 2021). Targeting the full plastics life cycle was also considered by the experts interviewed as essential for delivering a circular economy for plastics. Addressing the full life cycle of plastics allows for a more balanced distribution of the costs and benefits of activities across the global value chain (Simon et al., 2021).

Follows the zero waste hierarchy

The zero waste hierarchy (Figure 4) emphasises waste prevention as its top priority and also encompasses all of the 'Rs', of which many provide a vehicle for the delivery of the circularity concept. By integrating this hierarchy into the definition of plastics circularity, the focus shifts towards designing out waste from the beginning, rather than managing it after it's created. Following the waste hierarchy encourages the efficient use of resources, by promoting practices such as redesign, reuse, and repair, which conserve resources and reduce the need for new plastic production, aligning with the core concept of circularity.

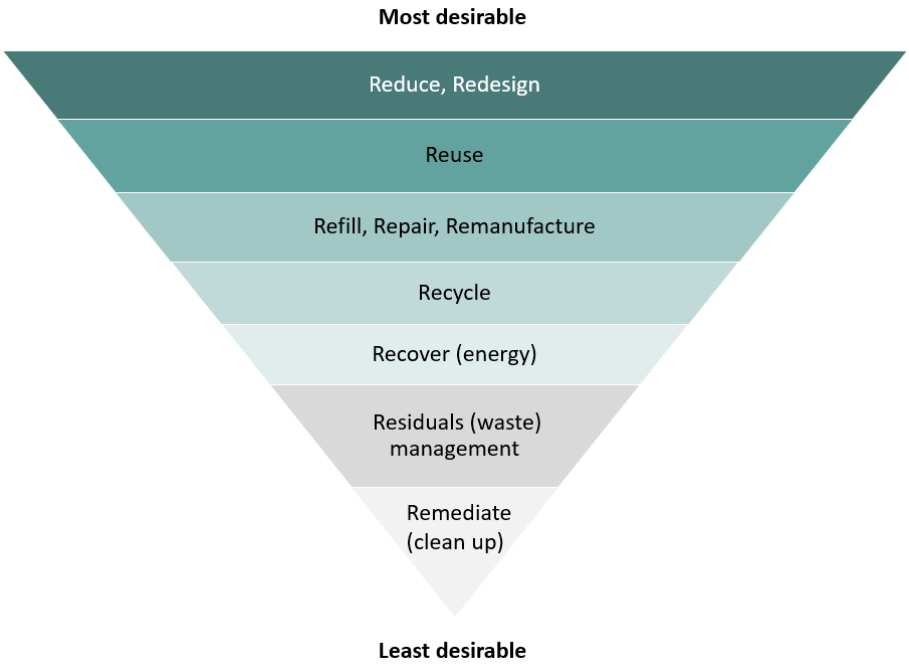

Figure 4. *Plastics zero waste hierarchy*

Public investment and policies at the bottom half of the waste hierarchy has resulted in a 'lock-in' phenomenon, solidifying societal assumptions that linear waste management services, along with the material infrastructures that sustain them, will persist (Sharmer et al., 2021). Plastics related policies are urgently needed at the higher stages of the zero waste hierarchy (March et al., 2022; Olatayo et al., 2022), and for this reason, this core element has also been selected as essential to a plastics circularity definition.

Maintaining the value of materials by keeping them in use as long as possible

This component highlights the goal of extending the lifespan of plastic materials and products, thereby reducing the need for new resource extraction. While highlighting the importance of using renewable resources for activity wherever possible, it also acknowledges the complexities involved in this transition. It is necessary to balance the use of renewable resources with considerations of biodiversity, land and water use, and overall environmental impact. This approach reinforces the need to maintain the economic and perceived value of materials. Maintaining the value of materials helps in changing the perception of reused or repaired products, or recycled materials from being seen as inferior to virgin material based materials or products, to being valued for their quality and sustainability (EU, 2018; Polyportis et al., 2022). This change in perception will drive not only consumer behaviour but also influence manufacturers' design choices (Rizos et al., 2016).

Removes or reduces waste

Removing or reducing waste is a fundamental aspect of circularity, as it directly addresses the problem of plastic (and other) pollution by reducing the amount of waste that is available to leak into the environment in the first place. This concept involves rethinking and redesigning products and processes to prevent waste creation from the outset, rather than just managing it after it's been produced. Reducing waste through design includes changing polymerisation or manufacturing processes to use fewer resources and generate less waste (including regarding the use of chemicals and additives), designing products for reuse instead of single use, using materials that are easier to recycle, designing products for easy disassembly, choosing designs that extend product lifespan, or substituting with alternative materials or products entirely (with sufficient analysis on resource use,

and other impacts). It also involves innovative approaches such as modular design, which allows for easy repair or replacement of parts instead of discarding the entire product.

Balances environmental integrity and social sustainability with economic value
Incorporating the potential for economic benefits is key to gaining support from decision-makers. This aspect of the definition demonstrates that a circular approach to plastics is not only environmentally beneficial but also economically viable (Paquin et al., 2015; Linder and Williander, 2017; McKinsey, 2017). It addresses concerns that sustainable practices might lead to higher costs by highlighting the economic opportunities and efficiencies that can arise from circular practices, such as job creation in remanufacturing sectors, lower structural unemployment, increased material productivity, innovation in materials processing, and long-term cost savings through resource conservation (Mitchell and James, 2015).

3.1.2 Analysis of a plastics specific, original definitions

To further identify what makes a plastics circularity definition useful, applicable and clear, a review of existing definitions was undertaken. The review identified what each definition may mean for plastic, strengths in relation to the six core elements of a definition identified in section 3.1.1, and any potential conflicts or trade-offs inherent to the definition.

Box 2. *Analysis of Defra's Maximising Resources, Minimising Waste definition of circularity*

Although not specific to plastics, the Maximising Resources, Minimising Waste (Defra, 2018) adopts the following definition:

"A circular economy is an approach to managing resources which involves products and materials being kept in use for as long as possible, extracting maximum value from them. It means products and materials are reused, repaired, remanufactured, recycled or regenerated whenever possible and appropriate."

The primary strengths of this definition include that it highlights the extraction of maximum value from products and materials, encourages efficient use of resources, and emphasises extending the lifespan of products and materials. This definition is comprehensive in that it covers both products and materials.

In terms of flexibility, the inclusion of 'whenever possible and appropriate' allows for practical application across diverse contexts and acknowledges the varying feasibility of implementing circular practices. However, this also poses ambiguity, where the interpretation of 'whenever possible and appropriate' is subjective and can lead to multiple interpretations, potentially resulting in inconsistent applications and reduced efforts through using this as a loophole for weaker implementation of circular practices. The definition does not detail how to prioritise or balance the different aspects stated to deliver the circular economy, namely reuse, repair, and recycling, which can vary in their environmental impacts and waste generation. Replacing these with the need to follow the zero waste hierarchy would make this prioritisation clearer.

There were 164 definitions of circularity for materials in general, with 60 of these being original definitions. Due to time constraints, not all of these could be evaluated for their strengths or trade-offs. Of the 20 plastics specific definitions, only 9 were original, of which three referred only to recycling of plastics under their circularity definitions. These were excluded since recycling is not a completely circular process, nor does it encompass full circular economy thinking. The following 6 plastics specific, original definitions were identified, and are assessed for their comprehensiveness and strengths against the six core elements of a definition identified in section 3.1.1.

A. “An ideal goal for the transformation of the plastic value chain is the concept of circular economy – the complete return of post-consumer plastic waste (PCPW) for repeated re-consumption after recovery and recycling processes.” (Lee, 2021)

This definition by Lee (2021), while it embraces the novel concept of transforming the plastic value chain, does not truly consider the whole value chain or plastics life cycle. The emphasis is on end of life (PCPW) and does not focus on the value retention of products, and makes no mention of returning the waste to original product use. Rather, the priority is on recycling only, and fails to consider the higher stages of the zero waste hierarchy. The ‘complete return’ does highlight the need to close the loop of the plastics economy, but without full consideration of the life cycle, loses its value in the definition. The definition does not explicitly promote reducing plastic use or reusing plastic products, nor does it highlight value retention.

B. “Circular economy of plastics is directly related to the methods to close the loop of plastic's life, by recycling, reusing and reducing in such a way that the post-consumer plastic wastes should no longer exist or affect environment and life forms. It focuses on the processing and reusing the plastic waste. [...]. Circular economy can be achieved once upcycling of plastic wastes is carried out. “ (Chawla et al., 2022)

The definition by Chawla et al (2022) clearly identifies the need to close the loop, but later ends the definition with an emphasis on waste, rather than focusing on the prevention of waste. The presentation of recycling, reuse and reduce is reversed from the optimum order of terms, prioritising recycling over reuse, and reuse over reduction, which does not align to the zero waste hierarchy. While upcycling can be beneficial, it may not always be the most feasible or efficient method for all types of plastics, especially those that degrade in quality. Prioritising upcycling could divert attention from more circular strategies, at the expense of other important aspects like design for longevity, reuse and reducing initial production.

C. “A circular economy is restorative and regenerative by design. This means materials constantly flow around a ‘closed loop’ system, rather than being used once and then discarded. In the case of plastic, this means simultaneously keeping the value of plastics in the economy, without leakage into the natural environment.” (ERM Sustainability Institute, 2022)

The ERM Sustainability Institute definition (2022) starts with a vague sentence about circular economy being restorative and regenerative by design, which runs the risk of pursuing circularity at any cost to prevent the material from leaving the system. The focus is more on cycling materials within the economy, which might inadvertently underemphasize the importance of reducing overall plastic production and consumption.

D. “The circular economy is an economy which is recognising and capturing the value of plastics as a resource, with the least impact on the environment, climate and society. The plastics industry is striving to transform the traditional linear economy - where plastics are typically disposed of at the end of their service life - into a plastics circular economy. The plastics circular economy is a sustainable model where plastics remain in circulation longer, and are reused and recycled at the end of their life span.” (Plastics Europe, 2022)

This definition by Plastics Europe (2022) is relatively comprehensive since it highlights the need to capture the value of plastics while at the same time reducing the impacts on the environment, climate and society. It then goes into a more politically aligned statement, which presents more of a position than a definition, which adds little insight into the purpose of a plastics circular economy, but does not pose any inherently conflicting suggestions. The definition then highlights the need to extend the length

of time that plastics are in circulation in the system, but does not specify whether this relates to materials or products (which would inherently change the nature of the system if only one), or both. The final phrase places no priority or reuse over recycling - and implies that reuse should only be applied at the end of a plastics life, rather than extending the lifespan, and again, is unclear if this applies to a product or material. This definition also makes no mention of any form of reduction in consumption or production of virgin materials.

E. "The overarching vision of the New Plastics Economy is that plastics never become waste; rather, they re-enter the economy as valuable technical or biological nutrients. The New Plastics Economy is underpinned by and aligns with circular economy principles. It sets the ambition to deliver better systemwide economic and environmental outcomes by creating an effective after-use plastics economy (the cornerstone and priority); by drastically reducing the leakage of plastics into natural systems (in particular the ocean); and by decoupling plastics from fossil feedstocks." (EMF, 2017)

The 'New Plastics Economy', defined by EMF (2017), which in essence refers to the circular economy for plastics, is very high level and lacks specificity. While it draws on important components such as reducing pollution and the need to deliver economic outcomes, it includes nothing tangible. For example, plastics that 'never become waste' is high ambition, but it is not necessarily possible to legislate for. Lastly, the inclusion of decoupling is positive, however 'decoupling plastics from feedstocks' lacks clarity regarding whether this is through a combination of recycling and biobased materials or through reduction in use.

F. Circular plastic products - are designed to be reused safely many times, and their material recycled or composted at the end of use, in practice and at scale, minimizing their adverse environmental impacts and respecting the rights, health and safety of all people involved across their life cycle (UNEP/PP/INC.1/7), including product users (adapted from UNEP/PP/INC.1/7 to include health considerations). (UNEP, 2023)

The UNEP definition for circular plastic products (2023) is one of the only ones that includes the entire life cycle of plastics, from production to end-of-use, rather than focusing on post consumer plastics. This definition prioritises reuse before recycling and composting, or other end of life approaches in line with the zero waste hierarchy. However, where the definition strongly emphasises reuse and recycling, this might inadvertently underplay the importance of reducing plastic production and consumption in the first place. Another strength is that including the rights, health, and safety of all individuals involved, as well as product users, adds a human-centric dimension, acknowledging the social aspects of sustainability. However, terms like 'safe reuse' and 'respecting rights' are subjective and could vary in interpretation, potentially leading to inconsistent application and standards. Lastly, the emphasis on environmental and health considerations is strong, but the definition fails to include any considerations for economic stability.

3.1.3 Options for the definition of plastics circularity

Based on the analyses of the suite of definitions, and in line with the core elements further identified with plastics and circularity experts, the following definitions are proposed as potential options for adoption.

Option 1:
Plastics circularity is an approach that aims to decouple economic activity from new resource extraction, minimising waste across the entire lifecycle of plastics. It adheres to prioritising the higher

levels of the zero waste hierarchy, maintaining the value of materials by keeping them in use as their original design for as long as possible, all the while ensuring circularity is achieved in an environmentally, socially and economically sustainable manner.

Option 2:
Plastics circularity is an approach that decouples economic activity from resource extraction by managing the entire life cycle of plastics in a way that reduces initial consumption and system inputs to maintain the value of materials and products and minimise all forms of waste associated with plastics. Circular materials, systems or products exist at the higher levels of the zero waste hierarchy, keeping products and materials in use for as long as possible and reducing the need for new resources, while ensuring that social, economic and environmental impacts are balanced.

Option 3:
Plastics circularity focuses on maintaining the value of plastic materials and products for as long as possible within their life cycle, while reducing all forms of waste and decoupling economic activity from new resource extraction. This approach pushes materials and products up the zero waste hierarchy to reduce new material inputs, and supports stable economic activity, social safeguarding and environmental preservation.

3.2 Principles

Box 3. *Purpose of a set of principles for plastics circularity*

The purpose of establishing a set of principles for plastics circularity alongside a definition is to provide practical guidelines that operationalize the core concepts within the definition. While the definition offers a high-level understanding, and determines whether or not a material, product or system is circular, the **principles act as "guard rails," guiding actions and decisions aligned with the overarching goal of circularity.**

3.2.1 Patterns in principles data

Of the 60 sets of principles identified, all were for general materials not plastics specifically. There were 32 (54%) original definitions , while 28 (46%) were based on other definitions (Figure 5).

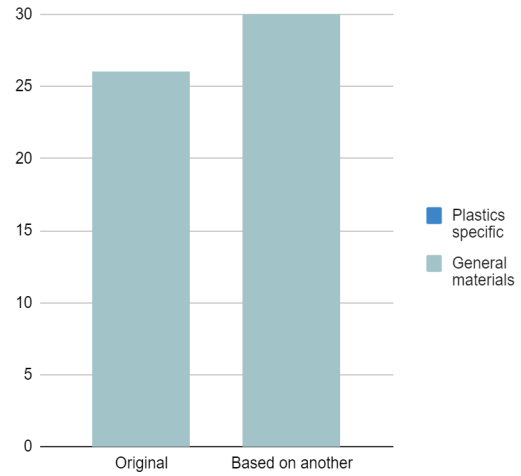

Figure 5. *Number of original circularity principles and circularity principles based on other sources (plastics or general).*

Of the 28 sets of principles based on another source, 19 (68%) cited the EMF principles of circularity:

- Eliminate waste and pollution
- Circulate products and materials (at their highest value)
- Regenerate nature

Based on the text coding and associated categorisation of all 60 sets of principles (Table 4), it is unsurprising that the three EMF principles (marked with an asterisk) were those with the highest occurrence, each present in over 40% of the full suite of principles in the database. The Rs of reuse (41%), recycle (34%), reduce (32%), refill, repair and remanufacture (19%) followed next as the most common principles upon which a circular economy is based.

Table 4. *Number of times each principle was included*

Principle	Count (n=60)	%
*Design out waste and pollution	26	44 %
*Circulate products and materials at highest value	25	42 %
*Protect, regenerate or restore nature	24	41 %
Reuse	24	41 %
Recycle	20	34 %
Reduce consumption / production	19	32 %
Refill, repair, remanufacture	11	19 %
Economic prosperity and job creation	10	17 %
Resource or material efficiency	9	15 %
Resource recovery / collection	9	15 %
Moving away from linear paradigm / take make waste	4	7 %
Saves energy	3	5 %
Polluter pays	2	3 %
eliminates chemicals or toxicity / human health	2	3 %
Standardisation	1	2 %
zero waste design	1	2 %

In terms of the sources of principles in the database, 78% were identified from peer reviewed academic articles, 12% from official reports and 8% from official websites by well known organisations, and 2% from policy briefs.

Essential principles identified by the interviewees were varied (Table 5), but circulated around a number of key common principles. The most commonly highlighted principles were the need to minimise waste and pollution (6 interviewees), including that associated with greenhouse gas emissions (3 interviewees); the need for protection of jobs and/or economic prosperity (5 interviewees); and the need to ensure the health, safety and human rights across the entire value chain (5 interviewees).

Table 5. *Essential principles for plastics circularity according to expert interviews*

Participant number	Key principles identified
P1	● Prevention in the first place ● Operates under zero waste hierarchy ● Economy and jobs must not be jeopardised ● Include considerations for climate
P2	● Waste is eliminated ● Must minimise pollution ● Must consider pollution across full life cycle including greenhouse and chemicals emissions ● Human health and environment must not be impacted ● Human safety and rights should not be jeopardised
P3	● Minimises waste ● Maximises resource efficiency ● Promotes environmental sustainability ● Inclusivity, considering the social impact of both the problem and the solutions ● Is flexible and responsive in policy design and policymaking
P4	● Eliminates plastic waste and pollution ● Acknowledges the societal reliance on / benefits of plastics and the way that plastic products perform ● Prioritises investment in alternatives to plastics employed for single-use purposes i.e. alternative systems for reuse and/or alternative materials. ● Simplifies or reduces the number of polymers used in plastic products ● Considers equity and economic prosperity
P5	● Recognises and protects rights, creates good quality jobs and fair work ● Includes provisions for micro, small and medium enterprises to enable circular models on smaller scales ● Ensures fair trade in supply chains ● Protects the environment
P6	● Does not inhibit innovation and economic activity ● Human health is not impacted by processes in the plastics value chain ● Must address associated carbon emissions

Evaluations of the identified principles, in consultation with the experts interviewed and the Defra project team, led to 'Circulate products and materials at highest value', and 'operating under the zero waste hierarchy' being excluded from further analysis, as this was already identified as an essential core element in the definition, which describes what makes a material, product, business or system circular rather than guiding decisions on circularity (see section 3.1 on definitions). Similarly, designing out waste was excluded, but not pollution since this was deemed necessary to expand further on what defines pollution (see principle description below). Further, the 'Rs' which include reuse, recycling, refill, repair, redesign, remanufacture, and others, were excluded since these do not guide decision making, but rather act as vehicles through which circularity can be delivered. Instead, all of these Rs sit within the zero waste hierarchy, which can be adopted as a priority within the principles.

Box 4. *Evaluation of priority principles identified by Defra in initial terms of reference*

This box assesses the realities of a circular economy in plastics in terms of avoidable plastic waste and ending plastic pollution, two priority principles identified by Defra in the initial call for work, and the strengths and weaknesses of including these.

Eliminating avoidable plastic waste

Avoiding unnecessary plastic waste can lead to more efficient use of it as a resource. It can promote a shift towards using only what is necessary, thereby retaining and conserving resources whilst reducing the dependency on new plastic production. However, the term 'avoidable' is ambiguous, and can be subjective or open to interpretation. What is considered avoidable in one context may be deemed necessary in another, leading to inconsistent approaches and application of the principles.

While this principle can drive innovation in product design, packaging, and alternative materials, it has not been included in the set of principles since the definition, which is considered to be more 'binding' than the principles, includes 'removing or reducing waste' to encompass waste beyond just that of plastics. In other words, excluding other forms of waste associated with the plastics industry.

Ending plastic pollution

The term 'ending plastic pollution' can be seen as somewhat nebulous. Does it refer to achieving zero leakage of plastics into the environment? Does it include cleaning up all existing (legacy) plastic pollution? Does it refer to only *new* plastic pollution? Clarifying these aspects would be necessary for setting realistic targets and actionable principles.

By limiting the principle to 'plastic pollution', this can be interpreted to only include the physical pollution of plastics in the environment. This would fail to also encompass the pollution generated during the production and recycling processes, such as chemical runoff and carbon emissions and therefore would not fully address the environmental and human health impact of plastics.

Successfully ending plastic pollution would require comprehensive global cooperation, which can be challenging to achieve. There might be trade-offs between actions at a local or national level and the need for coordinated international strategies.

While this principle has its strengths in ambition, it is ambiguous and would need to be clearly defined to be applicable. As such, it has been modified for inclusion in the essential principles to rather focus on minimising pollution for practicality, and not only by plastics themselves, but also from other plastics related processes.

Based on the literature review, expert discussions, and interviews, the following five principles have been identified as essential to guiding decisions on the circularity of plastics.

Any activity in line with plastics circularity must:

- Protect, restore or regenerate nature
- Ensure inclusive outcomes, quality job creation, fair and safe working conditions and that human rights are upheld
- Minimise pollution, including emissions and chemical leakages from plastics production, processing and disposal.
- Transition away from the production of virgin materials, in line with the zero waste hierarchy
- Uphold dynamic safeguarding

All of the principles apply and are relevant to every material in the plastics economy. Any decision, policy, activity or process related to plastics should conform to all of these principles. The principles follow no hierarchy, and should all be considered equally.

Protect, restore or regenerate nature

This principle guides actions towards not only minimising harm but also actively contributing to ecological restoration (EMF, 2015). It extends the scope of plastics circularity from mere waste management to a more holistic environmental stewardship, emphasising the restoration of ecosystems affected by fossil fuel extraction, and plastic production and waste (UNEP, 2019). This principle recognises that the economy is dependent on the delivery of ecosystem services that only healthy ecosystems can provide.

Ensure inclusive outcomes, quality job creation, fair and safe working conditions and that human rights are upheld

This approach emphasises the importance of creating a system where the benefits, such as environmental improvements, are equitably distributed, particularly to underrepresented and marginalised communities (Brown et al., 2022). It also focuses on generating new employment opportunities across the entire value chain of the plastics economy, from sustainable material sourcing to recycling, ensuring these jobs provide fair wages and safe conditions. Also included herein should be considerations for a just transition for the plastic production sector as virgin production is deprioritised according to the zero waste hierarchy (in line with the definition of plastics circularity). Furthermore, this principle underscores the need for the plastics circular economy to contribute to long-term economic stability, fostering resilient and scalable business models that are both environmentally sustainable and economically viable.

Minimise pollution, including emissions and chemical leakages from plastics production and processing

This principle acknowledges that while the focus often lies on the visible impact of plastic waste, the environmental footprint of plastics extends beyond just their disposal. It includes significant greenhouse gas emissions and chemical leakages during polymerisation, manufacturing and processing (Papamichael et al., 2023). By prioritising the reduction of these often-overlooked aspects, along with tackling the direct pollution caused by plastics, this principle advocates for a more holistic approach (UNEP, 2019). Adopting this principle is expected to drive innovation and efficiency within the plastics industry (Serna-Guerrero et al., 2022). By highlighting the need to reduce emissions and pollution, it encourages the development and adoption of cleaner, more sustainable production technologies and practices. This push for innovation can lead to more efficient use of resources, energy savings, and the development of new, less polluting materials. Furthermore, it raises awareness about the less visible aspects of plastic's environmental impact, broadening the conversation and understanding of what true sustainability in the plastics industry entails. Lastly, this principle aligns with broader environmental goals such as the commitments required under the Paris Climate Agreement and the Kunming-Montreal Biodiversity Framework.

Transition away from the production of virgin materials, in line with the zero waste hierarchy

By focusing on this transition, the principle reinforces the uppermost tiers of the zero waste hierarchy — reduce and reuse — before recycling and recovery, emphasising the importance of minimising the demand for new plastic production (Prochatzki et al., 2023). This approach not only reduces reliance on finite natural resources but also decreases the overall environmental impact associated with extraction and processing of virgin materials. Moreover, this principle supports a systemic change in the plastics industry, encouraging innovation in recycling technologies and the development of alternative materials. It guides businesses and policymakers to prioritise sustainable sourcing and to invest in circular economy models. By doing so, it ensures that the entire lifecycle of plastics is more sustainable, not just the waste management end, thereby deepening the commitment to a truly circular approach in the plastics sector.

Ensure dynamic safeguarding

In the pursuit of plastics circularity, all actions and strategies must be continually assessed to ensure they do not exacerbate existing environmental or social problems, nor create new ones. This involves a proactive approach to identifying and mitigating unintended consequences (Harriss et al, 2021). Recognising that systems and contexts evolve over time, this principle requires periodic re-evaluation and adjustment of practices to remain effective and relevant. Moreover, it aligns with frameworks like the green taxonomy to prevent undue harm, ensuring that the net impact of circularity efforts is beneficial and not detrimental to the environment and society. This principle guides decision making towards a cautious and adaptive approach, ensuring that the efforts to transition to a circular plastics economy are responsible, considerate of long-term impacts, and aligned with broader sustainability objectives.

Note: an analysis for the strengths, weaknesses and trade-offs of the principles for plastics circularity cannot be conducted since there were no plastics specific principles identified in the literature. Since there were 32 original, material agnostic sets of principles, due to time constraints, not all of these could be evaluated for their benefits or trade-offs.

3.2.2 Measurability of principles

Measurable principles allow for the tracking of progress which fosters a culture of accountability and transparency (March et al., 2022). When principles for circularity are quantifiable, they provide clear benchmarks that can guide decision-making processes (Figge et al., 2018). This allows for more objective evaluations of different strategies and interventions, helping to determine which approaches are most effective. The measurability of principles in plastics circularity is not just about tracking performance; it's about creating a structured, effective and evidence-based approach that encourages responsible action, informed decision-making, and continuous evolution towards achieving a fully circular approach to plastics that is in line with societal and environmental wellbeing.

A series of possible metrics or measurable targets for each principle are presented in Table 6. The examples for each metric are hypothetical and will need to be determined more specifically based on careful consideration of current context, and the most up to date data. Once a set of principles is formally adopted, a robust monitoring and evaluation (M&E) framework will need to be developed and fitted to the principles, which is beyond the scope of this study.

Table 6. *Possible metrics or measurable targets for each principle*

Principle	Potential metrics or measurable targets
Protect, restore or regenerate nature	**Increase in biodiversity** - measure the number of species or the increase in biodiversity in areas affected by plastic production or waste. E.g. Increase Biodiversity by 10% in key affected ecosystems within the next 5 years. **Habitat restoration** - quantify the area of habitats (like wetlands, forests, coastal areas) restored or regenerated due to industry initiatives. E.g. Restore 500 hectares of degraded habitat in areas impacted by plastic production by 2030. **Carbon sequestration** - monitor the amount of carbon sequestered as a result of ecosystem restoration or improved practices in plastic production. E.g. Achieve 15% more carbon sequestration annually through improved ecosystem management related to plastics production.
Deliver inclusive outcomes, job creation and economic stability	**New jobs created** - track the number of sustainable jobs created in the circular plastics industry. E.g., create 10,000 new sustainable jobs by 2025. **Economic contribution to local communities** - measure the economic value added to local communities or economies from circular plastics initiatives. E.g., boost local economies by 5% annually through circular plastics initiatives **Industry growth rate** - measure the growth rate of the circular plastics sector. E.g., target a 6% annual growth rate in the circular plastics industry over the next decade. **Investment in circular economy initiatives** - quantify the amount of investment directed towards circular economy projects in the plastics sector. E.g., increase investment in circular plastics initiatives by 20% annually for the next 5 years. **Economic diversity** - evaluate the diversification of the circular plastics economy to reduce reliance on a single market or product. E.g., expand the circular plastics market portfolio by 25% within the next 7 years. **Business stability** - monitor the survival rate of businesses within the circular plastics sector. E.g., achieve a 90% survival rate for new circular plastics businesses over their first 5 years.
Minimise pollution, including emissions and chemical leakages from plastics production and processing	**Reduction in greenhouse gas emissions** - quantify the decrease in greenhouse gas emissions from the plastics industry. E.g., reduce greenhouse gas emissions by 20% from the plastics industry by 2025. **Reduction in plastic leakage** - measure the decrease in plastic waste entering natural environments. E.g., cut plastic leakage into natural environments by 50% over the next 10 years. **Hazardous chemicals control** - monitor the reduction in hazardous chemicals used or released in the plastics production and processing. E.g., decrease hazardous chemical usage by 25% in plastics manufacturing by 2030.

Transition away from the production of virgin materials, in line with the zero waste hierarchy	**Increase in recycled material use** - monitor the increase in the use of recycled materials in new plastic products. E.g., increase the use of recycled materials to 40% in plastic production by 2026. **Reduction in virgin material use** - quantify the decrease in the use of new, raw materials for plastic production. E.g., reduce the use of virgin plastics by 30% in manufacturing processes by 2025. **Waste diversion rate** - measure the percentage of plastic waste diverted from landfills through recycling and reuse. E.g., achieve an 80% waste diversion rate for plastics away from landfills by 2030.
Ensure dynamic safeguarding	**Incidence of negative impacts** - track and reduce the number of incidents where plastic circularity initiatives have unintended negative consequences. E.g., reduce negative impact incidents by 50% within the next 5 years. **Response time of adaptability measures** - evaluate the frequency and effectiveness of policy or practice revisions in response to emerging challenges and information. E.g., implement policy revisions or new practices within 6 months of identifying significant unintended consequences.

4. Limitations

When researching or adopting a set of definitions and principles for plastics circularity, several limitations must be considered. First, definitions and principles in the literature and applied in practice are highly varied. There is a wide range of definitions and principles regarding plastics circularity, influenced by different academic, industrial, and governmental perspectives. This variation can lead to confusion and difficulties in establishing a universally accepted framework. Furthermore, definitions are in some instances contested, where the literature reflects ongoing debates and disagreements over the precise definitions of circularity in the context of plastics. These contested definitions can stem from differing priorities, such as environmental concerns versus economic feasibility.

Terms such as 'plastics', 'lifecycle', and others related to circular economy are often defined and applied inconsistently across various studies and practices. This inconsistency can lead to misunderstandings and hinder the development of cohesive approaches to circularity. For this reason, terms need to be clearly explained or defined, with no ambiguity about their use.

This research was restricted to open access literature, or that which is available behind paywalls to academic institutions, which may not encompass all available or relevant information on the topic. Important insights and data found in paywalled or unpublished studies were not included, especially in instances regarding the more foundational thinking of circularity.

Finally, limiting research to English-language sources excludes a significant body of work in other languages, potentially overlooking valuable insights, case studies, and approaches adopted in non-English speaking regions.

References

Brown, C., Conway, C., & Robshaw, H. (2022). A Just Transition to Reusable Packaging: Necessary Conditions, Benefits and Best Practice. https://wechoosereuse.org/wp-content/uploads/2022/10/Final-A-Just-transition-to-reusable-packaging.pdf

Chawla, S., Varghese, B. S., Chithra, Hussain, C. G., Keçili, R., & Hussain, C. M. (2022). Environmental impacts of post-consumer plastic wastes: Treatment technologies towards eco-sustainability and circular economy. Chemosphere, 308(135867), 135867. https://doi.org/10.1016/j.chemosphere.2022.135867

Ellen MacArthur Foundation. (2015). Delivering the circular economy: A toolkit for policymakers. Ellen MacArthur Foundation.

Ellen MacArthur Foundation (2017) The New Plastics Economy: Rethinking the future of plastics & catalysing action.

ERM Sustainability Institute. (2022). Creating a circular economy for plastics. ERM. Retrieved 24 November 2023, from https://www.sustainability.com/thinking/creating-a-circular-economy-for-plastics/

European Union, EU (2018). Behavioural Study on Consumers' Engagement in the Circular Economy - Final report. Available at: https://circulareconomy.europa.eu/platform/sites/default/files/ec_circular_economy_final_report.pdf

Figge, F., Thorpe, A. S., Givry, P., Canning, L., & Franklin-Johnson, E. (2018). Longevity and circularity as indicators of eco-efficient resource use in the circular economy. Ecological economics, 150, 297-306.

Harris, S., Martin, M., & Diener, D. (2021). Circularity for circularity's sake? Scoping review of assessment methods for environmental performance in the circular economy. Sustainable Production and Consumption, 26, 172–186. https://doi.org/10.1016/j.spc.2020.09.018

King S and Locock KES (2022) A circular economy framework for plastics: A semi-systematic review. Journal of Cleaner Production 364:132503.

Lau W, et al. (2020) Evaluating scenarios toward zero plastic pollution. Science 369: 1455-1461.

Lee, M. K. K. (2021). Plastic pollution mitigation – net plastic circularity through a standardized credit system in Asia. Ocean & Coastal Management, 210(105733), 105733. https://doi.org/10.1016/j.ocecoaman.2021.105733

Linder, M. and Williander, M. (2017), "Circular business model innovation: inherent Ncertainties", Business Strategy and the Environment, Vol. 26 No. 2, pp. 182-196.

March, A., Salam, S., Evans, T., Hilton, J., and Fletcher, S. (2022) A global review of plastics policies to support improved decision making and public accountability. Global Plastics Policy Centre. https://plasticspolicy.port.ac.uk/final-report/

McDonough, W., & Braungart, M. (2002). Cradle to Cradle: Remaking the Way We Make Things. North Point Press.

McKinsey Sustainability (2017). Mapping the benefits of a circular economy. McKinsey Quarterly. Available at: https://www.mckinsey.com/capabilities/sustainability/our-insights/mapping-the-benefits-of-a-circular-economy#/

Mitchell, P., & James, K. (2015). Economic growth potential of more circular economies. Waste and Resources Action Programme (WRAP): Banbury, UK.

Nobre, G. C., & Tavares, E. (2021). The quest for a circular economy final definition: A scientific perspective. Journal of Cleaner Production, 314, 127973.

OECD (2022), Global Plastics Outlook: Policy Scenarios to 2060, OECD Publishing, Paris.

Olatayo, K. I., Mativenga, P. T., & Marnewick, A. L. (2022). Does policy on plastic waste support higher waste management hierarchy options?. Recycling, 7(3), 36.

Papamichael, I., Voukkali, I., Loizia, P., Stylianou, M., Economou, F., Vardopoulos, I., Klontza, E. E., Lekkas, D. F., & Zorpas, A. A. (2023). Measuring Circularity: Tools for monitoring a smooth transition to Circular Economy. Sustainable Chemistry and Pharmacy, 36(101330), 101330. https://doi.org/10.1016/j.scp.2023.101330

Paquin, R.L., Busch, T. and Tilleman, S.G. (2015), "Creating economic and environmental value through industrial symbiosis", Long Range Planning, Vol. 48 No. 2, pp. 95-107.

Parrique T., Barth J., Briens F., C. Kerschner, Kraus-Polk A., Kuokkanen A., Spangenberg J.H., (2019). Decoupling debunked: Evidence and arguments against green growth as a sole strategy for sustainability. European Environmental Bureau.

Peña, C., Civit, B., Gallego-Schmid, A., Druckman, A., Pires, A. C., Weidema, B., ... & Motta, W. (2021). Using life cycle assessment to achieve a circular economy. The International Journal of Life Cycle Assessment, 26, 215-220.

Pearce, D. W., & Turner, R. K. (1989). Economics of Natural Resources and the Environment. Johns Hopkins University Press.

Plastics Europe. (2022). The Circular Economy of Plastics, a European Overview.

Polyportis, A., Mugge, R., & Magnier, L. (2022). Consumer acceptance of products made from recycled materials: A scoping review. Resources, Conservation and Recycling, 186, 106533.

Prochatzki, G., Mayer, R., Haenel, J., Schmidt, A., Götze, U., Ulber, M., Fischer, A., & Arnold, M. G. (2023). A critical review of the current state of circular economy in the automotive sector. Journal of Cleaner Production, 425(138787), 138787. https://doi.org/10.1016/j.jclepro.2023.138787

Rizos, V.; Behrens, A.; Van Der Gaast, W.; Hofman, E.; Ioannou, A.; Kafyeke, T.; Flamos, A.; Rinaldi, R.; Papadelis, S.; Hirschnitz-Garbers, M.; et al. Implementation of circular economy business models by small and medium-sized enterprises (SMEs): Barriers and enablers. Sustainability 2016, 8, 1212.

Rosenboom, J.-G., Langer, R., & Traverso, G. (2022). Bioplastics for a circular economy. Nature Reviews. Materials, 7(2), 117–137. https://doi.org/10.1038/s41578-021-00407-8

Sassanelli, C., Rosa, P., Rocca, R., & Terzi, S. (2019). Circular economy performance assessment methods: A systematic literature review. Journal of Cleaner Production, 229, 440-453.

Serna-Guerrero, R., Ikonen, S., Kallela, O., & Hakanen, E. (2022). Overcoming data gaps for an efficient circular economy: A case study on the battery materials ecosystem. Journal of Cleaner Production, 374(133984), 133984. https://doi.org/10.1016/j.jclepro.2022.133984

Sharmer S, Walton M, Baker V, Hepi M, Manning S. (2021). Realist review of interventions influencing waste management and minimization practices in New Zealand: protocol and initial program theory. Int J Qual Methods. 20:1–10.

Suárez-Eiroa, B., Fernández, E., Méndez-Martínez, G., & Soto-Oñate, D. (2019). Operational principles of circular economy for sustainable development: Linking theory and practice. Journal of cleaner production, 214, 952-961.

UNEP (2019). Plastics and Circular Economy: Community Solutions.

UNEP (2023) Turning off the Tap: How the world can end plastic pollution and create a circular economy. Nairobi.

Annexes

Annex 1: Inventory of definitions and principles

[see attached spreadsheet]

Annex 2: Defining circularity expert interviews

The following questions were asked in the interviews for WP 1 on defining circularity of plastics with 8 experts and actors in the plastics and circular economy field. The summary of results can be found in the 'Interview Coding' tab of Annex 1. Section 3 of the interview questions are used to contribute to the report for WP2 of this project.

1. Definition and features of a circular economy for plastics

a) Do you have a company/ organisation definition of the Circular Economy? What is it?
b) If yes, what is this definition based on? (ie. is the definition adopted based on an existing definition by another organisation?)
c) Do you have a definition that incorporates plastic materials and products specifically?
d) What features do you think are necessary in a circular economy definition at the national level?
e) Which of these features, or others, do you believe are important for a plastic circular economy specifically?

2. Principles and guard rails of a circular economy

We see a set of principles to accompany any circular economy definition as the guard rails to guide any activity or decisions that take place in the circular economy.

a) What principles, if any, do you or your organisation use in your work to guide circular economy thinking?
b) Based on your experience, what should a core set of principles regarding plastics circularity include?

3. Barriers and opportunities for plastics circularity

a) Where have you seen examples of the circular economy in relation to plastic?
b) What barriers do you believe exist for the growth of the circular economy in relation to plastic.
c) How would you suggest that these barriers could be overcome?
d) Which plastic products or materials do you think have the greatest opportunity to incorporate circular economy principles and why?
e) What would be needed to build on these opportunities?
f) Do you see/ know of any problematic products and/ or materials in terms of making them circular? Why are they problematic?
g) Do you know of any policies or standards (national, regional, or global) that exist as either enablers or barriers to plastics circularity?
h) Any priorities for policy or regulation that would enable the shift to more circularity of plastics?

Are there any other points you'd like to make beyond what has already been covered?