Department for Energy Security & Net Zero

Unlocking Resource Efficiency

Phase 2 Plastics Report

DESNZ Research Paper Series Number 2024/008

April 2024

Acknowledgements

We would like to acknowledge the stakeholders that contributed generously to this study with their knowledge, experience and viewpoints.

Any enquiries regarding this publication should be sent to us at: Resource_efficiency@energysecurity.gov.uk

Contents

List of Tables

Introduction

The Department for Energy Security and Net Zero (DESNZ) and the Department for Environment, Food and Rural Affairs (DEFRA) commissioned Eunomia Research and Consulting to undertake a research project exploring the potential benefits from increasing resource efficiency in the UK. This report outlines the findings of this research for the plastics sector.

For the purposes of this report, resource efficiency is defined as any action that achieves a lower level of resource use for a given level of final consumption. This can occur at any stage of the supply chain including production, consumption, and end-of-life. While material substitution may not always meet the definition of resource efficiency set out above, it is in scope of this research where it reduces whole life carbon.

This research was conducted in the second half of 2023, and reports were written in November 2023. As such, this report does not reflect sector developments beyond that point. Technical experts were consulted as part of research activities for this report. The following report reflects our understanding of the available evidence and is accurate to the best of our knowledge; however, if any factual errors are encountered, please contact us at Resource_efficiency@energysecurity.gov.uk.

Methodology

This aim of this research was to achieve four key objectives:

- Identify a comprehensive list of resource efficiency measures for each sector;
- Identify current and anticipated drivers and barriers which are affecting improvements in the identified resource efficiency measures in each sector, and their relative importance;
- Build consensus estimates for the current "level of efficiency" and maximum "level of efficiency" in 2035, for each of the identified resource efficiency measures in each sector; and
- Identify the extent to which industry is currently improving resource efficiency and build consensus estimates for the likely "levels of efficiency" in 2035 given current private sector incentives and the existing policy mix (a "business-as-usual" scenario), for each of the identified resource efficiency measures in each sector.

To achieve these research objectives, a mixed-methods methodology was developed. A literature review was conducted for each sector to synthesise evidence from the existing literature relevant to these objectives. In parallel, stakeholder interviews were conducted with industry and academic experts in each sector to test literature findings and fill any outstanding evidence gaps. A summary of findings was then presented and validated at sector-specific facilitated workshops with sector experts.

This project did not aim to identify policy recommendations but rather understand the potential for resource efficiency in the UK. It should be noted that some areas covered as part of the research fall under the responsibility of devolved nations of the UK; however, all reports cover the UK as a whole for completeness.

This project has attempted to identify three level of efficiency estimates for each resource efficiency measure:

- The **current level of efficiency** which is the best estimate for the current level of efficiency of the measure i.e., what is happening in the UK now (in 2023);
- The **maximum level of efficiency** which is the maximum level of efficiency that is technically possible by 2035 in the UK, without factoring in barriers that could be overcome by 2035 i.e., what is the maximum level that could be achieved; and
- The **business-as-usual (BAU) scenario** which is the level of efficiency that would be expected in the UK by 2035 with the current policy mix and private sector incentives i.e., what would happen if there were no substantial changes in the policy or private sector environment.

These levels of efficiencies have been identified to understand the potential for resource efficiency and do not represent government targets.

To estimate these levels of efficiency, indicators have been developed for each of the identified measures. These indicators have been chosen based on how well they capture the impact of the relevant measure, and how much data there is available on this basis (both in the literature review and from expert stakeholders).

For some measures, the current level of efficiency is baselined to 2023. This is not an indication of historic progress, but rather has been done in order to understand the potential for further progress to be made (in the maximum and BAU scenarios) where it was not otherwise possible to quantify a current level of efficiency.

Note, the purpose of the indicators in this research is so estimates on the current, maximum and BAU level of efficiency can be developed on a consistent basis. They are not intended be used as metrics to monitor the progress of these resource efficiency measures over time, or to be used as metrics for resource efficiency policies.

A high-level overview of the research stages is presented below. A more detailed version of this methodology is presented in the Phase 2 Technical Summary which accompanies this publication.

Literature Review

The literature sources were identified through an online search, and through known sources from DESNZ, DEFRA, the research team, and expert stakeholders.

Once literature sources had been identified they were reviewed by the research team and given an Indicative Applicability Score (IAS) ranging from 1 to 5 which indicated the applicability of the sources to the research objectives of this study. This score was based on five key criteria: geography, date of publication, sector applicability, methodolo-gies used and level of peer review.

After the five criteria of the IAS had been evaluated, the overall IAS score was calculated, ranging from 1 to 5, according to the number of criteria scoring ‘high’ and ‘low.’

A detailed overview of the parameters used to assess high / medium / low scores for each of the five criteria feeding into the IAS calculation and methodology for calculating the score can be found in Appendix A.

The research team drafted a rapid evidence assessment and literature summaries as part of interim reports for each sector which synthesised the best available evidence from the literature for each of the four research objectives. When drafting these summaries, literature sources with a higher IAS score were weighted more than those with a lower IAS score.

Stakeholder interviews

The findings from the literature review were presented to, and tested with, expert stakeholders from each sector through a series of stakeholder interviews. The interviews aimed to capture a range of sector experts from both academia and industry (covering different aspects of the value chain) but it should be noted this is not an exhaustive or representative sample of the sector. The purpose of these interviews was to test the findings of the literature review against stakeholder expertise, and to fill any evidence gaps from the literature.

Facilitated workshops

Following the completion of stakeholder interviews, one half-day facilitated workshop was conducted for each sector. Stakeholders who participated in interviews were given the chance to contribute to supplement and validate findings.

Stakeholders contributed through sticky notes in a shared virtual Mural board, by participating in the verbal discussions and by voting on pre-defined ranges on the levels of efficiency and the top drivers and barriers. They were also given the chance to contribute further information through a post-workshop survey. The stakeholders were asked to signal the level of confidence they had in their votes and were advised to vote for a ‘don’t know’ option if they felt the information fell outside their expertise. It is possible however that some votes were cast in areas where stakeholders may not have had expertise, so caution is advised when interpreting the findings.

Finally, the findings of the literature review and the stakeholder engagement were combined to reach final conclusions against each research objective. For the estimates on the level of efficiency for each measure (Objectives 3 and 4), a five-tier evidence RAG rating was assigned to indicate the level of evidence supporting the proposed figures. Only where the datapoints were supported by literature sources with high IAS and a high degree of consensus amongst experts in the interviews and workshop*,* were the datapoints considered to have a “green” evidence RAG rating. The definitions are as follows:

- **Red:** Limited evidence available from literature review or stakeholders
- **Red-Amber:** Some evidence available from literature review but it is not relevant/out of date, Limited evidence from stakeholders, stakeholders are not experts on this measure

- **Amber:** High quality evidence from either literature or stakeholders
- **Amber-Green:** High quality evidence from literature or stakeholders, evidence from stakeholders is supported by some information in the literature (or vice versa)
- **Green:** High quality evidence from literature supported by stakeholder expertise.

It should be noted that the business-as-usual (BAU) level of efficiency was only informed by the stakeholder engagement, so the maximum evidence RAG rating for the BAU is amber.

Limitations

This report was commissioned by the Government to improve the evidence base on the impact of resource efficiency measures. The methodology is designed to provide robust answers to the research objectives, based on the best available evidence at the time the work was undertaken.

While every effort was made to be comprehensive in the literature review, it is inevitable that some relevant literature may not have been captured. A full list of all the literature reviewed is provided in the annexes of each sector report.

The feedback captured during the interviews and workshops represent the views of a sample of stakeholders from industry, trade associations and academia. Effort was made to ensure that interviews and workshops included a cross-section of stakeholders from each stage of the sectors' supply chain, representing a range of backgrounds and perspectives. It is, however, noted that capacity and scheduling limitations meant that some stakeholders, whose view would have been valuable to the research, were not able to participate. As such, the views expressed by research participants in this report are not representative of the sector as a whole.

A key research objective of this project is to estimate the level of efficiency of resource efficiency measures in 2035. Any future projections are inherently uncertain as they depend on a range of different factors such as technological innovation, consumer behaviour change and the macro-economic environment. The estimates from this research are the best estimates that could be produced, based on the current literature and stakeholder expertise. Evidence RAG ratings have been provided to indicate the level of supporting evidence for each of these estimates.

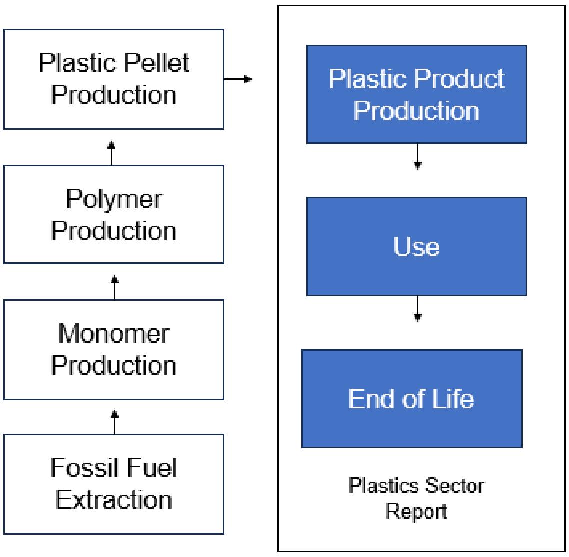
The report does not seek to make recommendations on the appropriate direction of Government policy or independent industry action. DESNZ and DEFRA will seek to conduct further engagement with stakeholders to inform the next steps for resource efficiency policy within Government, ensuring that any omissions or developments in the evidence reviewed in this report are taken into account.

Sector introduction

Plastic is a lightweight, versatile and affordable material traditionally derived from fossil-based materials. The two main types of plastic are thermosets and thermoplastics. Thermoplastics become malleable when heat is applied and become rigid again when cooled. This category of plastic is the most commonly used type of plastic and includes polymers such as HDPE, LDPE, PP, PET and PVC. Thermosets, on the other hand, undergo an irreversible chemical reaction during curing that results in an infusible network structure. As a result, thermosets cannot be melted or reshaped. Examples of thermosets include acrylic, polyesters and polyurethanes which are used in diverse applications due to their strength and temperature resistance.

The process of producing plastics involves five key steps. The first step is the extraction of raw materials, such as crude oil or natural gas, from the earth. In the second step, the fossil-based material is refined through heating, distillation and thermal cracking to produce ethylene, propylene and other chemicals, referred to as monomers. Monomers are essentially molecules which, when linked together, form the main ingredient of plastics (i.e., polymers). The third step is polymerisation, where monomers are bonded together to form polymers in a reaction chamber. The type of monomers used, and the structure of the linked monomers ultimately determines the polymer that is created. In the fourth step, any additives are added, and the molten plastic material is passed through an extruder and shredded into plastic pellets. These four steps contribute to around 60% of plastic's lifecycle carbon emissions.[1] In the fifth and final step, the plastic resin is used to produce plastic products through a moulding process such as injection moulding, extrusion or blow moulding. Step five contributes to around 30% of a plastic product's lifecycle emissions, with the remaining 10% typically associated with end-of-life treatment.[2] The key stages of the plastics lifecycle are outlined in Figure 1 below, with the phases within scope of this report shown in blue. Phases shown in white are covered by the chemicals sector report.

Figure 1: Scope of Plastics Sector Report



[1] Zheng, J. and Suh, S. (2019). Strategies to Reduce the Global Carbon Footprint of Plastics. Nature Climate Change. 9, p374-378.
[2] Zheng, J. and Suh, S. (2019). Strategies to Reduce the Global Carbon Footprint of Plastics. Nature Climate Change. 9, p374-378.

Due to the various mechanical and chemical properties of polymers, industries around the world use plastic as a material for a range of applications.

Table 1 provides examples of common plastic polymer types and their uses.

Table 1: Examples of plastic polymers and their uses

Plastic polymer	Examples of their use
Polyethylene (PE)	Packaging (bread bags and milk bottles) Water and gas pipes Toys
Polypropylene (PP)	Packaging (crisp packets, pots and tubs) Heat-proof food containers Carpets
Polyethylene Terephthalate (PET)	Packaging (drinks bottles) Clothing
Polystyrene (PS)	Packaging (yogurt pots) Building insulation Spectacle frames
Polyvinyl Chloride (PVC)	Window and door frames Cable insulation
Polyurethane (PUR)	Car seating fabrics Foam mattresses
Polycarbonate (PC)	Roofing sheet

Plastic plays a vital role in the UK economy. Around 6.3Mt of plastic is consumed in the UK each year.[3] The UK plastic industry directly employs around 155,000 people, spread across 5,800 companies.[4] Notably, the UK plastics industry has an annual turnover of £25bn, £10.5bn of which is from plastic exports, making plastic one of the UK's top 10 exported commodities.[5]

Much of the plastic consumed in the UK, by weight, is used for packaging (e.g., food, product and transport packaging). [6] In 2020, plastic packaging accounted for 34% of the UK's plastic consumption. Plastic packaging is commonly single-use, resulting in it becoming waste shortly after being produced. In contrast, construction plastics (such as pipes, gutters and window

[3] Plastics Europe (2023). Circular Economy for Plastics: United Kingdom – 2020.
[4] British Plastics Federation (N.D.). About the British Plastics Industry.
[5] Ibid.
[6] Plastics Europe (2023). Circular Economy for Plastics: United Kingdom – 2020.

frames) remain in use for much longer, and often take decades before they become waste. Construction plastics contributed to 19% of the UK's plastic consumption in 2020. Other plastic uses in the UK include automotive parts (11% of the UK's consumption in 2020), electrical and electronic equipment (10%), household goods (5%), agricultural equipment (4%) and other plastic items (17%).[7] Other studies analysing plastic material flows in the UK[8] and Europe[9] reveal similar consumption patterns, with packaging and construction being the largest consumers.

Plastic packing is also a key component of the plastic waste generated in the UK, accounting for 56% of plastic waste in 2020. Other plastic wastes in the UK include construction and demolition (9% of the UK's plastic waste in 2020), waste electrical and electronic equipment (8%), automotive parts (8%), household goods (4%), agricultural equipment (4%) and other plastic items (13%).[10] Similar findings have been reported in other studies analysing plastic material flows in the UK[11, 12] and Europe[13], with packaging being the highest contributor to plastic waste. Notably, the plastic waste that is generated is not necessarily the same plastic consumed that year, such as construction and automotive plastics, which can remain in use for decades. As such, some of the plastic waste generated today was designed and produced decades ago, which may not have been designed for recycling. This can cause issues with the plastic waste needing to be incinerated or landfilled, depending on its composition and presence of hazardous substances.

As discussed above, plastic is used in a variety of industries. The appropriate use of plastic within these industries can provide environmental benefits. For example, the use of plastics in vehicles (such as bumpers and interior trim) can vastly reduce a vehicle's weight compared with using other materials such as metal. This lower weight reduces fuel consumption. Similarly, appropriate use of plastic packaging for food can extend its shelf-life, reducing food waste. However, the high rate of plastic consumption globally, and especially that of single-use plastics (such as plastic drinks bottles, takeaway containers and wet wipes), has resulted in negative environmental and social impacts.[14]

Resource efficiency is key in reducing the negative environmental and social impacts from plastic production and waste, as it reduces the quantity of plastic waste being generated, reduces the extraction of finite raw materials for the production of virgin plastic, and increases the amount of plastic being recycled and reused. The Waste Hierarchy Principles promote waste prevention, followed by reuse, recycling/composting, energy recovery and finally

[7] Ibid.
[8] Mehta et al. (2021). Using regional material flow analysis and geospatial mapping to support the transition to a circular economy for plastics. Resources, Conservation and Recycling. 179.
[9] Hsu et al. (2021). How circular are plastics in the EU?: MFA of plastics in the EU and pathways to circularity. Cleaner Environmental Systems. 2, p1-9.
[10] Ibid.
[11] WWF (2018). A Plastic Future: Plastics Consumption and Waste Management in the UK.
[12] Mehta et al. (2021). Using regional material flow analysis and geospatial mapping to support the transition to a circular economy for plastics. Resources, Conservation and Recycling. 179.
[13] Hsu et al. (2021). How circular are plastics in the EU?: MFA of plastics in the EU and pathways to circularity. Cleaner Environmental Systems. 2, p1-9.
[14] World Economic Forum (2021). Future of Reusable Consumption Models: Platform for Shaping the Future of Consumption - Insight Report July 2021.

landfill.[15] This is for all materials, including plastic. In terms of the plastic sector, resource efficiency relates to a variety of actions throughout the plastic supply chain.

Many regulatory, technical and behavioural measures are being researched, developed and implemented around the world to maximise plastic resource efficiency. To date, much of the focus has been on minimising plastic pollution, such as ocean plastics and microplastics damaging natural habitats and risking harm to human health.[16]

In order to reduce plastic waste and promote a more a circular economy, the UK Government and the UK devolved nations have already implemented various legislative measures – such as the Plastic Packaging Tax, plastic packaging recycling targets associated with Extended Producer Responsibility and enforced single-use plastic bans. Similarly, there are a variety of voluntary commitments surrounding plastic reduction, which many public and private organisations have joined. These voluntary commitments include the UK Plastics Pact[17] and The Ellen MacArthur Foundation "Global Commitment 2022".[18] These commitments include reduction, reuse and recycling targets for plastic products.

Sector scope

The scope of this report covers resource efficiency opportunities and data relating to plastic products produced, consumed and/or treated as waste in the UK.

To ensure there is no overlap with the 'Phase 2 Chemicals Report', this report will cover resource efficiency measures on plastic from when it becomes plastic pellets, through to the plastic product's end-of-life treatment. It will not cover resource efficiency measures associated with the conversion of raw materials to polymers as these will be covered in the Chemicals report.

For material substitution measures which need to reduce whole life carbon to be considered in scope of this report, the emissions associated across the whole lifecycle of plastic products (from raw material extraction through to end-of-life) are taken into account.

With regard to polymers in scope, this report covers resource efficiency measures for fossil-based plastics. Bio-based plastic polymers are discussed in the context of material substitution, which replace fossil-based plastics. Bio-based plastics are plastics derived from biomass, such as plants. Note, 'bio-based' is not synonymous with 'biodegradable,' which indicates that a material can be broken down naturally by organisms in a defined ecosystem. Bio-based plastics can be classed as either biodegradable or durable, depending on the polymer type. Substitution with polymers that are biodegradable or compostable, regardless of whether they are fossil-based or bio-based, are not covered in this report. This is because biodegradable and compostable plastics do not provide an opportunity for resource efficiency savings as they are, by nature, single use. As such, the material is unable to be preserved. Additionally, there is currently a lack of infrastructure across the UK for collection and

15 Defra (2011). Guidance on applying the Waste Hierarchy.
16 The Ellen MacArthur Foundation (2022). The Global Commitment 2022.
17 WRAP (N.D.). The UK Plastics Pact.
18 The Ellen MacArthur Foundation (2022). The Global Commitment 2022.

treatment of biodegradable and compostable plastics. Without this infrastructure, the presence of biodegradable and compostable plastics in 'conventional' plastic waste streams can reduce the quality of the recycled plastic material if it is not rejected during sorting.[19]

Due to the broad range of industries using plastic, this report focuses primarily on those that contribute most to plastic consumption and plastic waste in the UK. These are packaging, construction and demolition, automotive parts, electrical and electronic equipment and textiles [20, 21, 22], which account for at least 75% of the UK's plastic consumption and plastic waste, by weight, based on the reviewed literature. Additionally, resource efficiency opportunities and data for these industries, and in particular packaging, were identified in the literature. However, it should be noted that each measure identified is not necessarily relevant to all of the industries in scope of this report. Where particular industries are identified as not applicable to certain measures, this is described in the description of the measure.

Plastics used for agricultural and medical equipment are not a focus of this report due to their limited contribution, by weight, to plastic consumption and plastic waste in the UK. Despite this, plastic resource efficiency opportunities and data that cover plastics across all sectors in the UK are still considered in the literature review.

Finally, this report only assesses plastic material savings and/or the greenhouse gas emission savings (for material substitution measures) associated with each resource efficiency opportunity. As such, non-plastic material savings, such as water and crude oil, are not covered in this report. For example, this report will not compare the volume of water used when replacing plastic with an alternative material.

Literature review approach

The literature review identified 155 sources that discussed resource efficiency in the plastics sector. These were identified using a range of search strings relating to resource efficiency, the circular economy and the plastics industry. The search strings are listed in Appendix B. Further sources were identified from sector experts via the interviews and a Call for Evidence sent directly to stakeholders. The full list of sources used are listed in Appendix C.

These 155 sources comprised of:

- 57 academic papers;
- 36 industry reports;
- 28 website articles;

[19] Gerassimidou et al. (2021). Development of an integrated sustainability matrix to depict challenges and trade-offs of introducing bio-based plastics in the food packaging value chain. Journal of Cleaner Production. 286, pp1-16.
[20] Plastics Europe (2023). Circular Economy for Plastics: United Kingdom – 2020.
[21] Mehta et al. (2021). Using regional material flow analysis and geospatial mapping to support the transition to a circular economy for plastics. Resources, Conservation and Recycling. 179.
[22] WWF (2018). A Plastic Future: Plastics Consumption and Waste Management in the UK.

- 19 technical studies;
- 14 policy documents; and
- 1 doctorate thesis.

The sources were considered of generally high applicability and credibility when assessed against the data assessment framework, which recognises the relevance of the sources and the strength of their methodology. The sources had an average IAS of 3.73 (out of 5), with 89 sources exhibiting a score of 4 or above. Of all the literature reviewed, 45 sources were specific to the UK market and 32 were specific to the European market. Additionally, 145 sources were published within the last ten years. Stakeholder responses in the interviews indicated that the list of measures developed from the initial literature review was comprehensive.

More detail on the purpose and approach for these literature reviews can be found in the accompanying main report.

Interview approach

A total of eight stakeholders were interviewed broadly representing the plastics sector value chain; one trade association, four researchers, one waste management company, one plastics product manufacturer, and one organisation that provides both waste management and product manufacturing services.

Workshop approach

There were six participants in attendance at the workshop: three participants from trade associations, two researchers, and one plastics manufacturer.

Drivers and barriers

Drivers and barriers were categorised using two separate systems:

- The PESTLE framework which is focused on the types of changes: political, economic, social, technological, legal and environmental;
- The COM-B framework which is focused on behaviour change:
    - **Capability**: can this behaviour be accomplished in practice?
        - Physical Capability – e.g., measure may not be compatible for certain processes
        - Psychological Capability – e.g., lack of knowledge
    - **Opportunity**: is there sufficient opportunity for the behaviour to occur?
        - Physical Opportunity: e.g., bad timing, lack of capital

        - Social Opportunity: e.g., not the norm amongst the competition
    - **Motivation**: is there sufficient motivation for the behaviour to occur?
        - Reflective motivation: e.g., inability to understand the costs and benefits,
        - Automatic motivation: e.g., lack of interest from customers, greater priorities

List of resource efficiency measures

The list of resource efficiency measures in the plastics sector identified via the literature review and interviews can be found in Table 2. Appendix D contains a list of resource efficiency measures that were discarded from the scope of this study.

Table 2: List of resource efficiency measures for the plastics sector

#	Lifecycle stage	Strategy	Measure name	Measure indicator
1	Design	Lightweighting	Lean design of plastic products	% mass reduction of total UK plastic consumption due to lightweighting and avoidance compared to 2023 levels
2	Design	Material substitution	Material substitution with non-plastic materials	% CO_2e reduction from substitution with alternative materials compared to 2023 levels
3	Design	Material substitution	Feedstock substitution with bio-based feedstocks	% fossil-based plastics consumption that can be replaced with bio-based, durable plastics production
4	Design	Recycled content	Recycled content in plastic products	% average recycled content
5	Manufacturing & assembly	Production efficiencies	Waste reduction in product manufacturing	% of plastic produced during the manufacturing process that is wasted
6	Sale & use	Life extension / reuse	Reuse of plastic products	% reduction in plastic demand compared to 2023 levels

7	End of life	Recycling	Recycling of post-consumer plastics	% UK post-consumer recycling rate

1.0 Measure 1 – Lean Design of Plastic Products

1.1 Plastics resource efficiency measure

1.1.1 Description

Reduction of plastic consumption due to lightweighting and avoidance of the use of unnecessary plastic in products.

This measure focuses on the lightweighting and avoidance of the use of plastic in packaging applications such as flexible mono-materials (e.g., films and carrier bags), rigid mono-materials (e.g., bottles, household goods, pots, tubs & trays, food service disposables and other rigid packaging) and multi-material goods (e.g., sachets, multilayer flexibles, nappies and plastic laminated paper products). This scope accounts for approximately 34% of UK plastic production, and almost all of the plastic waste that currently goes mismanaged or untreated globally.[23]

The lean design of plastic products was not deemed to be an applicable intervention to the construction, automotive, textiles or electronics industries.[24] The limited potential for reduction in the construction industry is due to the use-phase benefits that plastic delivers, such as the improved energy and thermal efficiency of buildings through the use of plastics-based insulation. Additionally, due to the high value of lean electronics and the tight weight restrictions on vehicles, the use of plastic has already been optimised with very limited opportunity for reduction within these sectors. While textiles have the technical potential to lightweight further, the reduction of material is intrinsically linked with a reduction in performance and durability and as such is not considered to be beneficial necessarily from an environmental perspective.

The lean design measure should deliver equivalent utility as is currently provided (e.g., preservation and protection of food). Strategies might include the redesign of overpackaging such as double-wrapping plastic film, decreased consumption of avoidable bags, lightweight formats to increase the utility per package (e.g., pouches in place of rigid bottles) and the development of packaging-free products.

Table 3: List of industries applicable to measure 1

Packaging & Household Goods	Construction	Automotives	Textiles	Electronics

[23] SystemIQ et al. (2020). Breaking the Plastic Wave Thought Partners: Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution.
[24] SystemIQ (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe

Applicable	Not applicable	Not applicable	Not applicable	Not applicable

1.1.2 Measure indicator

The indicator selected to measure the lean design of packaging products was **'percentage mass reduction of total UK plastic consumption due to lightweighting and avoidance compared to 2023 levels'** which is derived by dividing 'the mass of plastic eliminated' by 'the initial mass of plastic utilised.' This indicator demonstrates how much resource could be saved compared to a 2023 baseline by 2035.

This was the only indicator considered for this measure.

1.1.3 Examples in practice

Eliminating unnecessary packaging is a low-cost strategy that can be straightforward to implement as unnecessary packaging does not, by definition, provide any benefit to the consumer. The main perceived benefit is likely to only reside with the brand owner, who may want to use the packaging to demonstrate individuality or premiumisation. There may also be a disagreement between consumers and brand owners over what constitutes 'unnecessary' packaging as there is currently no clear, agreed definition. One definition identified in the literature is from WRAP in the Plastics Pact[25] which defines unnecessary as *'its use is avoidable or reusable options are available'* – however, even this is open to interpretation.

Examples of consumer packaging that could possibly be eliminated include overwraps (i.e., secondary plastic wrappings), tear-offs, plastic windows, excess films, rigid pots, tubs & trays and excessive packaging headspace/volume. There are also innovations under development to reduce unnecessary packaging though methods such as edible coatings for vegetables, dissolvable packaging, cleaning products sold in concentrated formats and solid products that traditionally come in liquid form, eliminating the need for packaging. Business-to-business (B2B) packaging can also be reduced, including mesh material secured with straps.[26]

Most plastic reductions implemented to date have focused mainly on lightweighting packaging and minimising use of small-mass items such as bags and straws.[27] Current product consumption bans and regulations focus on carrier bags and food service items, which together only make up 10% of plastic waste. As such, there is room for further reduction in sachets/multilayer flexibles (e.g., crisps and sweets packets), business-to-business packaging (e.g., crates and pallet wrap), mono-material films, and bottles. Additionally, one stakeholder interviewed noted that technologies such as foam-assisted or gas-assisted moulding as a direct material reduction technique can have an impact of lightweighting materials without affecting performance. The stakeholder pointed out that this was already used widely in the

[25] WRAP (n.d.) The UK Plastics Pact: Plastics Definitions. Accessed at link.
[26] Ellen MacArthur Foundation (2020). Upstream Innovation: a guide to packaging solutions.
[27] SystemIQ et al. (2020). Breaking the Plastic Wave Thought Partners: Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution.

automotive industry to lightweight materials and could feasibly be extended to other applications such as packaging materials. The one limitation to gas-assisted moulding techniques is that they cannot be applied to thin-walled injection moulding applications.

1.2 Available sources

1.2.1 Literature review

The literature review identified 16 sources, used in this report, that discussed lean design of plastic products. This comprised:

- two academic papers[28] [29];
- three policy documents[30] [31] [32];
- six industry reports[33] [34] [35] [36] [37] [38];
- four website articles[39] [40] [41] [42]; and
- one technical study[43].

The relevant sources were generally considered of high applicability when assessed against the data assessment framework, which recognises the relevance of the sources and the strength of the methodology within each. The sources exhibited an average IAS of 3.8 (out of 5), with 9 sources exhibiting a score of 4 or above. Of the literature reviewed for this measure, 8 sources were UK-specific and 5 were relevant to the European market. Additionally, 15 sources were published within the past ten years.

1.2.2 Interviews

Stakeholders interviewed unanimously agreed that the lean design of plastic products is vital for enhancing resource efficiency within the plastics sector. The indicator presented during the interviews was ‘percent mass reduction of plastic consumption due to lightweighting and

---

[28] Pomponi et al. (2022). Environmental benefits of material-efficient design: A hybrid life cycle assessment of a plastic milk bottle.
[29] Hynes et al. (2020). The impact of nature documentaries on public environmental preferences and willingness to pay: entropy balancing and the blue planet II effect. Journal of Environmental Planning and Management. 64:8. pp1428-1456.
[30] The Environmental Protection (Plastic Plates etc. and Polystyrene Containers etc.) (England) Regulations 2023.
[31] The Environmental Protection (Single-use Plastic Products) (Scotland) Regulations 2021.
[32] The Environmental Protection (Single-use Plastic Products) (Wales) Act 2023.
[33] WRAP (2022). The UK Plastics Pact Annual Report 2021-2022.
[34] WWF (2018). A Plastic Future: Plastics Consumption and Waste Management in the UK.
[35] SystemIQ (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe
[36] WRAP (2021). Plastics Market Situation Report 2021.
[37] Plastics Europe (2023). Circular Economy for Plastics: United Kingdom – 2020.
[38] The Ellen MacArthur Foundation (N.D.). The Global Commitment 2022.
[39] YouGov (2019). Most Brits support ban on harmful plastic packaging.
[40] WRAP (N.D.). The UK Plastics Pact.
[41] The Ellen MacArthur Foundation (N.D.). The Global Commitment 2022.
[42] Ellen MacArthur Foundation (2020). Upstream Innovation: a guide to packaging solutions.
[43] SystemIQ et al. (2020). Breaking the Plastic Wave Thought Partners: Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution.

avoidance' and this was not changed over the course of the interviews. Six stakeholders engaged in discussion about the measure qualitatively and three stakeholders provided feedback on levels of efficiency for this measure.

1.2.3 Workshop

Stakeholders questioned whether material substitution was in scope and whether wider impacts should be considered. In many cases stakeholders expressed a preference to vote for levels of efficiency within particular industries or applications instead of across the entire plastics sector.

The level of engagement in the workshop was as follows:

- Five stakeholders were active on the mural board and three stakeholders actively contributed to verbal discussion.

1.3 Drivers & Barriers

The drivers and barriers influencing this measure were identified through a combination of the literature review, stakeholder interviews and sector workshop.

1.3.1 Drivers

Table 4 below shows the main drivers for Measure 1. The most significant drivers are shown in bold as voted for by stakeholders in the workshop.

Table 4: Drivers for plastics sector measure 1

Description	PESTLE	COM-B
Regulatory requirements & standards	**Legal**	**Capability – psychological**
Reduced production costs	**Economic**	**Opportunity – physical**
Customer demand	**Social**	**Motivation – reflective**
Voluntary plastics reduction targets	Political	Motivation – automatic

Regulatory requirements & standards

Regulation surrounding plastic use in the UK revolves predominantly around plastic packaging. For example, England[44], Scotland[45] and Wales[46] have implemented bans on certain single-use plastic items, such as expanded polystyrene takeaway cups, plastic straws and plastic balloon sticks. Although alternative single-use materials have been used in many instances (alternative non-plastic materials will be discussed for Measure 2), there will likely also be avoided production and use of certain single-use plastic items.

Extended Producer Responsibility (EPR) for packaging is another example of a legislative mechanism relating to plastic packaging – in this case by incentivising reduced material use. The specific mechanism used here is referred to as 'eco-modulation', in which the packaging weight and material type determines the cost placed on packaging producers to fund packaging waste management. This financially incentivises packaging producers to reduce plastic (and other material) usage in order to lower their eco-modulation costs. EPR for packaging is an approach used in the UK and in other countries around the world.

Reduced production costs

By minimising plastic material use in products, production costs can be reduced. This is due to less raw material being used and the associated costs from reduced production time, machinery use and logistics. However, there may be cost increases associated with lightweighting, such as re-design and new manufacturing processes and equipment, which may incur higher costs. One stakeholder noted that there is a drive to lightweight products from the production side because brands only care about a product delivering on its specified design. If packaging producers can limit the material inputs to achieve any given design, they may save on cost.

Customer demand

Reducing the use of avoidable plastic in products, and especially packaging, can be driven by demand from consumers and brands. The "Attenborough effect" is an example of consumer demand for less plastic, with more consumers demanding less plastic in their packaging.[47] Additionally, YouGov found that many UK consumers feel guilty about their use of plastic and so are actively trying to reduce it.[48]

Voluntary plastics reduction targets

Setting plastic reduction targets through voluntary commitments, such as the UK Plastics Pact[49] and The Ellen MacArthur Foundation "Global Commitment 2022"[50], is a considerable

[44] The Environmental Protection (Plastic Plates etc. and Polystyrene Containers etc.) (England) Regulations 2023.
[45] The Environmental Protection (Single-use Plastic Products) (Scotland) Regulations 2021.
[46] The Environmental Protection (Single-use Plastic Products) (Wales) Act 2023.
[47] Hynes et al. (2020). The impact of nature documentaries on public environmental preferences and willingness to pay: entropy balancing and the blue planet II effect. Journal of Environmental Planning and Management. 64:8. pp1428-1456.
[48] YouGov (2019). Most Brits support ban on harmful plastic packaging.
[49] WRAP (N.D.). The UK Plastics Pact.
[50] The Ellen MacArthur Foundation (N.D.). The Global Commitment 2022.

driver for reducing plastic production and waste. The UK Plastics Pact, for instance, has set its signatories a target of eliminating problematic single-use plastics, such as expanded polystyrene, from plastic packaging by 2025.[51] In 2021/22, there had been an 84% reduction of problematic plastic material use from the UK Plastic Pact signatories compared with 2018 levels.[52] This highlights the effectiveness of voluntary commitments on reducing plastic use. Although a large focus of voluntary commitments is on single-use plastic packaging, this is important given the large contribution that single-use plastic packaging has towards plastic consumption and waste in the UK.[53]

1.3.2 Barriers

Table 5 below shows the main barriers for Measure 1. The most significant barriers are shown in bold as voted for by stakeholders in the workshop.

Table 5: Barriers for plastics sector measure 1

Description	PESTLE	COM-B
Efficiency nearly maximised	**Technological**	**Opportunity – physical**
Technical requirements	**Technological**	**Opportunity – physical**
Design for reuse	Technological	Capability – physical

Efficiency nearly maximised

In some cases, such as the automotive and construction industries, the use of plastic is already considered to be very effective and resource efficient.[54] For example, plastics allow vehicles to be lightweight and robust, by replacing much heavier alternative materials, such as metal and glass. Similarly, plastic used for construction materials, such as window frames, facia and pipes, is effective because it is durable and lightweight. As such, reducing plastic use for automotive and construction applications is considered to be limited. One stakeholder noted that most packaging applications with room for improvement in lean design, such as smaller bags in multipacks, are no longer the ‘easy wins’ and often require the redesign of the entire packaging line instead of just a single element.

Technical requirements

Plastic products must be robust enough to fulfil their specified function. In some cases, lightweighting techniques may make it difficult for these products to perform adequately. For example, an HDPE bottle designed to contain household chemicals should be able to

[51] WRAP (N.D.). The UK Plastics Pact.
[52] WRAP (2022). The UK Plastics Pact Annual Report 2021-2022.
[53] WWF (2018). A Plastic Future: Plastics Consumption and Waste Management in the UK.
[54] SystemIQ (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe

withstand the impact of being dropped from a reasonable height and a PET beverage bottle designed to contain carbonated drinks needs to be strong enough to withstand the required internal pressure. Thinner materials may not be able to perform against these requirements, thus placing a limitation on the potential for lightweighting.

Design for reuse

In some cases, businesses are moving towards reusable models for plastic products. As a result of these business model shifts, products must be strong enough to withstand longer lifecycles in which they are used for their intended function repeatedly. This often requires a redesign of the product to increase longevity, which may result in an increase in the amount of material used.

1.4 Levels of efficiency

Table 6: Levels of efficiency for plastics sector measure 1

Indicator: % mass reduction of total UK plastic consumption due to lightweighting and avoidance compared to a 2023 baseline			
Level of efficiency	Current	Maximum in 2035	Business-as-usual in 2035
Value	0%	2 – 4%	1 – 3%
Evidence RAG	Not applicable	Amber-Green	Amber-Green

1.4.1 Current level of efficiency

As the indicator for this measure is an index relative to current levels, the estimated level of efficiency is set at 0%, serving as a baseline for subsequent scenarios. The evidence RAG rating for this efficiency level is therefore not applicable.

One literature source estimates a 3% decrease on plastic packaging placed on the market in the UK between 2017 and 2019.[55] The decline was driven by 21% drops in primary packaging consumption from the non-grocery retail sectors. However, grocery retail, construction and hospitality packaging all saw slight increases in plastic packaging use. Another source from the same organisation found a 6% reduction in plastic packaging placed on the market between 2018 and 2022 amongst companies reporting to the UK Plastics Pact which is further indication of a historical packaging reduction trend, with this group representing 60% of the plastic packaging market in the UK.[56]

[55] WRAP (2021). Plastics Market Situation Report 2021.
[56] WRAP (2022). The UK Plastics Pact Annual Report 2021-2022.

However, it is not possible to attribute all of this reduction to lightweighting or avoidance of plastic packaging. Indeed, it is very possible that some of this reduction is a result of swapping plastic packaging out for other materials, as discussed in Measure 2. That said, the historical direction suggests a market trend of a reduction of plastic packaging and there is evidence (as discussed in Section 1.1.3 – Examples in practice) that this has occurred at least in part through lean design.

1.4.2 Maximum level of efficiency in 2035

The literature review and stakeholder engagement focused on figures describing a maximum level of efficiency within the packaging industry. This figure was then multiplied by the market share of the packaging industry to get the maximum level of efficiency across the entire plastics sector.

Only one study provided quantitative figures for the maximum level of efficiency for this measure, which suggested that direct elimination of unnecessary items and over-packing through existing and innovative solutions could reduce plastics demand by 5.6% by 2030, reaching 8% by 2050.[57] Stakeholders broadly agreed with this level of efficiency, with one suggesting that the maximum level of efficiency within the packaging sector might be 8% and another between 5 – 10%. The voting exercise during the stakeholder workshop yielded similar results. Four stakeholders believed that values between 6 – 10% were likely, with three stakeholders having a high level of confidence in this figure. Two stakeholders argued, with medium certainty, that the range was likely to be higher at >10%, with one noting that the maximum reduction was likely to be driven more through avoidance rather than lightweighting methods. Although participants who voted for >10% did not specify a value, neither made a comment suggesting the proposed range of 5 – 10% was significantly different from what they would expect. Therefore, we view these votes as consistent with a value marginally greater than 10%.

During discussions participants made it clear that the levels of efficiency between packaging products is likely to vary, making it difficult to compile the potential changes across all products into a single figure. The potential to lightweight films and flexibles, for example, is likely to be lower than the average maximum reduction rate across packaging. Another participant raised the point that packaging within the medical sector would face challenges to reduction, as there are separate sets of regulations within this sector. However, the general impact of this would likely be small given medical packaging makes up a small percentage of packaging in total.

While most of the votes were for 6 – 10% and stakeholders had the highest level of confidence in this range, there was no unanimity with two stakeholders suggesting that a higher value would be more appropriate. Therefore, a range of 6 – 12% is provided for the maximum level of efficiency within the packaging industry. As packaging applications make up 34% of UK plastic consumption[58], this range is multiplied by 34% to give a range of approximately 2 – 4% plastic reduction across all sectors in 2035. While the remaining 66% of the plastics market

[57] SystemIQ (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe
[58] Plastics Europe (2023). Circular Economy for Plastics: United Kingdom – 2020.

might also have room for reduction due to lean design, as discussed in 'Section 1.3.2. Barriers' it is likely there is limited scope for reduction in other major sectors.

The evidence RAG rating for this efficiency level is amber-green, reflecting general consensus between stakeholders and the figure found in the literature.

1.4.3 Business-as-usual in 2035

Similar to the approach taken in the maximum level of efficiency, the literature review and stakeholder engagement for the BAU level of efficiency focused on levels of efficiency within the packaging industry. This was then multiplied by the market share of the packaging industry to get the BAU level of efficiency across the entire plastics sector.

Commitments made through the Ellen MacArthur Foundation's Global Commitment on plastic and the European Plastic Pact combined with the Single-Use Plastic Directive (SUPD) in Europe are projected to eliminate up to 5% of plastic packaging from the waste stream by 2030 from a 2022 baseline.[59] Although the SUPD is driving policy in the EU and not the UK, members of the UK Plastics Pact, which represent 60% of the plastic packaging market in the UK, have declared an aim to eliminate problematic and unnecessary packaging, although no reduction target has been set for 2030.[60]

During interviews, one stakeholder claimed that the BAU level of efficiency was likely to be around 8%, which was the same level they gave as the maximum level of efficiency. This is due to their belief that all of the drivers are currently in place to achieve the maximum level of efficiency. Another stakeholder suggested that the BAU level of efficiency was between 1 – 3%, significantly lower than the 5 – 10% range they gave for the maximum level of efficiency. This stakeholder noted that the packaging applications with the greatest room for improvement sit outside of food and beverage packaging (e.g., cosmetics packaging) as there is less concerted pressure to reduce plastics in these areas. Within the food and beverage packaging market, stakeholders noted the conversion of plastic meat trays into films as a standout area for potential reduction.

During the workshop, six stakeholders provided estimates of between 6 – 10% with a medium degree of confidence, with one low degree of confidence vote made on the 0 – 5% range for films and flexibles specifically. As above, stakeholders commented that the levels of efficiency between types of packaging is likely to vary and these rates of 6 – 10% are likely to apply mostly to rigid applications, while the level of efficiency for films and flexibles is likely to be between 0 – 5%. Stakeholders noted during interviews that plastic films, by nature, are designed to use as little material as possible in order to provide maximum flexibility and as a result the potential to remove additional material within these applications is limited. Again, stakeholders noted that the diversity within the market makes it challenging to compile the potential changes across all products into a single figure.

[59] SystemIQ (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe.
[60] Wrap (2022). The UK Plastics Pact Annual Report 2021-2022.

As a result of stakeholder feedback along with the figures found in the literature, the level of efficiency within the packaging industry has been estimated to be somewhere between the two ranges presented during the workshop. This leads to a BAU level of efficiency between 2 – 8%, and a 1 – 3% level of efficiency across all plastics sectors, assuming again that the packaging industry accounts for 34% of plastic production in the UK. This figure is similar to the maximum level of efficiency, likely due to stakeholder feedback that lightweighting and avoidance are already an essential part of the plastics reduction strategies of many brands and retailers. The evidence RAG rating for this efficiency level is amber-green, reflecting general consensus between stakeholders and the figure found in the literature.

2.0 Measure 2 – Material Substitution with Non-Plastic Materials

2.1 Plastics resource efficiency measure

2.1.1 Description

Substituting plastic with alternative, non-plastic materials such as paper, glass, aluminium and steel.

Plastic substitution with non-plastic materials can provide resource efficiency benefits in applications that are hard to otherwise eliminate, reduce or recycle. The applicability of materials for substitution is typically constrained by issues with performance, climate impact, affordability and convenience. Alternative materials may have high greenhouse gas (GHG) emissions associated with their production, use or end-of-life and must be utilised carefully to avoid increasing overall emissions or other negative impacts (e.g., waste generation, pollution, supply chain instability). During interviews, one stakeholder noted that while it is clear that certain brands are trying to move away from plastics, in many cases substituting with another material may not necessarily be better for the environment.

Plastic reduction by means of material substitution was deemed by the research team to be an inapplicable intervention to the construction, automotive, textile and electronics industries within this report. The majority of textiles consumed in the UK are imported.[61] As a result, material substitution in textiles, which mainly applies to the production of textiles outside of the UK, is out of scope for this report. Additionally, plastic currently plays an important role in the safety and emissions performance of vehicles. In fact, the average car weight from plastic is expected to grow from 12% to 16% by 2030 in an effort to make cars increasingly lightweight[62] to save on fuel consumption. This trend is expected to continue with the shift to electric vehicles, where lighter weights will allow for a greater range. Whilst substitutes exist for certain plastic applications in construction and electronics, plastic is often the superior choice on not only an emissions basis, but also from a cost and performance perspective according to stakeholders interviewed.

Table 7: List of industries applicable to measure 2

Packaging & Household Goods	Construction	Automotives	Textiles	Electronics
Applicable	Not applicable	Not applicable	Not Applicable	Not applicable

[61] WRAP (2019). Textiles Market Situation report 2019.
[62] Hollins, O. (2021). Driving change: A circular economy for automotive plastic.

2.1.2 Measure indicator

The indicator selected to measure material substitution with non-plastic materials was **'percentage CO_2e reduction from substitution with alternative materials compared to 2023 levels'** which is defined as the percentage reduction in CO_2e emissions by substituting plastic material with non-plastic materials such as paper, glass, aluminium or steel. This indicator demonstrates how much CO_2e could be saved by 2035 compared to a 2023 baseline.

The following indicator was identified but not selected:

- Percent of plastic that can be replaced with substitute materials.

This indicator was not selected because theoretically all plastics can be replaced with substitute materials. However, substitution with certain materials may lead to an overall increase in GHG emissions. By focusing the indicator on measuring CO_2e reduction, it is ensured that substitutions that increase the overall emissions impact of the product remain out of scope.

2.1.3 Examples in practice

Substitution with fibre-based materials

Companies will often attempt to select a material substitute that has a lower environmental impact than plastic. There is a trend towards the use of paper and other fibre-based materials as a substitute for plastic and companies often try to compare the relative GHG emissions of plastic products with these alternatives. Whilst natural-based materials may in some cases be ideal substitutes for plastics, companies and policymakers should assess the viability of the transitions needed to pursue these alternatives, and indeed any alternative material, at scale. The impacts of the properties of each potential substitute need to be considered, including lifespan and domestic disposal capacity.

It is not uncommon for the emissions trade-offs to be unclear. For example, GHG emissions in paper production can vary depending on the location, energy mix and end-of-life treatment used.[63] Despite this, paper-based packaging is still likely to be a favourable substitute as production emissions associated with paper production are abated more easily than the emissions associated with fossil-based formats due to fibre being a renewable feedstock. Fibre recycling levels are also currently higher than they are for plastics, and CO_2 emissions from fibre production can be more easily addressed by switching to clean energy sources.[64]

Still, care should be taken to ensure that paper fibres are sourced from sustainable biomass that does not provide undue competition with other land use systems. Additionally, to ensure circularity, plastic coatings should be minimal enough such that the product may be recycled alongside paper waste streams. This excludes laminated materials such as beverage cartons and coffee cups which are only recyclable at a specialist recycling facility.

[63] Plastic IQ (2021). Plastic IQ Methodology Document.
[64] Material Economics (2018). Sustainable packaging: the role of materials substitution.

2.2 Available sources

2.2.1 Literature review

The literature review identified 22 sources, used in this report, that discussed material substitution with non-plastic alternative materials. This comprised:

- ten industry reports[65] [66] [67] [68] [69] [70] [71] [72] [73] [74];
- four academic papers[75] [76] [77] [78];
- three policy documents[79] [80] [81];
- two technical studies[82] [83]; and
- three website articles[84] [85] [86]

The relevant sources were generally considered of high applicability when assessed against the data assessment framework, which recognises the relevance of the sources and the strength of the methodology within each. The sources exhibited an average IAS of 4.0 (out of 5), with 14 sources exhibiting a score of 4 or above. Of the literature reviewed for this measure, 14 sources were UK-specific and 6 were relevant to the European market. Additionally, 17 sources were published in the past ten years.

2.2.2 Interviews

Stakeholders interviewed unanimously agreed that material substitution with non-plastic materials is relevant to resource efficiency within the plastics sector. However, many

[65] British Plastics Federation (2021). British Plastics Federation Recycling Roadmap
[66] WRAP (2021). Plastics Market Situation Report 2021.
[67] WRAP (2022). The UK Plastics Pact Annual Report 2021-2022,
[68] BPF (n.d.). Plastics: Recycling and Sustainability.
[69] Green Alliance (2020). Fixing the system: Why a circular economy for all materials is the only way to solve the plastic problem. (Including Methodology).
[70] SystemIQ (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe.
[71] Plastics Europe (2023). Circular Economy for Plastics: United Kingdom – 2020.
[72] Circular Analytics (2020). Supporting evidence Environmental performance of beverage cartons.
[73] WWF (2018). A Plastic Future: Plastics Consumption and Waste Management in the UK.
[74] Ellen MacArthur Foundation (2022). Global Commitment 2022.
[75] Koulompis et al. (2020). Potential trade-offs between eliminating plastics and mitigating climate change: An LCA perspective on Polyethylene Terephthalate (PET) bottles in Cornwall.
[76] Voulvoulis et al. (n.d.). Examining Material Evidence: The Carbon Footprint.
[77] Brandt and Pilz (2011). The impact of plastic packaging on life cycle energy consumption and greenhouse gas emissions in Europe.
[78] McManus and Taylor (2015). The changing nature of life cycle assessment.
[79] Legistlation.gov.uk (2023). The Environmental Protection (Plastic Plates etc. and Polystyrene Containers etc.) (England) Regulations 2023.
[80] Legistlation.gov.uk (2023). The Environmental Protection (Single-use Plastic Products) (Scotland) Regulations 2021
[81] Legistlation.gov.uk (2023). The Environmental Protection (Single-use Plastic Products) (Wales) Act 2023
[82] Trucost, The American Chemistry Council (2016). Plastics and Sustainability: A Valuation of Environmental Benefits, Costs and Opportunities for Continuous Improvement.
[83] Food Standards Agency (2023). Alternatives to single-use plastics in food packaging and production.
[84] Material Economics (2018). Sustainable packaging: the role of materials substitution.
[85] YouGov (2019). Most Brits support ban on harmful plastic packaging.
[86] WRAP (n.d.). The UK Plastics Pact: Plastics Definitions.

stakeholders expressed concern that shifts away from plastic towards other materials can, in some circumstances, result in unintended negative environmental impacts, which are discussed further in the sections below.

The indicator presented during the interviews was ‘percentage CO_2e reduction from the use of alternative materials within the packaging and non-packaging sectors.’ However, stakeholders were only asked to comment on the potential percent reduction in plastic mass from the use of alternative materials as this would be easier to discuss quantitatively. The intention was to then convert the reduction in plastic mass into a % emissions reduction. Five stakeholders engaged in discussion about the measure qualitatively; however, only one stakeholder provided a view on the quantitative levels of efficiency for this measure.

2.2.3 Workshop

For this measure, stakeholders were asked to vote for the percent of plastic packaging units placed on the market that could be replaced with alternate materials without resulting in an overall increase in GHG emissions. Stakeholders voted on material substitution rates individually for single-use plastic applications replaced with reusable glass, single-use paper, and single-use aluminium. Stakeholders were also asked to identify the main packaging applications that would be substituted out in this way. Stakeholders were then given the opportunity to identify any other material substitution, resulting in stakeholders voting on single-use plastic replacement with reusable steel. Overall, stakeholders seemed to be wary of the fact that the GHG emissions impact of substitutions were largely unknown and felt low confidence in their ability to report on this measure accurately.

The level of engagement in the workshop was as follows:

- Four stakeholders were active on the mural board and four stakeholders actively contributed to verbal discussion.

2.3 Drivers & Barriers

The drivers and barriers influencing this measure were identified through a combination of the literature review, stakeholder interviews and sector workshop.

2.3.1 Drivers

Table 8 below shows the main drivers for Measure 2. The most significant drivers are shown in bold as voted for by stakeholders in the workshop.

Table 8: Drivers for plastics sector measure 2

Description	PESTLE	COM-B
Customer demand	**Social**	**Motivation – reflective**
Regulatory requirements	Legal	Capability – psychological
Lifecycle assessments	Technological	Capability – physical
Voluntary commitments	Political	Motivation – automatic

Customer demand

Replacing plastics with other materials for products, and especially packaging, can be driven by consumer demand. Where a product material is required and cannot be avoided, alternative materials to plastic can be used. YouGov found that many UK consumers feel guilty about their use of plastic and would be willing to pay more for more sustainable alternatives to plastics for their grocery packaging.[87] This willingness to pay may have changed due to the current economic climate, but it highlights consumer beliefs and intentions. Examples of alternative materials to plastic include paper, cardboard, metal and glass. However, in order to avoid shifting environmental burdens from plastic over to other materials, the full lifecycle of product materials should be assessed and compared. This ensures that the use of alternative materials will not incur the same or worse environmental impacts as plastic.

Regulatory requirements

Regulation surrounding plastic use in the UK revolves predominantly around plastic packaging. For example, England[88], Scotland[89] and Wales[90] have implemented single-use plastic bans on certain single-use plastic items, such as expanded polystyrene takeaway cups, plastic straws, plastic cutlery and plastic balloon sticks. By banning such single-use plastic items from manufacture and supply, alternative single-use materials may be used – such as single-use paper cups, cardboard trays and wooden cutlery.

Lifecycle assessments

Lifecycle assessments are used to compare environmental impacts from products under different scenarios, such as using different materials. Lifecycle assessments should be used on a case-by-case basis, considering locations, processes and realistic comparisons. With advances in lifecycle assessment datasets, quality standards and calculations, more accurate estimates can be made on the overall environmental impacts from replacing plastic with alternative materials. For example, it has been found that the use of fibre-based composite

[87] YouGov (2019). Most Brits support ban on harmful plastic packaging.
[88] The Environmental Protection (Plastic Plates etc. and Polystyrene Containers etc.) (England) Regulations 2023.
[89] The Environmental Protection (Single-use Plastic Products) (Scotland) Regulations 2021.
[90] The Environmental Protection (Single-use Plastic Products) (Wales) Act 2023.

material for single-use drinks (i.e., beverage cartons) can produce lower carbon emissions than plastic PET bottles, but possibly with other negative impacts associated with land use change as discussed in the barriers section below.[91] As such, the use of lifecycle assessments can drive the appropriate replacement of plastic with other materials which reduce carbon emissions and other environmental impacts.

Voluntary commitments

Setting plastic reduction targets through voluntary commitments, such as the UK Plastics Pact[92] and The Ellen MacArthur Foundation "Global Commitment 2022",[93] can drive producers to replace plastic packaging with other materials. The UK Plastics Pact, for instance, has set its signatories a target of eliminating "problematic" single-use plastics, such as multipack wrap and PVC packaging, from plastic packaging by 2025. [94] This may require the use of alternative materials to be used, such as paper and cardboard.[95] Although a large focus of voluntary commitments is on single-use plastic packaging, this is important given the large contribution that single-use plastic packaging has towards plastic consumption and waste in the UK. [96]

2.3.2 Barriers

Table 9 below shows the main barriers for Measure 2. The most significant barriers are shown in bold as voted for by stakeholders in the workshop.

Table 9: Barriers for plastics sector measure 2

Description	PESTLE	COM-B
Technical properties	**Social**	**Capability – physical**
Negative environmental impact	Environmental	Capability – physical
Cost	Economic	Opportunity – physical
Lifecycle assessment complexities and variations	Technological	Capability – physical

Technical properties

As mentioned in Section 2.3.1, there is evidently demand for sustainable packaging and an apparent desire to reduce and avoid plastic packaging in the UK. However, there are barriers associated with the physical properties of packaging made from alternative materials. For

91 Circular Analytics (2020). Supporting evidence Environmental performance of beverage cartons.
92 WRAP (N.D.). The UK Plastics Pact.
93 The Ellen MacArthur Foundation (2022). The Global Commitment 2022.
94 WRAP (N.D.). The UK Plastics Pact.
95 WRAP (2022). The UK Plastics Pact Annual Report 2021-2022.
96 WWF (2018). A Plastic Future: Plastics Consumption and Waste Management in the UK.

example, paper and metal are not transparent, meaning consumers cannot see the produce they are purchasing. Glass is heavier and more fragile than plastic, meaning it can be inconvenient to handle and risks shattering if dropped.[97] These physical properties can limit the uptake and use of alternative materials, especially for food and drink packaging. Additionally, due to the durability and versatility of plastic, the use of alternative materials may pose technical, operational and safety risks. The use of plastic for certain automotive parts, for instance, is important as it can withstand high impacts. Replacing these plastic parts with alternative materials could therefore pose safety risks to passengers without rigorous testing. It is therefore considered undesirable to replace plastics with alterative materials for automotive and construction parts and products.[98]

Negative environmental impact

In the same way that environmental benefits can arise from replacing plastic with alternative materials, negative environmental impacts can also arise. For example, the use of glass or aluminium for a 500ml single-use drinks bottles has been found to produce higher carbon emissions than that of plastic.[99] As such, in some situations, replacing plastic with alternative materials can result in higher carbon emissions, along with other environmental impacts such as land use change. It is therefore important that lifecycle assessments are carried out on a case-by-case basis to avoid increasing the negative environmental impacts when redesigning a product.[100] Furthermore, lifecycle assessments should be conducted using accurate and realistic input data, reflecting recent and future changes, such as energy sources (e.g., increased use of renewable energy) and end-of-life treatment processes.

Cost

Plastic is a popular material for various applications due to its durability, versatility, and relatively low cost. Replacing plastic with alternative materials can therefore incur higher capital and operational costs. In terms of packaging, using alternative materials to plastic can be more expensive – such as glass and metal which can be more expensive to produce and transport compared to plastic. There are also high research and development costs for food and drink packaging made from alternative materials. These higher costs make it difficult for companies to compete with others that use plastic for their food and drink packaging. Due to these higher costs for alternative materials compared with plastic, it has been argued that for many consumers, they will more likely purchase the product in plastic packaging if it is cheaper.[101] As such, cost savings associated with plastic poses a financial barrier facing the uptake and use of alternative materials.

Lifecycle assessment complexities and variations

---

[97] Food Standards Agency (2023). Alternatives to Single-Use Plastics in Food Packaging and Production. FS900260

[98] SystemIQ (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe

[99] Green Alliance (2020). Fixing the system: Why a circular economy for all materials is the only way to solve the plastic problem.

[100] Voulvoulis et al. (N.D). Examining Material Evidence: The Carbon Footprint. Imperial College London.

[101] Food Standards Agency (2023). Alternatives to Single-Use Plastics in Food Packaging and Production. FS900260

Whilst lifecycle assessments are effective in terms of estimating and comparing environmental impacts of different products and services, they require accurate and detailed input information. This information, along with understanding and use of specialist software, can be resource and time intensive to gather and analyse. Additionally, lifecycle assessments often use different assumptions, system boundaries and datasets, meaning results are not possible to compare.[102] These complexities, costs and variations are barriers facing the effective use and comparability of results.

2.4 Levels of efficiency

Table 10: Levels of efficiency for plastics sector measure 2

Indicator: % CO_2e reduction from substitution with alternative materials compared to a 2023 baseline			
Level of efficiency	Current	Maximum in 2035	Business-as-usual in 2035
Value	0%	Not identified	Not identified
Evidence RAG	Not applicable	Not applicable	Not applicable

2.4.1 A note on findings

The levels of efficiency for this measure were not identified. The calculation of a reduction in CO_2e requires an understanding of two factors: (1) the anticipated change in mass of plastic placed on the market used along with the corresponding change in mass of each type of material used to replace plastic; and (2) the carbon impacts associated with the production of each of these materials on a lifecycle basis (noting that the emissions associated with each material can vary immensely depending on features such as the origin of each material, production method and local waste management methods). The research process did not yield sufficient information for both of these inputs to produce a meaningful level of efficiency for this measure and remains a significant evidence gap.

[102] McManus and Taylor (2015). The Changing Nature of Life Cycle Assessment. Biomass and Bioenergy. 82, pp12-26.

3.0 Measure 3 – Feedstock Substitution with Bio-Based Feedstocks

3.1 Plastics resource efficiency measure

3.1.1 Description

Substituting fossil-based plastic feedstocks with bio-based, durable plastic, including both drop-in and novel polymers.

Bio-based plastics are plastics derived from renewable raw materials such as plants. Biorefineries can be used to convert first-generation (i.e., edible plant products) and second-generation (i.e., non-edible biowastes) biomass into the same building blocks derived from petroleum. These monomers can then be polymerised into drop-in polymers (e.g., bio-PE, bio-PET), novel polymers (e.g., PEF) as well as biodegradable ones (e.g., PLA). 'Bio-based' is not synonymous with 'biodegradable,' which indicates that a material can be broken down naturally by organisms. Bio-based plastics can be classed as either biodegradable or non-biodegradable depending on the polymer type, but for the purposes of this analysis the focus is on *bio-based, non-biodegradable plastics* as replacements for fossil-based plastics.

Notably, there is a lack of consensus among academics and industry professionals as to the environmental benefits, such as GHG reductions, of bio-based plastics as an alternative to fossil-based plastics.[103,104] The variation often depends on assumptions around the bio-based feedstock, application and end-of-life treatment route. Use of renewable sources does not always equate to a sustainable product. Holistic sustainability depends not only on the building blocks of the material, but also factors such as how a material is made, how it is used, and whether or not it can be recycled.

Technological advances in bio-based plastics have the potential to move plastic-intensive industries towards a circular economy by making renewable feedstocks available to make up for plastic that is inevitably lost during the waste management process. Additionally, biorefinery processes have the potential to increase in efficiency while adhering to green chemistry principles (e.g., low energy demand, utilisation of non-toxic chemicals). As such, the environmental impacts of both fossil-based and bio-based materials must continue to be scrutinised.

[103] Samir et al. (2023). Bioplastic production in terms of life cycle assessment: A state-of-the-art review. Environmental Science and Ecotechnology.
[104] Gerassimidou et al. (2021). Development of an integrated sustainability matrix to depict challenges and trade-offs of introducing bio-based plastics in the food packaging value chain. Journal of Cleaner Production.

Regardless, bio-based plastic consumption is projected to increase globally in response to the demand for alternatives to fossil-based resources, but this is likely to need more regulatory support to be fully realised and its environmental effects managed.[105]

Table 11: List of industries applicable to measure 3

Packaging & Household Goods	Construction	Automotives	Textiles	Electronics
Applicable	Applicable	Applicable	Applicable	Applicable

3.1.2 Measure indicator

The indicator selected to measure feedstock substitution with bio-based feedstocks was **'percentage fossil-based plastics consumption that is replaced with bio-based, durable plastics production'** which is defined as the percentage reduction in plastics consumption that can be replaced with bio-based plastic materials, including a combination of both drop-in and novel bio-based polymers.

Other indicators that were identified but not selected included:

- percentage CO_2e reduction from substitution with bio-based plastics;
- percentage plastic consumption that can be replaced with drop-in biobased polymers; and
- percentage plastic consumption that can be replaced with novel bio-based polymers.

The first indicator was not selected as there is currently a large amount of uncertainty around the GHG emissions impact of substituting fossil-based plastics with bio-based plastics within the literature. [106,107] The second two indicators were not selected as they would not produce a holistic view of the potential material reductions achievable through the substitution of bio-based materials.

3.1.3 Examples in practice

Two potential production processes for durable bio-based plastics exist, and the choice among them relies on the specific feedstock and the desired polymer output. One process involves the chemical modification of natural polymers, such as starch, to create a bio-based plastic. Another process consists of two-step biomass conversion. This uses chemical catalysis to convert biomass into monomers, which are then polymerised to produce a bio-based plastic.

[105] Institute for Bioplastics and Biocomposites (2022). Biopolymers: Facts and Statistics 2022.
[106] Samir et al. (2023). Bioplastic production in terms of life cycle assessment: A state-of-the-art review. Environmental Science and Ecotechnology.
[107] Gerassimidou et al. (2021). Development of an integrated sustainability matrix to depict challenges and trade-offs of introducing bio-based plastics in the food packaging value chain. Journal of Cleaner Production.

This two-step biomass conversion process can produce two polymer types: drop-in polymers which are structurally identical to their fossil-based alternatives, or novel polymers which do not have fossil-based alternatives.

Drop-In Polymers

Drop-in bio-based plastics, such as bio-polyethylene (bio-PE) or bio-polypropylene (bio-PP) possess the same chemical structures and performance properties as their fossil-based counterparts, allowing them to fit into current processing and recycling systems seamlessly. This compatibility with existing infrastructure makes drop-in bio-based plastics an attractive option for reducing environmental impact without requiring significant changes to the plastics value chain or waste management infrastructure. However, these tend to have higher feedstock — and thus land use — requirements than their novel counterparts. Additionally, some polymer types, such as PVC and PS, do not currently have drop-in substitutes commercially available. One stakeholder noted that drop-in bio-PE is the only bio-based alternative that appears to have a lower carbon footprint than its fossil-based counterpart.

Novel Polymers

Novel polymers such as polytrimethylene terephthalate (PTT), and polyethylene furanoate (PEF), represent a more innovative approach to bio-based plastics. PTT and PEF can both be used as an alternative to PET with barrier properties that might make these materials a good choice for food and beverage packaging. Novel bio-based polymers can demonstrate higher efficiency in converting bio-based feedstocks into plastics, which results in reduced land use per tonne of plastic compared to their fossil-based or drop-in counterparts. Despite these benefits, competing against other polymers with established recycling routes such as PET can be challenging, particularly as they cannot typically compete on price. There is a need to strike a balance between compatibility with existing systems and maximising resource efficiency when considering the ideal mix of bio-based plastics.

3.2 Available sources

3.2.1 Literature review

The literature review identified 27 sources, used in this report, that discussed feedstock substitution with bio-based feedstocks. This comprised:

- fifteen academic papers[108] [109] [110] [111] [112] [113] [114] [115] [116] [117] [118] [119] [120] [121] [122];
- five industry reports[123] [124] [125] [126] [127];
- five technical studies[128] [129] [130] [131] [132]; and
- two policy documents[133] [134]

The relevant sources were generally considered of medium applicability when assessed against the data assessment framework, which recognises the relevance of the sources and the strength of the methodology within each. The sources exhibited an average IAS of 4.1 (out of 5), with 19 sources exhibiting a score of 4 or above. Of the literature reviewed for this measure, 4 sources were UK-specific and 17 were relevant to the European market. Additionally, all sources were published in the past ten years.

[108] Gerassimidou et al. (2021). Development of an integrated sustainability matrix to depict challenges and trade-offs of introducing bio-based plastics in the foodpackaging value chain.
[109] Kabasci (2020). Plastic Waste and Recycling: Environmental Impact, Societal Issues, Prevention, and Solutions. Chapter 4: Biobased Plastics.
[110] Havstad (2020). Plastic Waste and Recycling: Environmental Impact, Societal Issues, Prevention, and Solutions. Chapter 5: Biodegradable Plastics.
[111] Belboom and Leonard (2016). Does biobased polymer achieve better environmental impacts than fossil polymer? Comparison of fossil HDPE and biobased HDPE produced from sugar beet and wheat.
[112] Nejad et al. (2021). Carbon and energy footprints of high-value food trays and lidding films made of common bio-based and conventional packaging materials
[113] Zheng and Suh (2019). Strategies to reduce the global carbon footprint of plastics.
[114] Rosenboom et al. (2022). Bioplastics for a circular economy.
[115] Samir Ali et al (2023). Bioplastic production in terms of life cycle assessment: A state-of-the-art review.
[116] Brizga et al. (2020). The Unintended Side Effects of Bioplastics: Carbon, Land, and Water Footprints.
[117] IfBB – Institute for Bioplastics and Biocomposites (2023). Biopolymers facts and statistics: 2022 - Production capacities, processing routes, feedstock, land and water use
[118] Gursel et al. (2021). Comparative cradle-to-grave life cycle assessment of bio-based and petrochemical PET bottles
[119] Zheng, J. and Suh. (2019). Strategies to Reduce the Global Carbon Footprint of Plastics. Nature Climate Change. 9, p374-378
[120] Zwicker et al. (2023). Consumer attitudes and willingness to pay for novel bio-based products using hypothetical bottle choice
[121] Letcher (2020). Plastic Waste and Recycling: Environmental Impact, Societal Issues, Prevention, and Solutions.
[122] Loos et al. (2020). A Perspective on PEF Synthesis, Properties, and End-Life
[123] European Bioplastics (2023). Bioplastics - Facts and Figures
[124].Plastics Europe (2022). Plastics - The Facts 2022
[125].Chen J. (2019). Global Markets and Technologies for Bioplastics
[126] Aeschelmann, F. & Carus, M. (2015). Biobased building blocks and polymers in the world: capacities, production, and applications–status quo and trends towards 2020
[127] Technavio (2019). Global Bioplastic Packaging Market 2019-2023
[128] Systemiq et al. (2020). Breaking the Plastic Wave Thought Partners: Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution
[129] Trucost, The American Chemistry Council (2016). Plastics and Sustainability: A Valuation of Environmental Benefits, Costs and Opportunities for Continuous Improvement
[130] Food Standards Agency (2023). Alternatives to single-use plastics in food packaging and production
[131] ISO (2015). ISO 16620:2015 Plastics – Biobased Content
[132] European Bioplastics (2023). Fact Sheet: Bioplastics – Industry Standards & Labels
[133] UK Government (2023). Misleading environmental claims.
[134] European Commission (2022). Biobased plastics: Sustainable Sourcing & Content.

3.2.2 Interviews

Stakeholders considered this to be an important measure, but there were differing opinions on the practical feasibility of feedstock substitution with bio-based feedstocks at scale. Additionally, many stakeholders expressed concern that shifts away from fossil-based feedstock towards bio-based feedstocks can, in some circumstances, result in unintended negative environmental impacts, which are discussed further in the sections below.

The indicator presented during the interviews was ‘percent CO_2e reduction from use of bio-based plastic’ including both drop-in and novel bio-based polymers. However, following discussions with stakeholders, a decision was made to change the indicator to ‘percentage fossil-based plastics consumption that can be replaced with bio-based, durable plastics production’. This choice was motivated due to the fact that there is currently a large amount of uncertainty around the GHG emissions impact of substituting fossil-based plastics with bio-based plastics. Five stakeholders engaged with this measure qualitatively and two provided quantitative feedback on the levels of efficiency in the interviews.

3.2.3 Workshop

Overall, stakeholders conceptually understood this measure but lacked specialist expertise in this area. Stakeholders flagged that, although this measure is relevant to resource efficiency, there are ethical considerations to implementation such as the impact of land use on food production. Additionally, stakeholders stated that there is uncertainty around whether the plastics are, indeed, the best applications for bio-based feedstocks. Generally, the views of the stakeholders were that the bio-based market is so underdeveloped at present it is unrealistic for it to increase significantly in the time period being represented without significant external influences. As such, it should be noted that their input was unlikely to represent technical limitations to substituting fossil-based feedstocks for bio-based feedstocks, but rather the perceived technical limitations to the market’s ability to produce an adequate amount of bio-based feedstock within the prescribed timeframe.

The level of engagement in the workshop was as follows:

- All six stakeholders were active on the mural board and four stakeholders actively contributed to verbal discussion.

3.3 Drivers & Barriers

The drivers and barriers influencing this measure were identified through a combination of the literature review, stakeholder interviews and sector workshop.

3.3.1 Drivers

Table 12 below shows the main drivers for Measure 3. The most significant drivers are shown in bold as voted for by stakeholders in the workshop.

Table 12: Drivers for plastics sector measure 3

Description	PESTLE	COM-B
Carbon and raw fossil-based material savings	**Environmental**	**Opportunity - physical**
Customer demand	**Social**	**Motivation – reflective**
Technological advances	Technological	Capability – physical
Certification schemes and standards	Legal	Capability – psychological

Carbon and raw fossil-based material savings

The use of biomass as a feedstock avoids the use of fossil-based resources as a feedstock, reducing the environmental impacts associated with fossil-fuel extraction. The use of biomass can also reduce carbon emissions associated with the production of plastic products. Various studies using lifecycle analysis have calculated carbon emission savings from bio-based plastic compared with fossil-based plastic. One study assessing bio-based plastic at a global level in 2050, estimated between 25-38% lower carbon emissions from replacing all fossil-based plastic with bio-based plastic derived from sugarcane.[135] Despite some positive findings, there is a lack of consensus amongst academics and industry professionals over the environmental benefits of bio-based plastics. This is mostly surrounding the negative impacts that bio-based plastic has on land use, water use and competition for food and biofuel. Additionally, energy requirements during the biorefinery and polymerisation stages can vary based on feedstock being used, resulting in different carbon emissions. Such energy requirement differences can result in bio-based plastics producing higher or lower carbon emissions than fossil-based plastics.[136] As such, whilst the replacement of fossil-based plastic with bio-based plastic can result in carbon emission and fossil-based resource savings, this is not always the case and other environmental and social impacts need to be carefully considered. Promisingly, ISO 22526 has been developed to provide guidelines and requirements for carbon and environmental footprint assessments for bio-based plastic products, with a European standard being developed for lifecycle assessments that compare environmental impacts from bio-based products with fossil-based products. [137]

[135] Zheng, J. and Suh, S. (2019). Strategies to Reduce the Global Carbon Footprint of Plastics. Nature Climate Change. 9, p374-378.
[136] Gerassimidou et al. (2021). Development of an integrated sustainability matrix to depict challenges and trade-offs of introducing bio-based plastics in the food packaging value chain. Journal of Cleaner Production. 286, pp1-16.
[137] European Bioplastics (2023). Fact Sheet: Bioplastics – Industry Standards & Labels.

Customer demand

Despite the current low consumption rates of bio-based plastic compared with fossil-based plastic, uptake of bio-based plastic in Europe is increasing at around 10% per annum.[138] Part of this growth is due to consumer demand for sustainable products. One 2023 study, surveying over 500 UK residents, found that 96.8% of respondents preferred bio-based plastic drinks bottles over fossil-based plastic drinks bottles. Furthermore, the respondents would be willing to pay up to 40% more for bio-based plastic bottles than fossil-based plastic bottles.[139] It is important to note that this willingness to pay more may have changed in light of the current economic climate. During interviews, stakeholders identified similar trends, with a large consumer demand for sustainable products, including bio-based plastic. As such, consumer demand is a strong driver for bio-based plastic as an alternative to fossil-based plastic.

Technological advances

Research and development are crucial for maximising the resource efficiency credentials of bio-based plastics. Novel polymers, such as PEF, are being developed and commercialised, which can have superior technical properties over fossil-based alternatives.[140] In terms of PEF, there has been substantial research and development into this novel bio-based polymer in recent years. PEF has similar (and in some cases superior) properties to fossil-based PET, allowing it to be used in various applications. For instance, PEF has superior carbon dioxide barrier properties compared with PET, making it effective for carbonated drinks packaging. However, the end-of-life treatment options for PEF, including mechanical recycling suitability, are still being assessed and developed.[141] Additionally, research and development into the use of food waste and other biomass residues as a bio-based plastic feedstock is advancing. Using food waste and biomass residues can avoid the use and competition for land, water, agricultural fertilisers and pesticides and other precious resources, whilst harnessing the value of an otherwise waste material. Such advances in bio-based plastics could therefore lower resource depletion, waste arisings, competition for land, fertilisers, pesticides and food and lower carbon emissions associated with the production of bio-based plastics. [142] However, the plastics sector will compete with other sectors for available biomass and its currently unknown how industry will split the limited supply of biomass between sectors. Priority applications for biomass within the UK is discussed in the Biomass Strategy 2023.

Certification schemes and standards

To ensure that products are consistently and correctly defined, the use of certification schemes and standards are widely adopted. This also provides reassurance and gains trust with businesses and consumers that products meet certain requirements. An example of a standard

138 Rosenboom et al. (2022). Bioplastics for a Circular Economy. Nature Reviews Materials. 7, pp117-137.
139 Zwicker et al. (2023). Consumer attitudes and willingness to pay for novel bio-based products using hypothetical bottle choice. Sustainable Production and Consumption. 35, pp173-183.
140 Samir Ali et al. (2023). Bioplastic production in terms of life cycle assessment: A state-of-the-art review. Environmental Science and Ecotechnology. 15, pp1-21.
141 Loos et al. (2020). A Perspective on PEF Synthesis, Properties, and End-Life. Frontiers in Chemistry. 8, 585. pp1-18.
142 Samir Ali et al. (2023). Bioplastic production in terms of life cycle assessment: A state-of-the-art review. Environmental Science and Ecotechnology. 15, pp1-21.

for bio-based plastic is ISO 16620, which provides guidelines for calculating bio-based carbon content in plastic material. It is also being developed to include guidelines on declaring bio-based content in a plastic product.[143] A similar European standard for bio-based products is EN 16640. Depending on the amount of bio-based content in the product, certification is awarded and certain bio-based product labelling can be used. [144] As for lifecycle assessment standards, the European standard EN 16760 and ISO 16620 provide guidelines and requirements for lifecycle assessments on bio-based products. An additional standard is also being developed which will provide guidelines and requirements for lifecycle assessments that compare bio-based products with fossil-based products.[145] In terms of communication standards relating to bio-based products, the European standards EN 16848 and EN 16935 have been developed for business-to-business and business-to-consumer communications, respectively.[146] These certification schemes and standards should improve consistency for lifecycle assessments and communications regarding bio-based plastic products.

3.3.2 Barriers

Table 13 below shows the main barriers for Measure 3. The most significant barriers are shown in bold as voted for by stakeholders in the workshop.

Table 13: Barriers for plastics sector measure 3

Description	PESTLE	COM-B
Land use & lack of feedstock production capacity	**Environmental**	**Opportunity – physical**
Cost	**Economic**	**Opportunity – physical**
Wider environmental and social impacts	**Environmental**	**Opportunity – physical**
Recycling complexity	Technological	Capability – physical
Greenwashing / lack of credible carbon accounting methods	Political	Opportunity – social

Land use & lack of feedstock production capacity

Land use plays a crucial role in the production of bio-based plastics, and it is essential to evaluate the potential impact that bio-based plastic production will have on land resources. While crop residues can be utilised in some cases for bio-plastics production, large-scale production generally requires cultivating feedstock crops such as sugarcane, maize or other

143 ISO (2015). ISO 16620:2015 Plastics – Biobased Content.
144 European Bioplastics (2023). Fact Sheet: Bioplastics – Industry Standards & Labels.
145 European Bioplastics (2023). Fact Sheet: Bioplastics – Industry Standards & Labels.
146 European Bioplastics (2023). Fact Sheet: Bioplastics – Industry Standards & Labels.

cellulose-producing plants. This raises concern about the availability and competition for arable land, which is already under pressure to meet food demands. To ensure sustainable land use, including biodiversity and protecting against deforestation, it is important to strike a balance between bio-based plastic production and other land-dependent activities. A recent EU publication[147] notes producing 100% of plastics with bio-based feedstocks globally would likely require about 4% of the total currently available agricultural land, which suggests that the land required for bio-based plastics will be a small proportion of the overall land demand. However, that is not to say that the small percentage will be inconsequential in a world where the population is still growing quickly, and climate change makes agricultural outputs less reliable due to frequent droughts, fires and floods.

Cost

Currently, bio-based plastic tends to cost more to produce than fossil-based plastics. For example, bio-ethylene is roughly 30% more expensive than fossil-based ethylene.[148] Despite this, it is argued that the depletion, and therefore increased price, of oil combined with cost efficiencies through economies of scale may result in bio-based plastics being more affordable in the future.[149, 150] However, currently, bio-based plastic is more expensive to produce compared with fossil-based plastic.[151] Despite customers self-reporting a willingness to pay more for bio-based plastic products, it has been argued that in practice many consumers are more likely to purchase a product in fossil-based plastic packaging if it is cheaper.[152] This point surrounding willingness-to-pay is especially relevant in the current economic climate. As such, these higher costs may limit the uptake of bio-based plastic.

Wider environmental and social impacts

Although bio-based plastic may mitigate resource depletion of fossil-based resources and reduce carbon emissions compared with fossil-based plastic, there are negative environmental and social impacts commonly associated with bio-based plastic. These include eutrophication (the accumulation of nutrients) of water bodies, increased land and water use and even food poverty as more agricultural resources, such as land, water and fertiliser, are required for growing crops for bio-based plastic.[153] Due to these negative impacts, the replacement rate of

---

[147] Publications Office of the European Union (2022). Biobased plastic: Sustainable sourcing and content: final report.
[148] Fiorentino G, Ripa M, Ulgiati S. (2017). Chemicals from biomass: technological versus environmental feasibility. A review. Biofuels Bioprod Biorefin.
[149] Brizga et al. (2020). The Unintended Side Effects of Bioplastics: Carbon, Land, and Water Footprints. One Earth. 3, pp45-53.
[150] Food Standards Agency (2023). Alternatives to Single-Use Plastics in Food Packaging and Production. FS900260
[151] Gerassimidou et al. (2021). Development of an integrated sustainability matrix to depict challenges and trade-offs of introducing bio-based plastics in the food packaging value chain. Journal of Cleaner Production. 286, pp1-16.
[152] Food Standards Agency (2023). Alternatives to Single-Use Plastics in Food Packaging and Production. FS900260
[153] Samir Ali et al. (2023). Bioplastic production in terms of life cycle assessment: A state-of-the-art review. Environmental Science and Ecotechnology. 15, pp1-21.

fossil-based plastic with bio-based plastic will be limited by competition for agricultural resources and the negative environmental and social impacts that may arise.[154]

Recycling complexity

As with many fossil-based plastic polymers, many non-biodegradable bio-based plastic polymers (such as bio-PET and bio-PE) can be mechanically or chemically recycled. However, there is widespread confusion amongst consumers as to whether bio-based plastic waste should be sorted as dry mixed recyclate or as compostable organic waste. As such, consumers may incorrectly sort their durable bio-based plastic waste into their compost bin, or general waste bin due to uncertainty, or falsely believe that it is acceptable to litter durable bio-based plastic waste as it will biodegrade in the environment.

Although biodegradable plastic is out of scope in this report, it is worth highlighting that biodegradable bio-based plastic poses a major contamination risk to plastic recycling. Levels of as low as 0.1% of biodegradable plastic within plastic recyclate feedstock can result in detrimental physical and aesthetic effects on the output recycled plastic material – such as PLA affecting PET recycled material due to yellowing, agglomeration and physical properties. These detrimental impacts can render the recycled material unsuitable for many end products.[155] As a result, sorting facilities and plastic recyclers are investing in more advanced sorting equipment to identify and remove biodegradable plastic, and therefore maximise recycled plastic quality. [156]

Greenwashing / lack of credible carbon accounting methods

There is inconsistency amongst studies that calculate carbon emission savings associated with bio-based plastic production. Specifically, there is a lack of consensus and consistency on how carbon sequestration during the growth of crops as a bio-based plastic feedstock and carbon released due to land use change are accounted for.[157] This inconsistency and lack of consensus can result in large differences in carbon emissions from bio-based plastic when compared against fossil-based plastic, with different outcomes for which plastic feedstock produces the least carbon emissions. For instance, one paper reviewed literature surrounding bio-based plastic.[158] The authors found that where studies included carbon sequestration in their comparisons, bio-based plastic could produce lower carbon emissions than fossil-based plastic. The authors concluded that carbon sequestration accounting could be a significant determinant of the carbon emissions of bio-based plastic.[159] As mentioned above, a European

[154] Brizga et al. (2020). The Unintended Side Effects of Bioplastics: Carbon, Land, and Water Footprints. One Earth. 3, pp45-53.
[155] Letcher, T. (2020). Plastic Waste and Recycling: Environmental Impact, Societal Issues, Prevention, and Solutions. Elsevier Academic Press. ISBN:978-0-12-817880-5.
[156] Gerassimidou et al. (2021). Development of an integrated sustainability matrix to depict challenges and trade-offs of introducing bio-based plastics in the food packaging value chain. Journal of Cleaner Production. 286, pp1-16.
[157] Ibid.
[158] Brizga et al. (2020). The Unintended Side Effects of Bioplastics: Carbon, Land, and Water Footprints. One Earth. 3, pp45-53.
[159] Gerassimidou et al. (2021). Development of an integrated sustainability matrix to depict challenges and trade-offs of introducing bio-based plastics in the food packaging value chain. Journal of Cleaner Production. 286, pp1-16.

standard is being developed for lifecycle assessments that compare environmental impacts from bio-based products with fossil-based products.[160]

'Greenwashing' is the dissemination of a false or misleading claims about a service or product, which claims to have environmental benefits. In terms of bio-based plastic products, it may be claimed that they are 'sustainable' or 'eco-friendly' despite there being no lifecycle assessment conducted. Consumers may be influenced to purchase these bio-based plastic products based on potentially false or misleading environmental claims. The use of greenwashing from bio-based plastic may therefore pose a barrier to carbon emission savings from bio-based plastic products if false or misleading claims are used for products which do not have carbon emissions savings associated with them.

In order to prevent greenwashing, communication standards have been developed that relate to bio-based products. The European standards EN 16848 and EN 16935 have been developed for business-to-business and business-to-consumer communications, respectively.[161] Similarly, the UK Government has established a Green Claims Code which provides guidance to producers and consumers and investigates and enforces action on possible greenwashing claims.[162] These standards and codes aim to improve consistency, accuracy and assurance behind communications regarding products such as bio-based plastics.

3.4 Levels of efficiency

Table 14: Levels of efficiency for plastics sector measure 3

Indicator: % fossil-based plastics consumption that can be replaced with bio-based, durable plastics production			
Level of efficiency	Current	Maximum in 2035	Business-as-usual in 2035
Value	<1%	1 – 3%	0 – 2%
Evidence RAG	Amber-Green	Red-Amber	Amber

3.4.1 Current level of efficiency

According to Plastics Europe, it is estimated that around 1% of plastic production across Europe in 2022 was sourced from bio-based feedstocks.[163] This level of substitution is lower than the 2.3% rate reported for 2021 by the same organisation, although it is unclear whether this trajectory is meaningful as the report notes that figures cannot always be directly

[160] European Bioplastics (2023). Fact Sheet: Bioplastics – Industry Standards & Labels.
[161] European Bioplastics (2023). Fact Sheet: Bioplastics – Industry Standards & Labels.
[162] UK Government (2023). Misleading environmental claims.
[163] Plastics Europe (2023). Plastics – The Facts 2023.

compared with those of previous years due to changes in estimates. Additionally, the change in percentage does not speak to the change in volume of bio-based plastics production as it is possible there was an increase in total volume, but a decrease in percentage relative to an overall increasing plastics market.

These figures incorporate all bio-based plastics, including biodegradable options (which are out of scope for this measure), so the level of efficiency for durable bio-based plastics only is likely to be lower. The projected market share of durable bio-based plastics only was not found in the literature and so the 1% current level of efficiency is likely to be an over-estimate.

The data for this literature source were collected by Plastics Europe (the pan-European association of plastics manufacturers) and EPRO (the European Association of Plastics Recycling and Recovery Operations).

Although specific data for the market share of bio-based plastics within the UK could not be found, Plastics Europe reports that only 0.2% of bio-based plastics across the EU27+3 are produced in the UK, with the majority of bio-based plastics production occurring in Germany (50.9%) and Italy (27%). However, the lack of bio-based feedstock production capacity does not necessarily mean there is an equally low market share of bio-based plastics products within the UK, rather that it is unlikely that these products are made of plastics sourced from domestic feedstocks.

Stakeholders were presented with the 2021 figure (2.3%) during the workshop. An initial reaction from one stakeholder was that this figure was much higher than what they would have expected. However, over the course of the discussion the same stakeholder reviewed their preferred source (the Plastics Europe report) and came around to agree that the figure presented was accurate. They did, however, note that a more recent version of the report was available which led us to the <1% figure presented above. Overall, although participants did not vote on the current level of efficiency, the verbal consensus from stakeholders during the workshop was that a very low proportion of feedstocks within the plastics industry are bio-based.

The evidence RAG rating for this efficiency range is amber-green, indicating a reasonably high degree of certainty despite lacking UK-based literature evidence as the literature source was of high quality and there was agreement among stakeholders that this estimate is reasonable.

3.4.2 Maximum level of efficiency in 2035

According to a 2022 study published in the academic journal *Nature*, global growth across all bio-based plastics could reach between 10-20% provided the correct political support and subsidies are in place, similar to biofuels, with particular capacity for growth in drop-in polymers that can be processed on standard equipment.[164] Packaging is the largest market for short-lived plastics and, therefore, also for bio-based plastics.

[164] Rosenboom et al. (2022). Bioplastics for a circular economy.

One study estimated the technical substitution potential of fossil-based plastic polymers with bio-based plastics, separating biodegradable and non-biodegradable polymers in their analysis, finding an overall maximum level of efficiency of 31%.[165] The findings regarding the technical substitution potential with durable bio-based plastics by polymer is shown below in Table 15. The maximum levels of efficiency for each polymer are then converted into the total replacement rate of the total plastics market by multiplying the two. These totals are then added to give the overall maximum level of efficiency across the market.

This study found that almost complete substitution of fossil-based plastics with bio-based plastics within the packaging sector is likely possible based on material properties required alone. These data represent only technical substitution potential and factors such as economic feasibility and resource availability are not taken into account in this analysis.

Table 15: Literature review findings behind measure 3 maximum level of efficiency

Polymer	Market Share of Virgin Fossil-based Plastic Demand[166]	Bio-based alternatives	Maximum Replacement Rate by Polymer[167]	Overall Maximum Replacement Rate[168]
PE	27.4%	Bio-PE	50 – 55%	13.7%
PP	18.9%	Bio-PP	10%	1.9%
PVC	13.0%	Bio-PVC	50%	6.5%
PS	7.0%	Not applicable	0%	0.0%
PUR	6.3%	Bio-PUR	80%	5.0%
PET	6.1%	Bio-PET, PEF, PTT	60%	3.7%
Other fossil-based	21.3%	Not applicable	Not applicable	0%
TOTAL	100%	Not applicable	Not applicable	30.8%

Stakeholders disagreed with the methodologies in the studies found during the literature review and therefore the findings on maximum level of efficiency, voting for a maximum level of efficiency between 1–3% across the market as shown below in Table 16. During discussion it became clear that stakeholders did not believe that any figure that does not account for the

165 Brizga et al. (2020). The Unintended Side Effects of Bioplastics: Carbon, Land, and Water Footprints.
166 Plastics Europe (2022). Plastics – The Facts 2022.
167 Brizga et al. (2020). The Unintended Side Effects of Bioplastics: Carbon, Land, and Water Footprints.
168 Calculation based on the 'market share of virgin fossil-based plastic demand' and 'maximum level of efficiency'

limitations of land use and lack of feedstock production capacity would be useful. The views of the stakeholders were that the bio-based market is so underdeveloped at present that it is unrealistic for it to increase significantly in the time period being represented without significant external influences such as those discussed in 'Section 3.1.1 – Drivers'. As such, the maximum levels of efficiency from stakeholder input are unlikely to represent technical limitations to substituting fossil-based feedstocks for bio-based feedstocks, but rather the perceived technical limitations to the market's ability to produce an adequate amount of bio-based feedstock within the prescribed timeframe.

Table 16: Stakeholder engagement findings behind measure 3 maximum level of efficiency

Polymer	Market Share of Virgin Fossil-based Plastic Demand[169]	Maximum Replacement Rate by Polymer[170]	Overall Maximum Replacement Rate
PE	27.4%	2 – 5%	0.5 – 1.4%
PP	18.9%	1 – 4%	0.2 – 0.8%
PVC	13.0%	0%	0%
PS	7.0%	0%	0%
PUR	6.3%	0%	0%
PET	6.1%	3 – 10%	0.2 – 0.6%
Other fossil-based	21.3%	Not applicable	Not applicable
TOTAL	100%	Not applicable	0.9 – 2.8%

The concluding maximum level of efficiency is 1 – 3%. However, it should be noted that figures up to 31% were found over the course of the research given the wide range of interpretation of how the maximum level of efficiency could, or indeed should, be conceptualised. The evidence RAG rating for this level of efficiency is red-amber because there is a lack of consensus between stakeholders and the literature. Stakeholders unanimously voted for ranges lower than what was found in the literature. However, it is worth noting that these stakeholders represented the fossil-based plastics industry, with no representatives of the bio-based plastics industry present.

[169] Plastics Europe (2022). Plastics – The Facts 2022.
[170] Workshop input

3.4.3 Business-as-usual in 2035

According to a 2022 study published in *Nature*, the overall global market share of bio-based plastics is expected to remain low at 2% with a compound annual growth rate of 4% in line with the expected fossil-based growth.[171] The growth rate in Europe, however, is projected to be higher at 10%, mainly driven by upcoming market regulations.[172] The historical compound annual growth rate of bio-based plastic use within the packaging industry based on observed data is also higher than average, at 18%.[173] These figures include the projected share of all bio-based plastics, including biodegradable options. The projected market share of durable bio-based plastics only was not found in the literature, and the growth rate for durable bio-based plastics could be higher or lower than what is presented.

Several major organisations have committed to utilising more sustainable plastics, which is expected to increase future bio-based plastic demand. For example, Nestlé has committed up to $2 billion to develop sustainable plastics technologies such as bio-PET and automotive company Peugeot Citroën SA has pledged to source 20% of its plastics from renewable sources. Additionally, Toyota has committed to purchasing 25% of the bio-PET from Brasem's plant in Brazil despite its 30 – 50% price markup compared to fossil-based PE.[174]

During interviews, one stakeholder stated that the bio-based plastics market could supply enough material to cover 5% of the entire plastics market by 2035. However, during workshops, stakeholders claimed that they believed the trends within the plastics sector were moving away from bio-based feedstocks due to the barriers described in Section 3.3. Stakeholder input from the workshop voting exercise resulted in a 0 – 1.4% BAU level of efficiency by 2035 as shown in Table 17. This varied by polymer, including votes for between 0 – 3% in PE, 0 – 2% in PP, 1 – 4% in PET, and <1% in PVC, PS and PUR.

The overall level of efficiency is presented as 0 – 2% which encompasses findings from both the literature review and the workshop. The evidence rating for this level of efficiency is amber because the consensus of the stakeholders generally matched the figures found in the literature, although with a low level of certainty.

171 Rosenboom et al. (2022). Bioplastics for a circular economy.
172 Rosenboom et al. (2022). Bioplastics for a circular economy.
173 Technavio (2019). Global Bioplastic Packaging Market 2019–2023. Market Report.
174 Chen, J. (2019). Global Markets and Technologies for Bioplastics.

Table 17: Stakeholder input on measure 3 BAU levels of efficiency

Polymer	Market Share of Virgin Fossil-based Plastic Demand[175]	Maximum Replacement Rate by Polymer[176]	**Overall Maximum** Replacement Rate
PE	27.4%	0 – 3%	0 – 0.8%
PP	18.9%	0 – 2%	0 – 0.4%
PVC	13.0%	0%	0%
PS	7.0%	0%	0%
PUR	6.3%	0%	0%
PET	6.1%	1 – 4%	0.1 – 0.2%
Other fossil-based	21.3%	Not applicable	Not applicable
TOTAL	100%	Not applicable	0.1 – 1.4%

[175] Plastics Europe (2022). Plastics – The Facts 2022.
[176] Workshop input

4.0 Measure 4 – Recycled Content in Plastic Products

4.1 Plastics resource efficiency measure

4.1.1 Description

Inclusion of post-consumer recycled content from mechanical or chemical recycling processes in plastic products.

Post-consumer plastic waste can be processed via a mechanical or chemical recycling process. These processes are discussed in detail in 'Section 7.0 – Recycling of Post-Consumer Plastics.' Once plastic waste has been reprocessed it is important that there is demand to incorporate this into new products. This measure is focused on the end markets for recycled plastic and measures the inclusion of *post-consumer* recycled content in the manufacture of new products. This is essential as the end markets drive recycling systems by allowing them to deliver value through their output material.

There is limited data currently available on the average recycled content within plastic products. Most data available describes the distribution of recyclate across the industries as opposed to describing the proportion of recycled content compared to virgin within each industry. For example, in the UK, the construction sector uses the largest proportion of the available recyclate (48%), followed by packaging and home goods (28%).[177] Sectors that utilise more complex, technical plastics make up a lower share of the recycled plastic market such as automotive (2%) and electronics (1%).[178] Recycled content in textiles is out of scope for this measure as the majority of textiles consumed in the UK are not produced domestically, and therefore the UK has limited control over the way these goods are produced. Additionally, recycled content in textiles is covered within the "Unlocking Resource Efficiency: Phase 2 Textiles Report." The British Plastics Federation (BPF) has a partnership agreement to use the Monitoring Recyclates for Europe (MORE) tool to improve the quality of recycled plastic content data in the UK.[179]

Table 18: List of industries applicable to measure 4

Packaging & Household Goods	Construction	Automotives	Textiles	Electronics
Applicable	Applicable	Applicable	Not applicable	Applicable

[177] BPF (2021). British Plastics Federation Recycling Roadmap.
[178] Ibid.
[179] Ibid.

4.1.2 Measure indicator

The indicator selected to measure recycled content in plastic products was **'percent average recycled content'** which is derived by dividing the 'mass of recycled content' by the 'total mass of plastic products' across all sectors. This was the only indicator that was identified for this measure.

4.1.3 Examples in practice

The average level of recycled content varies by industry. Even within the packaging industry itself there is a wide range of applications with differing requirements depending on product specifications. Additionally, food contact regulations prevent certain products, such as those made from PP, from using any recycled content at all. Other applications such as bottles made of PET and HDPE have been made from closed-loop recycled content for years, with some manufacturers adding up to 100% recycled material. The average level of recycled content in the UK bottle market is estimated to be between 15 – 18% for PET bottles and 20 – 25% for HDPE bottles.[180] Other packaging formats, such as thin, multilayer film packs and PP pots, tubs & trays are less capable of achieving high levels of recycled content due to technical challenges in processing recycled content compared to virgin plastic. Film packaging, for example, has a 7% average recycled content in food-grade applications and a 12% average recycled content in non-food grade applications.[181]

The level of recycled content achievable within an application depends on a number of factors, including the aesthetic requirements of the product (e.g., whether the customer will allow haze in the product or whether they require a high level of clarity), performance demands of the product (e.g., impact performance, durability, suitability for use in elevated temperature environments), and the purity of the recyclate used. Recyclate purity is often impacted by features of recycling systems (e.g., hot wash and separate collection will lead to greater purity within recycled material streams) and sorting specificity. Sorting specificity refers to how specifically a material is targeted during the sorting process. While sorting for a specific waste stream allows for recyclate to be used in a wider variety of applications, there is a drawback in that a larger quantity of material is rejected during the sorting process. Additionally, more advanced sorting processes can be more expensive to run than cruder ones. As a result, aiming to incorporate recycled content in high quality applications may lead to an overall lower level of recycled content across the market.

4.2 Available sources

4.2.1 Literature review

The literature review identified 38 sources, used in this report, that discussed recycled content in plastic products. This comprised:

[180] BPF (2021). British Plastics Federation Recycling Roadmap.
[181] WRAP (2020). Plastics Market Situation Report 2021.

- sixteen industry reports[182] [183] [184] [185] [186] [187] [188] [189] [190] [191] [192] [193] [194] [195] [196] [197];
- nine academic papers[198] [199] [200] [201] [202] [203] [204] [205] [206];
- two policy documents[207] [208];
- six technical studies[209] [210] [211] [212] [213] [214]; and
- five website articles[215] [216] [217] [218] [219].

[182] BPF (2021). British Plastics Federation Recycling Roadmap.
[183] WRAP (2020). Plastics Market Situation Report 2021.
[184] WRAP (2022). The UK Plastics Pact Annual Report 2021-2022.
[185] Oakdene Hollins (2021). Driving change: A circular economy for automotive plastic.
[186] ECOS (2021). Too Good To Be True? A Study of Green Claims On Plastic Products.
[187] Circular Plastics Alliance (2020). Circular Plastics Alliance - State of Play on Collection and Sorting: Automotive Working Group.
[188] Circular Plastics Alliance (2020). Circular Plastics Alliance - State of Play on Collection and Sorting: Electronics and Electrical Equipment Working Group.
[189] CEFIC (2022). Chemical Recycling: Delivering recycled content to meet the EU's circular economy ambitions – the Single Use Plastics Directive Implementing Act and the Packaging and Packaging Waste Directive revision.
[190] Plastics Europe (2022). The Circular Economy for Plastics.
[191] Plastics Europe (2023). Plastics – The Facts 2023.
[192] Plastics Europe (2023). Circular Economy for Plastics: United Kingdom – 2020.
[193] Systemiq (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe.
[194] Plastics Europe (2022). Plastics – The Facts 2022.
[195] British Plastics Federation (2020). Recycled content used in plastic packaging applications
[196] Green Alliance (2020). Fixing the system: Why a circular economy for all materials is the only way to solve the plastic problem. (Including Methodology)
[197] Green Alliance (2021). Completing the circle: Creating effective UK markets for recovered resources.
[198] Letcher, T. (2020). Plastic Waste and Recycling: Environmental Impact, Societal Issues, Prevention, and Solutions. Elsevier Academic Press. ISBN:978-0-12-817880-5.
[199] Bauer et al. (2023). Reducing plastic waste through voluntary agreements. Learning from the EU Green Deal implementation.
[200] Zheng, J. and Suh, S. (2019). Strategies to Reduce the Global Carbon Footprint of Plastics. Nature Climate Change. 9, p374-378.
[201] Dormer et al. (2013). Carbon footprint analysis in plastics manufacturing. Journal of Cleaner Production.
[202] Shamsuyeva and Endres (2021). Plastics in the context of the circular economy and sustainable plastics recycling: Comprehensive review on research development, standardization and market. Composites Part C: Open Access. 6, pp1-16.
[203] Van Der Vegt et al. (2022). Understanding Business Requirements for Increasing the Uptake of Recycled Plastic: A Value Chain Perspective. Recycling, 7(42), pp1-17.
[204] Eriksen et al. (2020). Dynamic Material Flow Analysis of PET, PE, and PP Flows in Europe: Evaluation of the Potential for Circular Economy.
[205] Lase et al. (2023). How Much Can Chemical Recycling Contribute to Plastic Waste Recycling in Europe? An Assessment Using Material Flow Analysis Modelling.
[206] Ragaert et al. (2017). Mechanical and chemical recycling of solid plastic waste
[207] UK Government (2023). Plastic Packaging Tax
[208] UK Government (2023). Open consultation: Plastic Packaging Tax - chemical recycling and adoption of a mass balance approach. Published 18 July 2023.
[209] Deloitte (N.D.). How consumers are embracing sustainability.
[210] SCS Standards (2023). Supplemental Criteria for Electrical and Electronic Equipment: SCS-103 Recycled Content Standard Annex A.
[211] ISO (2016). ISO 14021:2016(en) Environmental labels and declarations — Self-declared environmental claims
[212] Google and AFARA (2022). Closing the Plastics Circularity Gap: Full Report.
[213] Viridor (2022). Bridging the Gap: Ending Britain's Reliance on Plastic Waste Export.
[214] Textile Exchange (2022). 2025 Recycled Polyester Challenge: First Annual Report.
[215] The Guardian (2019). War on plastic waste faces setback as cost of recycled material soars.
[216] The Carbon Trust (2022). Can the UK Plastic Tax help decarbonise the packaging industry?
[217] Financial Times (2022). Recycled plastic prices double as drinks makers battle for supplies.
[218] Lets Recycle (2022). High energy costs put plastic recycling 'at risk'.
[219] Apple (2022). Product Environmental Report: iPhone 14 Pro Max.

The relevant sources were generally considered of medium applicability when assessed against the data assessment framework, which recognises the relevance of the sources and the strength of the methodology within each. The sources exhibited an average IAS of 3.6 (out of 5), with 22 sources exhibiting a score of 4 or above. Of the literature reviewed for this measure, 10 sources were UK-specific and 16 were relevant to the European market. Additionally, 37 sources were released over the past ten years.

4.2.2 Interviews

Stakeholders considered recycled content in plastic products to be an important measure for resource efficiency within the plastics sector. However, it was noted that this measure has significant overlap with Measure 7 – Recycling of Post-Consumer Plastics given that recycled content cannot be incorporated without recycling processes in place to provide the necessary materials.

The indicator presented during the interviews was ‘percent post-consumer recycled content in plastic products’ and this did not change throughout the research process. Eight stakeholders engaged with this measure qualitatively and six stakeholders provided quantitative feedback on the levels of efficiency in the interviews.

4.2.3 Workshop

Stakeholders were highly familiar with the concept of recycled content and believed that this measure is highly relevant to resource efficiency. Stakeholders emphasised that the outputs of mechanical and chemical recycling processes are different and that there are different limitations to incorporating each type of recycled content into products. Stakeholders also emphasised the importance of mechanical and chemical recycling systems working synergistically, with chemical recyclers only processing the material that mechanical recyclers are unable to. Additionally, it was noted that legislative drivers for chemical recycling technology and recycled content are both essential requirements to enabling this measure, both of which are highly uncertain. As a result, researchers should take caution in drawing conclusions for any figures presented in isolation, which was taken into consideration when synthesising the research findings. This is apparent as levels of efficiency are presented in the sections below for individual plastics applications and industries. However, only evidence applicable to the full plastics sector was included in developing the levels of efficiency presented in this report.

The level of engagement in the workshop was as follows:

- All six stakeholders were active on the mural board and four stakeholders actively contributed to verbal discussion.

4.3 Drivers & Barriers

The drivers and barriers influencing this measure were identified through a combination of the literature review, stakeholder interviews and sector workshop.

4.3.1 Drivers

Table 19 below shows the main drivers for Measure 4. The most significant drivers are shown in bold as voted for by stakeholders in the workshop.

Table 19: Drivers for plastics sector measure 4

Description	PESTLE	COM-B
Taxes and other regulatory mechanisms	**Political**	**Capability – psychological**
Customer demand	**Social**	**Motivation – reflective**
Voluntary commitments	**Political**	**Motivation – automatic**
Carbon and raw material savings	Environmental	Opportunity – physical
Certification schemes and standards	Legal	Capability – psychological
Cost savings	Economic	Opportunity – physical

Taxes and other regulatory mechanisms

The UK's Plastic Packaging Tax places a tax (currently just over £200 per tonne) on plastic packaging and certain other plastic items which contain less than 30% recycled plastic content. This tax financially incentivises packaging producers to incorporate recycled plastic into their plastic packaging and certain other plastic products. This also drives demand and therefore investment into recycled plastic throughout the supply chain.[220]

Customer demand

The use of recycled content in products is one of several environmental considerations that consumers make when purchasing products. A YouGov survey of more than 2,000 UK adults, for instance, identified that 65% of respondents considered products made of recycled content to be "sustainable" and 23% responded that it was a consideration when purchasing an item.[221] In response to consumer demand for more sustainable and recycled products, producers are setting themselves ambitious recycled content targets for their products. [222] As such, consumer demand for sustainable products, including recycled content, is a driver to increasing recycled plastic in products.

[220] Letcher, T. (2020). Plastic Waste and Recycling: Environmental Impact, Societal Issues, Prevention, and Solutions. Elsevier Academic Press. ISBN:978-0-12-817880-5.
[221] Deloitte (N.D.). How consumers are embracing sustainability.
[222] Ellen MacArthur Foundation (2022). The Global Commitment 2022. Available online.

Voluntary commitments

Setting plastic recycled content targets through voluntary commitments, such as the UK Plastics Pact, is another driver for encouraging packaging producers to incorporate recycled plastic into their packaging. The UK Plastics Pact has set a recycled content target of 30% by 2025. In 2021/22, there was 22% recycled content in packaging produced by the UK Plastic Pact signatories compared with 13.5% in 2018. [223]

Another voluntary commitment relating to recycled plastic content is the “Circular Plastics Alliance”. The Circular Plastics Alliance consists of over 300 signatories from various industries across Europe, such as agriculture, automotive, construction, packaging and textiles. The signatories pledge to ensure that at least 10 million tonnes of recycled plastic content is used in new products placed on the EU market by 2025. Whilst this is a voluntary commitment, there is pressure from the European Commission that should this commitment not be met, then regulatory measures may be introduced.[224]

Carbon and raw material savings

As mentioned earlier in this report, the extraction and polymerisation of fossil-based resources, such as oil, into plastic pellet typically contributes to around 60% of a plastic product’s lifecycle carbon emissions.[225] As such, using recycled plastic content in products can reduce carbon emissions compared with using virgin plastic content.[226] One study, for example, calculated a 24% reduction in carbon emissions by increasing recycled plastic content in PET plastic food trays from 85% to 100%. The study concluded that the use of recycled content had a significant effect on the tray’s lifecycle emissions.[227] Similarly, the use of recycled plastic content in automotive parts can reduce carbon emissions by over 70% for ABS and PP, which are commonly used polymers in the automotive sector.[228]

In addition to potential carbon emission savings, reduced use of raw materials, such as oil, gas and biomass, can be achieved by utilising recycled plastic. These resource savings are not only associated with the plastic material, but also from the resources associated with energy and transportation used for oil extraction through to the production of plastic pellet.

Certification schemes and standards

With risks surrounding greenwashing from producers about the amount of recycled content in their products, certification schemes can be used to independently verify and provide recognisable and consistent messaging about recycled content in a product. This is especially relevant where brand-owners use misleading and/or unverified claims that their products

[223] Wrap (2022). The UK Plastics Pact Annual Report 2021-2022.
[224] Bauer et al. (2023). Reducing plastic waste through voluntary agreements. Learning from the EU Green Deal implementation.
[225] Zheng, J. and Suh, S. (2019). Strategies to Reduce the Global Carbon Footprint of Plastics. Nature Climate Change. 9, p374-378.
[226] The Carbon Trust (2022). Can the UK Plastic Tax help decarbonise the packaging industry?
[227] Dormer et al. (2013). Carbon footprint analysis in plastics manufacturing. Journal of Cleaner Production. 51, pp133-141.
[228] Oakdene Hollins (2021). Driving change: A circular economy for automotive plastic.

contain recycled plastic content. For instance, one study reviewed environmental claims featured on 82 different plastic products, including clothing and packaging. Sixteen products claimed to contain recycled plastic content, of which 13 were not supported by recognised standards, trusted labels or independent verification. The authors added that there was a lack of clarity on the source of the recycled plastic content (i.e., post-consumer or post-industrial – plastic waste from manufacturing and other industrial processes) and to what extent the product contained recycled plastic.[229]

An example of recycled plastic content certification is the SCS Standards in the USA. The SCS Standards includes a certification and labelling standard for electrical and electronic equipment meeting or exceeding certain minimum recycled plastic content rates. The standard includes achievable plastic recycled content levels for various polymers, which was developed with major stakeholder groups.[230] Another example is ISO 14021 on environmental labels and declarations, in which requirements for use of recycled plastic content from post-consumer and post-industrial waste (plastic waste from manufacturing and other industrial processes) are defined.[231] As such, the use of certification schemes and standards for recycled content should improve consistency and assurance regarding recycled plastic content in products.

Cost savings

Using recycled plastic content in plastic products can reduce costs relating to oil extraction through to the production of plastic pellet, with the majority of virgin plastic costs being the fossil-based feedstock (i.e., the oil or gas).[232] The overall cost difference between recycled plastic content and virgin plastic content is dependent on multiple factors, such as market conditions and demand for recycled plastic, oil and energy prices and the desired plastic quality.[233] In the automotive sector, for instance, recycled plastic content can cost around 10% less than virgin plastic,[234] with one case study example showing a 40% cost saving by using a blend of post-consumer and post-industrial (plastic waste from manufacturing and other industrial processes) recycled plastic content for interior trim.[235] One study modelled the global average cost per tonne for virgin versus recycled plastic content from 2019 to 2040 for six polymers. Under all scenarios, including business-as-usual, it was estimated that by 2040, recycled plastic content would cost substantially less than virgin plastic content.[236]

As discussed in the barriers section, recycled plastic content does not always cost less than virgin fossil-based plastic, especially for high quality plastic content, such as for food-grade packaging applications. With technological advances in plastic recycling and the recent

[229] ECOS (2021). Too Good To Be True? A Study of Green Claims On Plastic Products.
[230] SCS Standards (2023). Supplemental Criteria for Electrical and Electronic Equipment: SCS-103 Recycled Content Standard Annex A.
[231] ISO (2016). ISO 14021:2016(en) Environmental labels and declarations — Self-declared environmental claims (Type II environmental labelling).
[232] Google and AFARA (2022). Closing the Plastics Circularity Gap: Full Report.
[233] Shamsuyeva and Endres (2021). Plastics in the context of the circular economy and sustainable plastics recycling: Comprehensive review on research development, standardization and market. Composites Part C: Open Access. 6, pp1-16.
[234] Oakdene Hollins (2021). Driving change: A circular economy for automotive plastic.
[235] Van Der Vegt et al. (2022). Understanding Business Requirements for Increasing the Uptake of Recycled Plastic: A Value Chain Perspective. Recycling, 7(42), pp1-17.
[236] Google and AFARA (2022). Closing the Plastics Circularity Gap: Full Report.

introduction of the UK's Plastic Packaging Tax, which places a tax of currently just over £200 per tonne for plastic packaging with under 30% recycled content,[237] it is hoped that the cost of recycled plastic content may become increasingly competitive than that of virgin fossil-based plastic.

4.3.2 Barriers

Table 20 below shows the main barriers for Measure 4. The most significant barriers are shown in bold as voted for by stakeholders in the workshop.

Table 20: Barriers for plastics sector measure 4

Description	PESTLE	COM-B
Availability of recycled material	**Technological**	**Opportunity – physical**
Price volatility	**Economic**	**Opportunity – physical**
Technical barriers	Technological	Opportunity – physical
Regulatory uncertainty around recycled content calculations	Legal	Capability – psychological

Availability of recycled material

Although it fluctuates based on market conditions, the availability of recycled plastic content is generally limited, with demand often exceeding supply. Reasons for the limited availability of recycled plastic content include low recycling rates from consumers, losses of plastic recyclate through the waste management system and difficulties in recovering plastic from mixed material products.[238] Additionally, the export of plastic waste from the UK to low-income countries, which can lack sufficient recycling infrastructure, reduces confidence in the exported plastic waste being recycled. Plastic waste is generally exported due to a lack of plastic recycling infrastructure in the UK combined with low costs offered for recycling plastic in other countries. For instance, it is estimated that the UK has a plastic waste recycling capacity of 0.9Mt per annum. For plastic packaging waste, 1.1Mt per annum is sorted and available for recycling, of which 0.6Mt is recycled in the UK and 0.5Mt is exported for recycling. [239] As such, there is an opportunity to recycle this exported plastic waste in the UK. During workshop discussions one stakeholder noted that achieving 50% average recycled content within the UK plastics industry would require £1.8 billion investment in the recycling system.

[237] UK Government (2023). Plastic Packaging Tax.
[238] Letcher, T. (2020). Plastic Waste and Recycling: Environmental Impact, Societal Issues, Prevention, and Solutions. Elsevier Academic Press. ISBN:978-0-12-817880-5.
[239] Viridor (2022). Bridging the Gap: Ending Britain's Reliance on Plastic Waste Export.

In the automotive sector, vehicles are not commonly designed for dismantling. As such, shredders are commonly used. However, sorting plastic from the shredded material is not currently cost-effective. As such, much of the plastic from end-of-life vehicles is incinerated or landfilled, and so cannot be recycled into new products. [240] As for waste electrical and electronic equipment, only one-third of appliances are recovered through appropriate recycling routes in Europe. Additionally, the quality of plastic from waste electrical and electronic equipment is low, meaning the plastic is often downgraded to lower value products, such as plant pots. Because of these limitations, it is estimated that only 1% of plastic used for electricals and electronic equipment is closed-loop recycled content (i.e., recycled back into electrical and electronic plastics).[241]

Similarly, the availability of sufficient quality plastic is limited, with the demand for food-grade recycled plastic exceeding its availability. Recycled food-grade PP, for instance, is in demand from packaging producers. However, the absorbent characteristics of PP make it difficult and costly to remove contaminants (such as odour and chemical components) to allow it to be used for food-contact use.[242] As such, the availability and cost of good quality (and often requiring closed-loop) recycled plastic are barriers facing uptake of recycled plastic content.

Price volatility

The cost difference between virgin plastic and recycled plastic can vary depending on supply and demand rates of recycled plastic, energy costs (which are highly influential on the cost of recycling processes) and the market price of fossil-based resources, such as oil and gas, affecting virgin plastic. The increasing demand for recycled plastic for packaging across Europe, for instance, has resulted in rising recycled plastic prices, with some recycled plastic costing more than virgin plastic.[243] The cost difference will also depend on the polymer and the required quality of the recycled plastic, which can require certain processing and treatments – for example, for food-contact packaging[244] or meeting certain aesthetic requirements.[245] Finally, energy prices can have major impacts on recycled plastic costs. Energy costs have been rapidly increasing in recent years, especially for electricity, and have had detrimental impacts on European plastic recycling facilities since processing equipment is often powered by high-voltage electricity. Plastic Recyclers Europe reported that, before the energy price rises in 2022, the European plastic recycling facilities' operating costs were mostly for energy, labour and maintenance, with energy accounting for roughly 15-20%. However, the increase in energy prices in 2022 meant that energy costs now account for around 70% of operating costs. Some facilities have suspended operations because of these high costs.[246]

---

[240] Circular Plastics Alliance (2020). Circular Plastics Alliance - State of Play on Collection and Sorting: Automotive Working Group.
[241] Circular Plastics Alliance (2020). Circular Plastics Alliance - State of Play on Collection and Sorting: Electronics and Electrical Equipment Working Group.
[242] Letcher, T. (2020). Plastic Waste and Recycling: Environmental Impact, Societal Issues, Prevention, and Solutions. Elsevier Academic Press. ISBN:978-0-12-817880-5.
[243] Financial Times (2022). Recycled plastic prices double as drinks makers battle for supplies.
[244] Letcher, T. (2020). Plastic Waste and Recycling: Environmental Impact, Societal Issues, Prevention, and Solutions. Elsevier Academic Press. ISBN:978-0-12-817880-5.
[245] Oakdene Hollins (2021). Driving change: A circular economy for automotive plastic.
[246] Let's Recycle (2022). High energy costs put plastic recycling 'at risk'.

Technical barriers

As mentioned above, the availability of high quality recycled plastic content is limited. For example, thermoset plastics cannot be broken down through mechanical recycling processes in the way that thermoplastics can. Additionally, issues impacting the quality of recycled plastic include the presence of contaminants which require removal from the recycled plastic material, and thermal or mechanical properties which can be degraded when it has been used and treated as waste. As such, the suitability of plastic for high value products, such as food-grade packaging and vehicle body panels, can present a barrier to recycled plastic content. In the automotive sector, post-industrial plastic waste (plastic waste from manufacturing and other industrial processes) can retain around 90% of the plastic's mechanical properties, allowing it to be used without any modifications. However, post-consumer plastic waste often requires modifications to meet certain structural, heat resistant, aesthetic and even odour requirements.[247] As such, meeting certain quality requirements will depend on the choice and use of recycled plastic, which can also be impacted by availability and cost, compared with virgin plastic.

Regulatory uncertainty around chain of custody models and recycled content calculations

The accounting of recycled plastic content in plastic products involves determining the proportion (by weight) of recycled plastic content within a plastic product. This approach is used for calculating recycled plastic content for the UK's Plastics Packaging Tax in order to determine whether the plastic packaging components exceed the 30% minimum recycled content requirement. However, whilst these calculations are relatively straight forward for recycled plastic content from mechanical recycling, the approach for recycled plastic content from chemical recycling is difficult, since the recycled content cannot be distinguished from virgin content. As of September 2023 a consultation is underway by the UK Government to determine whether and how a mass balance approach could be applied for calculating chemically recycled plastic content in plastic packaging.[248] Similarly to what is happening in the UK, the approach used for calculating recycled plastic content in plastic products under the EU's Circular Economy Action Plan and its related targets has been questioned, with a mass balance approach being proposed as one solution.[249] As such, the role of chemical recycling in the production of recycling plastic content may be largely dependent on the calculations used in UK and European plastic legislation.

[247] Oakdene Hollins (2021). Driving change: A circular economy for automotive plastic.

[248] UK Government (2023). Open consultation: Plastic Packaging Tax - chemical recycling and adoption of a mass balance approach. Published 18 July 2023.

[249] CEFIC (2022). Chemical Recycling: Delivering recycled content to meet the EU's circular economy ambitions – the Single Use Plastics Directive Implementing Act and the Packaging and Packaging Waste Directive revision.

4.4 Levels of efficiency

Table 21: Levels of efficiency for plastics sector measure 4

Indicator: % average recycled content			
Level of efficiency	Current	Maximum in 2035	Business-as-usual in 2035
Value	7 – 13%	37 – 61%	19%
Evidence RAG	Amber-Green	Amber	Red

4.4.1 Current level of efficiency

The literature review identified an average level of recycled content across plastics products in all sectors to be between 7 – 13%. This level of efficiency was determined through an evaluation of five different literature sources, one which was specific to the UK market and four of which focus on the European market more broadly but likely with general applicability to the UK market due to overlap in packaging production supply chains. A report from Plastics Europe utilising 2020 data found 7% post-consumer recycled plastics in plastics products within the UK specifically.[250] A second industry report from Plastics Europe utilising 2020 data from various databases including Eurostat, EPR and interview data found a similar average recycled content in Europe of 8.5%[251] while another more recent Plastics Europe report utilising 2022 data found that the average post-consumer recycled content in Europe had risen to 12.9% excluding textiles, adhesives and coatings.[252] Another source performing a dynamic material flow analysis of PET, PE and PP in Europe reported 12% closed loop recycled content across these polymers specifically in Europe[253] and an analysis by SystemIQ of European plastics material flows based on available academic and industry data found an average recycled content of 8%.[254]

Stakeholder votes were generally consistent with the level of efficiency found in the literature regarding specific applications. However, stakeholders expressed a limited ability to comment on the current level of efficiency across all plastics industries given the scope of their expertise. As a result, some stakeholders voted to comment only on recycled content found within individual applications. A summary of the current level of recycled content incorporated within particular industries and applications is found in Appendix E. These levels of efficiency were not used to inform the reported current level of efficiency across the entire plastics sector as the current level of efficiency is covered reasonably well in the literature and any assumptions

[250] Plastics Europe (2023). Circular Economy for Plastics: United Kingdom – 2020.
[251] Plastics Europe (2022). The Circular Economy for Plastics.
[252] Plastics Europe (2023). Plastics – The Facts 2023.
[253] Eriksen et al. (2020). Dynamic Material Flow Analysis of PET, PE, and PP Flows in Europe: Evaluation of the Potential for Circular Economy.
[254] Systemiq (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe.

applied to the figures below run the risk of misinterpreting the findings. However, these are included below as they are useful to understand which industries in particular are driving the majority of the overall recycled content across the plastics sector today.

The evidence RAG rating for this level of efficiency is amber-green as this measure is documented well in the literature and stakeholders generally did not disagree with the range presented. However, in the workshop, stakeholders expressed limited confidence when voting on the overarching level of efficiency across the plastics sector.

4.4.2 Maximum level of efficiency in 2035

The maximum level of recycled content across plastics products in all sectors is estimated to be between 37 – 61% based on a review of three literature sources and feedback from stakeholders during the workshop. Heavier weight was placed on findings from the literature sources as stakeholders expressed a high level of uncertainty when asked to validate the figures found in the literature. An analysis by SystemIQ modelling an alternate circularity scenario in Europe found that while 92% of plastic is currently sourced from virgin feedstock, this could reduce to 63% by 2030 and 41% by 2050.[255] This trajectory suggests a 37% average recycled content by 2035 assuming a linear progression from 2030 to 2050. Results from the dynamic material flow analysis of PET, PE and PP referenced above estimated that a more circular system could lead to 46% average recycled content in Europe through closed loop recycling.[256] A third study performed a material flow analysis of how much chemical recycling could contribute to plastic waste recycling in Europe by 2030. This was based on five scenarios using varied technological advancements and recycling processes and resulted in between 38 – 61% average recycled content.[257]

Stakeholders again expressed a limited ability to comment on the maximum level of efficiency given the scope of their expertise and the wide range of uncertainty at play. As a result, only two stakeholders opted to provide a range representing the plastics sector, resulting in one vote for <40% with medium confidence and one between 40 – 60% with low confidence. Most stakeholders elected to specify levels of efficiency within specific polymers and applications, such as polyolefins in packaging (10 – 15% with medium confidence), automotives and construction (15 – 25% with medium confidence) and PET in packaging (>60% with high confidence). Based on discussions, these figures likely relate strictly to the incorporation of mechanically recycled content in products and that chemically recycled material is virtually identical in terms of properties to virgin material, so presumably the maximum level of efficiency including chemically recycled content would be somewhat higher depending on recycled material availability than the levels expressed during voting.

A summary of the maximum level of recycled content thought possible to incorporate within particular industries and applications is found in Appendix E. These levels of efficiency were not used to inform the reported maximum level of efficiency across the entire plastics sector,

[255] Systemiq (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe.
[256] Eriksen et al. (2020). Dynamic Material Flow Analysis of PET, PE, and PP Flows in Europe: Evaluation of the Potential for Circular Economy.
[257] Lase et al. (2023). How Much Can Chemical Recycling Contribute to Plastic Waste Recycling in Europe? An Assessment Using Material Flow Analysis Modelling.

but are included as they are useful to understand which industries have the greatest scope for improvement compared to the current level of efficiency within industries.

The evidence RAG rating for this level of efficiency is amber as this measure is documented in the literature albeit with some uncertainty due to the literature focusing on Europe as opposed to the UK specifically, and the variations within possible future scenarios. Stakeholders did not express disagreement with the levels of efficiency found in the literature, but again expressed limited confidence when voting on the overarching maximum level of efficiency across the plastics sector.

4.4.2 Business-as-usual level of efficiency in 2035

As was the case in the current and maximum levels of efficiency, many data points were available within specific applications and industries. However, these levels of efficiency were not easily combined as the data gathered reported BAU levels of efficiency inconsistently. For example, one source reported a BAU level of efficiency across the entire packaging industry[258], while others reported figures for specific polymers[259] (e.g., PET, HDPE), applications[260] (e.g., C&I films, bottles), or subsets of polymers[261] (e.g., HDPE excluding food-grade applications). Therefore, the BAU level of efficiency was taken from the only source found in the literature that provided a single figure that applies to the plastics industry as a whole.[262] This source was a recent study that modelled five scenarios of plastics recycling in Europe based on various technological advances. Specifically, the BAU level of efficiency used the modelled scenario 1, which considered an improvement in waste collection rate, sorting and mechanical recycling in 2030 towards breakthrough of currently known best practices in 2022. This study suggests that 19% recycled content could be achieved across the market, with the average varying by industry (e.g., 13% within packaging, 22% within building and construction, 6% within automotive, 3% within electronics).

During the workshop, stakeholders felt unable to vote on the BAU level of efficiency across the plastics sector as a whole. Of the stakeholders who participated, six voted for a BAU level of efficiency of <40% with medium to high confidence, specifying that this was likely to fall between 5 – 20% depending on the application. For example, one stakeholder voted for a range of 5% recycled content within thin film applications and another voted for between 10 – 20% for polyolefins within the construction industry. However, due to the stakeholders' inability to vote across the sector as a whole, the level of efficiency was taken from the literature. The evidence RAG rating for this efficiency level is red, reflecting the fact that this level of efficiency was taken from a single literature source and the lack of ability for stakeholders to comment on the level of efficiency across the plastics sector.

---

[258] Lase et al. (2023). How Much Can Chemical Recycling Contribute to Plastic Waste Recycling in Europe? An Assessment Using Material Flow Analysis Modelling.
[259] British Plastics Federation (2020). Recycled content used in plastic packaging applications
[260] Ibid.
[261] Interview.
[262] Lase et al. (2023). How Much Can Chemical Recycling Contribute to Plastic Waste Recycling in Europe? An Assessment Using Material Flow Analysis Modelling.

Once again, a breakdown of the BAU level of recycled content incorporation within particular industries and applications is found in Appendix E. This was not used to calculate the total BAU level of efficiency for the reasons stated above.

5.0 Measure 5 – Waste Reduction in Product Manufacturing

5.1 Plastics resource efficiency measure

5.1.1 Description

The reduction of plastic waste generated during the manufacturing of plastic products.

This measure looks at the generation of plastic waste during the manufacturing process. Reduction of manufacturing waste reduces cost while improving resource efficiency. For the purposes of this measure, material is defined as waste if it is sent for treatment offsite. Plastic scrap that is fed back into the manufacturing process is not considered waste as it does not meet the criterion of offsite treatment.

Table 22: List of industries applicable to measure 5

Packaging & Household Goods	Construction	Automotives	Textiles	Electronics
Applicable	Applicable	Applicable	Applicable	Applicable

5.1.2 Measure indicator

The indicator selected to measure waste reduction in product manufacturing was **'percentage of plastic produced during the manufacturing process that is wasted'** which is derived by dividing the 'mass of plastic waste sent offsite for treatment' by the 'mass of plastic products produced'. This was the only indicator considered for this measure.

5.1.3 Examples in practice

Plastics manufacturing processes all produce scrap material. This can originate from defective parts that are rejected during the quality control process (e.g., a leaking bottle) or waste generated during the extrusion or moulding processes such as head waste, tails, moils, runners, flashings and startup scrap. This material has the potential to become waste treated offsite in the same process as other industrial plastic waste. However, the majority of this scrap is recaptured to be reground and fed back into the manufacturing process according to stakeholder interviews.

Manufacturing of plastic products happens via a moulding process such as extrusion, injection or blow moulding to form the plastic into the desired shape. These processes often cause a certain amount of plastic material to be processed without ending in in a final product. For example, when bottles are produced via blow moulding, excess material referred to as 'flash' is created when the mould closes around the parison. Material at the bottom ('tail') and top ('moil') must be trimmed and is typically removed upon mould release or at a later stage in production. There are also startup scraps created as unusable products are produced while the machine warms up. First time yield varies according to the processing technology but is typically upwards of 90% according to one stakeholder. However, the stakeholder also clarified that the scrap material is typically fed back into the process. The exception is if any of this material touches the floor or any other unintended surface, in which case it is often wasted for quality control purposes.

Lean manufacturing guidance

Another example is lean manufacturing, which involves improving efficiencies in a business, maximising production and minimising waste. The Lean Six Sigma approach is one example of lean principles for the manufacturing sector. This requires analysing, identifying and adjusting manufacturing processes to improve production efficiencies, reduce product defects and ultimately reduce waste. It involves a five-step process: 1) Define the problem; 2) Measure the problem; 3) Analyse the problem; 4) Improve the process; 5) Control the process. This is commonly referred to as the "DMAIC" process. Various manufacturing processes that can produce product defects and waste are analysed, including over-processing and over-producing products.[263] In terms of plastic manufacturing, Lean Six Sigma has been found to reduce plastic waste by minimising defects on the produced plastic products. For instance, one study used Lean Sigma Six to reduce plastic waste at a manufacturing facility that produced PVC drainage parts, using an injection moulding process. By adopting the DMAIC process, it was found that defects (such as bubbles and excess plastic "flash") resulted in 18% of the PVC drainage parts being rejected. By adjusting the injection speed, pressure and temperature, among other interventions, the rejection rate reduced to 7%.[264]

5.2 Available sources

5.2.1 Literature review

The literature review identified 3 sources that discussed waste reduction in product manufacturing. This comprised:

- two academic papers [265] [266]; and

[263] Mishra et al. (2015). Six Sigma Methodology In A Plastic Injection Molding Industry: A Case Study. International Journal of Industrial Engineering and Technology, 7(1), pp15-30.
[264] Alshammari et al. (2018). Quality Improvement in Plastic Injection Molding Industry: Applying Lean Six Sigma to SME in Kuwait. Proceedings of the International Conference on Industrial Engineering and Operations Management Bandung, Indonesia.
[265] Mishra et al. (2015). Six Sigma Methodology In A Plastic Injection Molding Industry: A Case Study. International Journal of Industrial Engineering and Technology, 7(1), pp15-30.
[266] Alshammari et al. (2018). Quality Improvement in Plastic Injection Molding Industry: Applying Lean Six Sigma to SME in Kuwait. Proceedings of the International Conference on Industrial Engineering and Operations Management Bandung, Indonesia.

- one website article[267].

The relevant sources were generally considered of medium applicability when assessed against the data assessment framework, which recognises the relevance of the sources and the strength of the methodology within each. The sources exhibited an average IAS of 3.0 (out of 5), with 1 source exhibiting a score of 4 or above. Of the literature reviewed for this measure, 1 source was UK-specific and all sources were recent studies from within the last 10 years. The impacts of the relatively low level of evidence identified in the literature review for this measure are discussed in ‘Section 5.4 – Levels of efficiency.’

5.2.2 Interviews

Stakeholders considered this measure as relevant to resource efficiency within the plastics sector, but as having a lower priority than other measures. They recognised that there might be room for improvement in waste reduction in product manufacturing but that many operators have already implemented measures to reduce plastic waste. From their perspective, there is not a compelling reason to drive further improvement in this regard because waste levels are very low and resource efficiency has likely already been maximised. The indicator presented during interviews was ‘percent of pre-consumer plastic waste generated from product manufacturing’. The wording of this indicator was amended post-workshop for clarity while the meaning of the indicator was meant to stay the same. Only one stakeholder engaged with this measure either qualitatively or quantitatively as most stakeholders focused discussion on other measures perceived to have greater relevance to resource efficiency improvements within the sector.

5.2.3 Workshop

Stakeholders were familiar with the concept of waste reduction within manufacturing processes and engaged in discussion on the definition of waste as it relates to this measure. During the workshop it was agreed that this measure would use the legal definition of waste, and that plastic byproducts that are fed back into the system are excluded. Overall stakeholders felt this measure was less relevant as a maximum level of efficiency has likely already been reached.

The level of engagement in the workshop was as follows:

- All six stakeholders were active on the mural board and four stakeholders actively contributed to verbal discussion.

5.3 Drivers & Barriers

The drivers and barriers influencing this measure were identified through a combination of the literature review, stakeholder interviews and sector workshop.

[267] Kent, R. (2022). Sustainability management in plastics processing.

5.3.1 Drivers

Table 23 below shows the main drivers for Measure 5. The most significant drivers are shown in bold as voted for by stakeholders in the workshop.

Table 23: Drivers for plastics sector measure 5

Description	PESTLE	COM-B
Lower input material required per tonne of output	**Economic**	**Opportunity – physical**
Reduction in energy consumption and other environmental impacts	**Economic / Environmental**	**Opportunity – physical**

Lower input material required per tonne of output

Manufacturers are driven to reduce waste to minimise economic losses. Improved optimisation technologies and processes aim to reduce waste and improve raw material resource efficiency, which in turn reduces raw material and waste management costs for businesses. This is particularly true for the manufacturing of plastics products where, according to a stakeholder interview, the cost of raw material makes up 80% of the total cost of production and margins are only around 5%.

Reduction in energy consumption and other environmental impacts

As discussed in the driver above, waste reduction during product manufacturing results in an improved yield. This reduces overall manufacturing energy consumption and associated cost and greenhouse gas emissions associated with energy use per unit of output. A reduction in waste also leads to a reduction in the environmental impacts associated with energy and transportation used for oil extraction through to the production of raw plastic material.

5.3.2 Barriers

Table 24 below shows the main barriers for Measure 5. The most significant barriers are shown in bold as voted for by stakeholders in the workshop.

Table 24: Barriers for plastics sector measure 5

Description	PESTLE	COM-B
Efficiency nearly maximised	**Technological**	**Opportunity – physical**
Regulatory hurdles	**Legal**	**Capability – psychological**
Performance tracking & monitoring	Technological	Capability – physical
Cost of process change	Economic	Opportunity – physical

Efficiency nearly maximised

The use of plastic in product manufacturing is already considered to be very effective and efficient due to the longstanding economic drivers to develop efficient processes. As a result, the current level of efficiency is already very high, and it is difficult to make any further improvements from a technical perspective unless a fundamental change in processing practices were to occur.

Regulatory hurdles

In some cases, regulations exist around what types of material can get fed back into the product manufacturing process to ensure quality standards within the industry. This is particularly the case for contact sensitive applications such as food packaging and cosmetics. For example, any scrap that has touched the ground cannot be fed back into the process while maintaining a contact sensitive quality designation. These sets of rules act as a necessary barrier to increasing the amount of plastic that gets fed back into the process in order to ensure quality and safety of products.

Performance tracking & monitoring

There was a lack of data relating to manufacturing plastic waste to set baselines and forecast resource savings. As such, a key barrier relates to the lack of publicly available performance indicators and plastic waste data from manufacturing facilities. During interviews, stakeholders confirmed that plastic waste performance data is recorded internally within manufacturing facilities, however this is not typically made publicly available or shared between organisations.

Cost of process change

Changes to manufacturing processes to minimise plastic waste (such as those identified through lean manufacturing processes) may incur large capital and operational costs. This may be from adding new manufacturing equipment or other systems to increase efficiencies and reduce plastic waste. Cost may be a particularly relevant barrier in the current economic climate, with high inflation rates and energy costs.

5.4 Levels of efficiency

Table 25: Levels of efficiency for plastics sector measure 5

Indicator: % of plastic produced during the manufacturing process that is wasted			
Level of efficiency	Current	Maximum in 2035	Business-as-usual in 2035
Value	0 – 1%	0 – 1%	0 – 1%
Evidence RAG	Green	Amber	Amber

5.4.1 Current level of efficiency

The rate of generation of post-industrial scrap varies significantly by process. For example, injection moulding has an average first-time yield (FTY) of 94%, extrusion has an average FTY of 96% and blow moulding has an average FTY of 70%.[268] However, FTY only measures the rate of waste generation, not the percentage of waste generation that is sent offsite for reprocessing. While this data is not readily available, expert interviews revealed that essentially 100% of plastic scrap is currently fed back into the process. The only situations in which this is not the case is where accidents result in plastic scrap dropping on the floor, or in the very few manufacturing facilities that do not have the capacity to regrind the scrap themselves. To account for these highly uncommon scenarios, the range is presented as between 0 – 1%.

This figure was validated by stakeholders during the workshop. Of the stakeholders who voted, three voted for a current level of efficiency of <0.5% with high confidence and three voted for a current level of efficiency of between 0.5 – 1% (two high confidence, one medium confidence). The evidence RAG rating for this efficiency level is green, given this measure has a longstanding history of measurement within the plastics manufacturing sector and the consensus of the stakeholders.

5.4.2 Maximum level of efficiency in 2035

No literature data were available to estimate a maximum efficiency level for this measure. Stakeholders generally agreed that this measure is likely to be optimised as far as possible within the plastics sector, with only limited potential for improvement. Of the stakeholders who voted, three voted for a maximum level of efficiency of <0.5% (two high confidence, one medium confidence), two voted for a maximum level of efficiency of between 0.5 – 1% (one high confidence, one medium confidence), and one voted for a maximum level of efficiency of >1% (high confidence). In the absence of data from the literature but with general agreement amongst stakeholders that the maximum level of efficiency for this measure is between 0 – 1%, the evidence RAG rating for this efficiency level is amber.

[268] Kent, R. (2022). Sustainability management in plastics processing.

5.4.3 Business-as-usual in 2035

Similar to the maximum level of efficiency, there was no available literature data to estimate a BAU level of efficiency for this measure and only one stakeholder gave an indicative value during interviews. However, the stakeholder interviewed was deemed to have a high level of knowledge on the topic, being an expert in the plastics manufacturing field. Stakeholders agreed there would be limited room for improvement during the workshop. Of the stakeholders who voted, five voted for a BAU level of efficiency of between 0.5 – 1% with high or medium confidence, and one voted for a BAU level of efficiency of <0.5% with high confidence. Therefore, again a range of 0 – 1% is suggested for the BAU scenario. Despite stakeholder consensus, this range is not supported by literature and as a result, the evidence RAG rating for this efficiency level is categorised as amber.

This research has estimated the current, maximum and business as usual levels of efficiency for this measure to be within the 0-1% range, indicating that there is limited room for further improvement in this measure.

6.0 Measure 6 – Reuse of Plastic Products

6.1 Plastics resource efficiency measure

6.1.1 Description

Increase in the utilisation of plastic products that are placed on the market to accomplish multiple rotations of being refilled or reused for the same purpose for which they were conceived.

This measure focuses on the scaling up of reuse models to drive resource efficiency and waste reduction. This is done by effectively decoupling product utility from material use. The measure is intended to deliver the equivalent utility on each use. Additionally, reuse strategies must not involve redesign of the product to include alternative materials to increase reusability (e.g., glass bottles in place of plastic bottles) in order to avoid double counting alongside the material substitution measure.

From a carbon perspective, single-use products tend to carry a larger footprint than reusable products made from the same material. However, the actual reduction in emissions is dependent on the number of times the item is reused. This is addressed further in 'Section 6.3 – Drivers & Barriers.'

For the purposes of this study, reuse was deemed a relevant measure for the packaging & household goods and automotive sectors. Textiles are considered out of scope for the reuse measure as much textiles waste is generated before the end of its usable lifespan and, as such, reuse within the textiles sector is mostly centred around a reduction in consumption. Additionally, interventions looking at increasing the longevity of textile products are covered within the 'Unlocking Resource Efficiency: Phase 2 Textiles Report'. Reuse in the construction sector is reliant on upstream interventions such as design for reuse, modular building design and standardisation of components. However, many of these have limited impact on circularity of construction plastics before 2050, let alone 2035 given the long lifespan of plastics within the construction sector. As a result, reuse within the construction sector is also out of scope of this report. Additionally, the reuse of plastic components within electronics is out of scope of this report to avoid double counting as the reuse, repair and remanufacture of electricals is covered in the 'Unlocking Resource Efficiency: Phase 2 Electricals Report'.

Table 26: List of industries applicable to measure 6

Packaging & Household Goods	Construction	Automotives	Textiles	Electronics
Applicable	Not applicable	Applicable	Not applicable	Not applicable

6.1.2 Measure indicator

The indicator selected to measure reuse of plastic products was '**percent reduction in plastic demand compared to 2023 levels'** which is defined as the percentage reduction in plastics produced in the sector – overall required to meet the same plastics utility. This indicator demonstrates how much resource could be saved by 2035, compared to a 2023 baseline.

Other indicators that were identified but not selected included:

- percent increase in return/rotation rate of reusable plastic products; and
- percent increase in lifespan of plastic products.

These indicators were not selected as they do not give a direct measure for the reduction in plastic use across the sectors.

6.1.3 Examples in practice

Packaging & Household Goods

The concept of reuse models for packaging is growing in popularity. The Ellen MacArthur Foundation has identified four types of reuse models for packaging that involve both refill and return schemes for packaging and established retailers are piloting reusable packaging systems.[269] Three application groups in particular represent the majority of the reduction potential of reuse models and systems[270]:

- Beverage bottles: shared systems for reusable bottles and scaling refill at home solutions (e.g., SodaStream, Muuse);
- Transport packaging: utilising reusable alternatives for transport of goods (e.g., EnviroWrap) and e-commerce (e.g., RePack); and
- Refills for home care and non-food contact groceries: implementing a smart shopping experience with in-store refill delivery models (e.g., Algramo), reusable packaging (e.g., Loop, MIWA) and packaging-free home delivery solutions (e.g., Everdrop).

Household goods are more limited in their potential for increasing reuse compared to packaging products as a greater proportion are reusable by nature.

Automotive

There is an opportunity for reduction of plastic demand within the automotive sector through the development of standardised plastic component design and a higher degree of modularity in vehicles. These components could then be refurbished and reused via a resale channel for used parts. Similar to the construction sector, the preservation of these materials is also dependent on non-destructive dismantling processes. These models also require technical

[269] The Ellen MacArthur Foundation (2019). Reuse – Rethinking Packaging.
[270] SystemIQ (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe.

specifications for parts to remain static or become more flexible for non-safety critical components so they can be reused over multiple lifespans of vehicles.

During workshop discussions on this measure, stakeholders shared that they have noticed a trend in the market where certain automotive components (e.g., air intakes, air boxes) are sent for repair separate from the rest of the vehicle. This has served as an opportunity for automotive and electronics companies to develop partnerships to provide this service offering to customers. However, stakeholders noted that these types of business models are currently limited to non-cosmetic automotive components.

6.2 Available sources

6.2.1 Literature review

The literature review identified 28 sources, used in this report, that discussed reuse of plastic products. This comprised:

- seven industry reports[271] [272] [273] [274] [275] [276] [277];
- eight academic papers[278] [279] [280] [281] [282] [283] [284] [285];
- one doctorate thesis[286];

[271] The Ellen MacArthur Foundation (2019). Reuse – Rethinking Packaging.
[272] SystemIQ (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe.
[273] Wrap (2022). The UK Plastics Pact Annual Report 2021-2022.
[274] The Ellen MacArthur Foundation (2022). The Global Commitment 2022: Progress Report.
[275] Tesco (2022). Use. Reuse. Repeat. Sharing Learnings on Reusable Packaging. Tesco Reuse Report 2022.
[276] Reloop & Zero Waste Europe (2020). Reusable vs Single-Use Packaging. A Review of Environmental Impacts.
[277] Plastics Europe (2023). Circular Economy for Plastics: United Kingdom – 2020.
[278] Coelho et al. (2020). Sustainability of Reusable Packaging – Current Situation and Trends. Resources, Conservation & Recycling. 6, pp1-11.
[279] Albrecht et al. (2013). An extended life cycle analysis of packaging systems for fruit and vegetable transport in Europe. The International Journal of Life Cycle Assessment. 18, pp1549-1567.
[280] Koskela et al. (2014). Reusable plastic crate or recyclable cardboard box? A comparison of two delivery systems. Journal of Cleaner Production. 69, pp83-90.
[281] Zhu et al. (2022). Packaging Design for the Circular Economy: A Systematic Review. Sustainable Production and Consumption. 32, pp817-832.
[282] Silva et al. (2020). Rethinking and Optimizing plastic waste management under COVID-19 pandemic: Policy solutions based on redesign and reduction of single-use plastics and personal protective equipment. Science of the Total Environment. 742, pp1-8.
[283] Winton et al. (2022). Drivers of public plastic (mis)use — New insights from changes in single-use plastic usage during the Covid-19 pandemic. Science of the Total Environment. 849, pp1-10.
[284] Vink and Blanksma (2023). Steps towards standardization of plastic reusable packaging: A preliminary study into standardization in the reuse sector. January 2023.
[285] Betts et al. (2022). Key metrics to measure the performance and impact of reusable packaging in circular supply chains. Frontiers in Sustainability. 3, pp1-21.
[286] Hesseling, I (2022). From single-use to reuse: development of a decision support tool for FMCG packaging. University of Twente.

- five policy documents[287] [288] [289] [290] [291];
- six technical studies[292] [293] [294] [295] [296] [297]; and
- one website article[298].

The relevant sources were generally considered of medium applicability when assessed against the data assessment framework, which recognises the relevance of the sources and the strength of the methodology within each. The sources exhibited an average IAS of 3.6 (out of 5), with 14 sources exhibiting a score of 4 or above. Of the literature reviewed for this measure, 8 sources were UK-specific and 8 were relevant to the European market. Additionally, 27 sources were recent studies released over the past ten years.

6.2.2 Interviews

Stakeholders recognised that this measure holds significant potential for enhancing resource efficiency, however stakeholders found they were unable to quantify the impacts of reuse systems. This was due to the fact that reuse business models are relatively new and untested. The indicator presented during interviews was ‘percent mass reduction of plastic consumption due to reuse’ and this did not change over the course of the interviews. The phrasing of the indicator was amended post-workshop for clarity, but the meaning of the indicator was intended to stay the same. As a result of the lack of engagement during interviews, the levels of efficiency presented in this report are a result of findings from the literature review and the workshop.

6.2.3 Workshop

Stakeholders agreed that the reuse of plastic products is highly relevant to resource efficiency within the sector. However, overall, stakeholders had greater levels of experience with reuse within the packaging sector than with the automotive sector, which was also in scope for this measure. As a result, most input regarding the automotive sector for this measure is anecdotal.

---

[287] The Packaging Waste (Data Reporting) (England) Regulations 2023
[288] The Environmental Protection (Plastic Plates etc. and Polystyrene Containers etc.) (England) Regulations 2023.
[289] The Environmental Protection (Single-use Plastic Products) (Scotland) Regulations 2021.
[290] The Environmental Protection (Single-use Plastic Products) (Wales) Act 2023.
[291] European Commission (2022). Biobased plastics: Sustainable Sourcing & Content.
[292] McKinsey & Company (2023). The potential impact of reusable packaging. 05 April 2023.
[293] Rethink Plastic (2021). Realising Reuse: The Potential for Scaling Up Reusable Packaging and Policy Recommendations. July 2021.
[294] World Economic Forum (2021). Future of Reusable Consumption Models: Platform for Shaping the Future of Consumption - Insight Report July 2021.
[295] Systemiq et al. (2020). Breaking the Plastic Wave Thought Partners: Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution
[296] Deloitte (2023). The Sustainable Consumer 2023
[297] Vink and Blanksma (2023). Steps towards standardization of plastic reusable packaging: A preliminary study into standardization in the reuse sector.
[298] WRAP (2015). Household Waste Prevention Hub: Reuse – Barriers to Re-Use.

The level of engagement in the workshop was as follows:

- Four stakeholders were active on the mural board and two stakeholders actively contributed to verbal discussion.

6.3 Drivers & Barriers

The drivers and barriers influencing this measure were identified through a combination of the literature review, stakeholder interviews and sector workshop.

6.3.1 Drivers

Table 27 below shows the main drivers for Measure 6. The most significant drivers are shown in bold as voted for by participants in the workshop.

Table 27: Drivers for plastics sector measure 6

Description	PESTLE	COM-B
Voluntary commitments	**Political**	**Motivation – automatic**
Regulatory requirements	Legal	Capability – psychological
Customer demand	Social	Motivation – reflective
Cost savings	Economic	Opportunity – physical
Carbon and raw material savings	Environmental	Opportunity – physical
Increased variety in business models	Economic	Opportunity – physical

Voluntary commitments

Setting plastic reuse targets through voluntary commitments, such as the UK Plastics Pact and Ellen MacArthur Foundation "Global Commitment 2022", is another driver for encouraging packaging producers to implement reusable and refillable packaging. Both the UK Plastics Pact and Ellen MacArthur Foundation "Global Commitment 2022" have set a target for 100% of packaging to be recyclable, compostable or reusable/refillable by 2025. In 2021/22, 70% of packaging produced by the UK Plastic Pact members were recyclable, compostable or reusable/refillable, compared with 66% in 2018. [299] Whilst this 100% target could be met through design for recycling or composting, the use of reusable and refillable packaging may pose a suitable method for hard-to-recycle or compost packaging formats. Notably, the Ellen

[299] WRAP (2022). The UK Plastics Pact Annual Report 2021-2022.

MacArthur Foundation's "Global Commitment 2022" progress report highlighted that Coca Cola had set itself a target of 25% of volume sales to be through a reuse model by 2030.[300]

Regulatory requirements

Extended Producer Responsibility (EPR) for packaging is an example of a legislative mechanism incentivising reusable and refillable plastic packaging. Among other requirements, EPR for packaging in the UK charges obligated packaging producers for the management of packaging waste, based on the weight and type of packaging placed on the UK market each year. By charging producers for certain reusable packaging placed on the UK market for the first time only, and not per time the packaging is reused or refilled, producers can reduce their compliance costs compared with single-use packaging, which is charged per item placed on the UK market. This financially incentivises producers to introduce reusable packaging (including reusable plastic packaging) to lower their fees.[301]

Additionally, England[302], Scotland[303] and Wales[304] have implemented single-use plastic bans on certain single-use plastic items, such as expanded polystyrene takeaway cups, plastic straws and plastic balloon sticks. These bans can incentivise the uptake of reusable and refillable alternatives. For example, by banning the manufacture and supply of single-use expanded polystyrene cups, consumers may be incentivised to use refillable plastic cups. Similarly, the ban on single-use plastic cutlery may incentivise consumers to use reusable plastic cutlery. Despite these opportunities, alternative single-use materials are widely used, such as paper cups and wooden cutlery, which can limit the uptake of reusable alternatives.

Customer demand

Consumer demand for durable, repairable and reusable products, including plastic products, can drive an increase of reusable products on the market. In a recent YouGov survey of over 2,000 UK adults, 45% identified durable products as being "sustainable", with 52% claiming durability to be a consideration when purchasing a product. Similarly, the survey found that 44% of respondents identified repairable products to be "sustainable", with 34% claiming repairability to be a consideration when purchasing a product.[305] As such, durable and repairable products are characteristics in demand by consumers. In addition, it is argued that reusable packaging solutions can provide better user experience and brand loyalty, through customised packaging and refill options, which can improve consumer satisfaction.[306]

Similarly, the UK supermarket chain, Tesco, collaborated with the reusable packaging service provider, Loop, to pilot prefilled reusable packaging for a variety of branded and own-brand products. The packaging included plastic and metal containers, prefilled with food and non-food produce. A deposit was paid for the container, which was refunded when the consumer

---

300 The Ellen MacArthur Foundation (2022). The Global Commitment 2022: Progress Report.
301 The Packaging Waste (Data Reporting) (England) Regulations 2023
302 The Environmental Protection (Plastic Plates etc. and Polystyrene Containers etc.) (England) Regulations 2023.
303 The Environmental Protection (Single-use Plastic Products) (Scotland) Regulations 2021.
304 The Environmental Protection (Single-use Plastic Products) (Wales) Act 2023.
305 Deloitte (N.D.). What consumers care about when it comes to sustainability
306 Ellen MacArthur Foundation (2019). Reuse – rethinking packaging.

returned their empty container either through their next online delivery or in-store at a collection point. The pilot consisted of two phases – the first phase being for online shopping between July 2020 and June 2021, and the second phase being for in-store shopping at 10 stores in England. Survey responses from customers revealed that 50% of customers were motivated to use prefilled reusable packaging as they wanted to do their "bit for the planet" and "reduce single use plastic". Tesco also met their target for customer participation, with over 80,000 products sold over the two-year period.[307]

Cost savings

There is limited literature assessing cost differences between reusable and single-use plastic products. Where there have been cost comparisons made, they tend to focus on transport packaging, such as plastic crates. The widespread use of reusable pallets, bulk containers, and barrels for business-to-business transactions has been made possible due to the standardisation of these packaging systems, allowing the entire supply chain to accept and handle these packaging items. Adopting a reusable and refillable packaging model, including plastic packaging, can result in cost savings when compared with single-use packaging. However, there are various factors that determine the net cost savings of reusable and refillable packaging, as highlighted by one literature review study on reusable packaging. The deciding factors include transport distance, the number of times the packaging is reused, the volume of reusable packaging on the market (economies of scale), cleaning and handling labour required and use of standardised systems.[308] As such, there are some scenarios in which reusable plastic packaging solutions are more expensive than single-use packaging solutions. For instance, one case study modelling carbon emissions and costs associated with e-commerce deliveries in Germany compared single-use paper mailing bags and boxes against reusable PP mailing bags and boxes being reused 20 times. The study concluded that the reusable bag scenario was around 50% more expensive than the single-use bag scenario, whilst the reusable mailing box scenario was 200% more expensive than the single-use box scenario. Around 75% of the cost for the reusable packaging scenarios was associated with logistics.[309] Further research is needed to understand how many uses are required to make the reusable bag a viable option and whether or not this exceeds the average lifespan of a reusable bag.

Carbon and raw material savings

The use of reusable plastic products instead of single-use products can result in carbon and raw material savings. For example, one study compared the environmental impacts of single-use cardboard and single-use wooden boxes against those of reusable plastic crates for transporting fruit and vegetables within Europe. The single-use cardboard boxes had the highest negative environmental impacts, including carbon emissions, with the reusable plastic crates having the lowest negative environmental impacts, including carbon emissions. Single-use wooden boxes had only slightly higher negative environmental impacts than the reusable

[307] Tesco (2022). Use. Reuse. Repeat. Sharing Learnings on Reusable Packaging. Tesco Reuse Report 2022.
[308] Coelho et al. (2020). Sustainability of Reusable Packaging – Current Situation and Trends. Resources, Conservation & Recycling. 6, pp1-11.
[309] McKinsey & Company (2023). The potential impact of reusable packaging. 05 April 2023.

plastic crates. Notably, the study found that the reusable plastic crates needed to be used between 5 and 15 times to break even with the single-use cardboard boxes. This would take between 1 to 3 years under the modelled scenario, resulting in much lower negative environmental impacts compared with single-use cardboard boxes, since the lifespan of the reusable plastic crates were estimated at 10 to 20 years.[310] Conversely, another study compared the environmental impacts of single-use cardboard boxes against those of reusable plastic crates for transporting bread. The single-use cardboard boxes had lower environmental impacts, including carbon emissions, than the reusable plastic crates, due mostly to the transportation emissions associated with the reusable crates in their scenarios.[311]

As such, there are various factors which determine the net carbon emissions and raw material savings associated with reusable plastic products, such as the number of times the products are reused before they become waste, the materials and manufacturing methods used to create the reusable product and the operational activities involved in the reusable system – such as logistics and cleaning.[312] For instance, one case study modelling carbon emissions and costs associated with takeaway packaging in Belgium compared single-use paper cups and containers against reusable plastic cups and containers being reused 20 times. The study concluded that the reusable cup scenario produced around 150% higher carbon emissions compared with the single-use cup scenario, whilst the reusable container scenario produced around 140% higher carbon emissions compared with the single-use container scenario. Just under 50% of the carbon emissions from the reusable packaging scenarios was associated with logistics.[313]

Increased variety in business models

The range of reusable and refillable packaging models and types, including plastic packaging, can benefit customer needs and improve brand loyalty. The Ellen MacArthur Foundation categorises four reuse models for business-to-consumer packaging. These are ‘refill at home’, ‘refill on the go’, ‘return from home’ and ‘return on the go’. Each reuse model has its own set of unique characteristics, allowing businesses to decide the most suitable model for their range of products and business model. For instance, online retailers may choose to adopt the ‘refill at home’ model, with their customers receiving home deliveries of produce to refill their container with – such as concentrate capsules which can be mixed with tap water to produce hand soap. This ‘refill at home’ model can be combined with subscription services to increase brand loyalty and improve customer satisfaction with automated reordering.[314]

The prefilled reusable packaging pilot by Tesco and Loop, as mentioned earlier, is an example of ‘return from home’ and ‘return on the go’. Tesco found that suppliers, retailers and customers could more easily adapt to the use of prefilled reusable packaging, since the

---

310 Albrecht et al. (2013). An extended life cycle analysis of packaging systems for fruit and vegetable transport in Europe. The International Journal of Life Cycle Assessment. 18, pp1549-1567.
311 Koskela et al. (2014). Reusable plastic crate or recyclable cardboard box? A comparison of two delivery systems. Journal of Cleaner Production. 69, pp83-90.
312 Coelho et al. (2020). Sustainability of Reusable Packaging – Current Situation and Trends. Resources, Conservation & Recycling. 6, pp1-11.
313 McKinsey & Company (2023). The potential impact of reusable packaging. 05 April 2023.
314 The Ellen MacArthur Foundation (2019). Reuse – Rethinking Packaging.

production processes, storage and shopping behaviours are similar to those of single-use packaging models. As such, Tesco believed that the choice of prefilled 'return from home' and 'return on the go' packaging models were most effective for their stores. [315]

6.3.2 Barriers

Table 28 below shows the main barriers for Measure 6. The most significant barriers are shown in bold as voted for by stakeholders in the workshop.

Table 28: Barriers for plastics sector measure 6

Description	PESTLE	COM-B
Consumer behaviour	**Social**	**Motivation – reflective**
Perceived hygiene concerns	**Social**	**Opportunity – social**
Upfront cost	Economic	Opportunity – physical
Lack of standardisation	Legal	Capability – psychological
Challenges to scalability	Technological	Opportunity – physical
Limited awareness and infrastructure	Social	Opportunity – physical
High reuse rates needed to achieve benefits	Technological	Capability – physical

Consumer behaviour

The convenience of single-use plastic products, especially packaging, is a major barrier to the uptake of reusable alternatives by consumers. Two separate studies reviewing literature on sustainable packaging, for instance, identified inconvenience as a major barrier to the uptake of reusable packaging. The authors listed various aspects of reusable packaging which may be perceived as inconvenient by consumers – the additional weight of reusable packaging compared with single-use packaging, the ease of use when refilling the packaging, the management of the reusable containers at home and the risk of refillable options being unavailable.[316, 317] Whilst some reusable packaging models may be perceived as being more convenient than others (in certain contexts), there are various aspects that need to be addressed to ensure the reusable solutions are as convenient or more than single-use. These

[315] Tesco (2022). Use. Reuse. Repeat. Sharing Learnings on Reusable Packaging. Tesco Reuse Report 2022.
[316] Coelho et al. (2020). Sustainability of Reusable Packaging – Current Situation and Trends. Resources, Conservation & Recycling. 6, pp1-11.
[317] Zhu et al. (2022). Packaging Design for the Circular Economy: A Systematic Review. Sustainable Production and Consumption. 32, pp817-832.

aspects include increasing flexibility for consumers to refill or return their containers and ensuring the containers are a suitable size and shape.[318] As such, effective design of reusable plastic products, along with minimising the required operational input from consumers, pose opportunities to addressing these barriers.

Perceived hygiene concerns

Public concerns surrounding hygiene and associated risks of infections were heightened at a global level during and after the Covid-19 pandemic. As a result, the use of single-use plastic products such as PPE (gloves, masks and aprons), carrier bags and packaging increased. During the height of the Covid-19 pandemic, the use of reusable plastic products reduced, and in some countries were banned, due to fears of reusable products transmitting coronavirus. Many businesses, such as retailers, cafes and takeaways, also refused to accept reusable bottles, cups, containers and carrier bags.[319] Non-governmental organisations and academics did, however, run campaigns to dispel myths regarding hygiene benefits of single-use products compared with reusable products, with many businesses responding by reinstating acceptance of reusable plastic cups and containers.[320] During workshop discussions, stakeholders noted that halal considerations were another element of hygiene concerns with reusable packaging as ‘halal safety’ requires traceability within food packaging systems that is not yet in place. As such, consumer and supply-chain concerns regarding hygiene may pose a barrier to the uptake of reusable plastic products, especially that of food-contact packaging.

Upfront cost

Although the use of reusable plastic packaging can result in cost savings in the long-term[321] there are capital and operational costs which may pose a barrier to the uptake of reusable packaging systems. These costs include those on the consumer, such as purchasing reusable containers or paying a deposit for the hire of containers. Producers may incur large costs for designing reusable packaging systems and installing new manufacturing equipment. Retailers may incur large costs associated with the installation and maintenance of refill dispensers, along with handling, cleaning and logistics costs.[322] Such capital and operational costs, compared with single-use packaging, pose financial barriers to the uptake of reusable packaging (including plastic).

Lack of standardisation

Standardisation is considered by many in the packaging industry and by academics as a major enabler to the uptake of reusable and refillable packaging (including plastic) by consumers and

[318] Tesco (2022). Use. Reuse. Repeat. Sharing Learnings on Reusable Packaging. Tesco Reuse Report 2022.
[319] Silva et al. (2020). Rethinking and Optimizing plastic waste management under COVID-19 pandemic: Policy solutions based on redesign and reduction of single-use plastics and personal protective equipment. Science of the Total Environment. 742, pp1-8.
[320] Winton et al. (2022). Drivers of public plastic (mis)use — New insights from changes in single-use plastic usage during the Covid-19 pandemic. Science of the Total Environment. 849, pp1-10.
[321] Coelho et al. (2020). Sustainability of Reusable Packaging – Current Situation and Trends. Resources, Conservation & Recycling. 6, pp1-11.
[322] Zhu et al. (2022). Packaging Design for the Circular Economy: A Systematic Review. Sustainable Production and Consumption. 32, pp817-832.

the supply-chain. Specifically, the adoption of harmonised standards, such as packaging dimensions, logistics and cleaning can allow reusable packaging to be manufactured, handled, transported and cleaned efficiently. Doing this at a large-scale can achieve economies of scale, thereby reducing costs, environmental impacts and complexities associated with the reusable packaging system.[323] Examples of widely recognised standardised reusable packaging mostly relate to business-to-business packaging, such as Europallets. Europallets are pallets of a specific dimension, allowing logistics and companies to adapt to these consistent dimensions.[324] However, there is a lack of standardised reusable consumer primary packaging, such as reusable plastic containers, cups and bottles. Reasons for this lack of standardisation in consumer primary packaging are mostly due to technical complexities and branding/marketing limitations. In terms of technical complexities, food, drink and other consumer produce vary in size and shape. As for branding, brand-owners often use packaging design to differentiate their products from their competitors. In both cases, the use of standardised dimensions and shapes restricts effectiveness of the reusable packaging.[325] As such, the lack of widely recognised and implemented standardised reusable packaging systems poses a barrier towards the uptake of reusable plastic packaging.

Challenges to scalability

Increasing the share of reusable plastic products, such as packaging, in the market requires addressing various barriers from consumers, the supply-chain and the public sector. Such barriers have been discussed in this section, as above, and include convenience, cost, hygiene, awareness and infrastructure and a lack of standardisation. The presence of these barriers limit uptake of reusable packaging by the supply-chain and consumers. These barriers have been considered by various organisations, such as the Ellen Macarthur Foundation and World Economic Forum, who have identified opportunities to encourage greater uptake. These include increasing brand loyalty through refill subscriptions, business opportunities for logistics and cleaning firms and integrating technology such as RFID chips which can provide valuable data to brand-owners and retailers.[326] [327]

Limited awareness and infrastructure

The availability and opportunity to purchase and/or trade reusable plastic products poses a barrier to the uptake of reusable plastic products. Where reusable plastic products (such as toys and household goods) are intended for sale or donation, there may be various barriers to placing the products on the market. These include the lack of knowledge about what reuse services are available, where the products can be sold/donated or in some cases there may be a lack of facilities available to accept the products.[328] Additionally, in terms of reusable

[323] Rethink Plastic (2021). Realising Reuse: The Potential for Scaling Up Reusable Packaging and Policy Recommendations. July 2021.
[324] Vink and Blanksma (2023). Steps towards standardization of plastic reusable packaging: A preliminary study into standardization in the reuse sector. January 2023.
[325] Hesseling, I (2022). From single-use to reuse: development of a decision support tool for FMCG packaging. University of Twente.
[326] The Ellen MacArthur Foundation (2019). Reuse – Rethinking Packaging.
[327] World Economic Forum (2021). Future of Reusable Consumption Models: Platform for Shaping the Future of Consumption - Insight Report July 2021.
[328] WRAP (2015). Household Waste Prevention Hub: Reuse – Barriers to Re-Use.

packaging, uptake may be limited due to a lack of availability of refill dispensers in nearby stores. One author added that even where refillable infrastructure is available, consumers may be concerned that the produce will be unavailable/not in stock.[329]

High reuse rates needed to achieve benefits

In order for products, including plastic products, to be reused multiple times, they need to be durable. As such, the material use and resultant carbon emissions from their production can be higher than those of single-use products. One study, for instance, compared the economic and environmental impacts from reusable PP boxes, reusable PP bags and single-use cardboard boxes for an organisation providing online deliveries and click-and-collect services. The study assessed costs associated with the packaging materials, cleaning, handling, storage, transportation and damages and losses of packaging. It was found that the reusable PP boxes would need to be used between 32 and 81 times in order to reduce carbon emissions compared with the single-use cardboard boxes, depending on the recycled content in the cardboard boxes and PP boxes.[330] As such, it is important that businesses and consumers maximise the number of times that reusable products are reused, compared with using single-use products. Furthermore, ensuring the reusable products are durable enough to withstand the likes of handling, cleaning and transportation numerous times is also very important.[331]

6.4 Levels of efficiency

Table 29: Levels of efficiency for plastics sector measure 6

Indicator: % reduction in plastic demand compared to a 2023 baseline			
Level of efficiency	Current	Maximum in 2035	Business-as-usual in 2035
Value	0%	2 – 8%	0 – 3%
Evidence RAG	Not applicable	Amber	Red

6.4.1 Current level of efficiency

As the indicator for this measure is an index, relative to current levels, the estimated level of efficiency is set at 0%, serving as a baseline for subsequent scenarios. The evidence RAG rating for this efficiency level is therefore not applicable. However, to put future reductions into context, it has been reported that as of 2021, only 1.2% of all plastic packaging was reusable

[329] Zhu et al. (2022). Packaging Design for the Circular Economy: A Systematic Review. Sustainable Production and Consumption. 32, pp817-832.
[330] Betts et al. (2022). Key metrics to measure the performance and impact of reusable packaging in circular supply chains. Frontiers in Sustainability. 3, pp1-21.
[331] Reloop & Zero Waste Europe (2020). Reusable vs Single-Use Packaging. A Review of Environmental Impacts.

for organisations that are EMF's Global Commitment Signatories,[332] which is a lower value from the 1.5% reported in 2019, although it is unclear whether this decrease indicates a significant reduction.

6.4.2 Maximum level of efficiency in 2035

The literature review and stakeholder engagement focused on figures describing a maximum level of efficiency within the packaging and construction industries. These figures were then multiplied by the market share of each industry and added together to get the maximum level of efficiency across the entire plastics sector.

Packaging & Household Goods

One study demonstrated that it could be technically possible to reduce packaging demand across Europe by 13% by 2030 and 27% by 2040, with up to a 30% reduction by 2050 through use of new delivery models and reuse systems such as deposit return schemes.[333] The three application groups identified to have the largest share of reduction potential were beverage bottles (33% reduction in beverage bottle waste by 2030), transport packaging (3% reduction in overall packaging waste by 2030) and refillable home care and grocery packages (3% reduction in overall packaging waste by 2030).

Stakeholders were presented with a range of 13 – 27% as the maximum level of efficiency for packaging & household goods during the workshop. The voting exercise yielded similar results to the literature review, although stakeholders generally felt the maximum level of efficiency would be lower than what was found in the literature. Three stakeholders voted for a maximum level of efficiency between 0 – 10% with two stakeholders having high confidence in this figure and one with medium confidence. Two participants voted for a maximum level of efficiency between 11 – 20%, both with medium confidence. While most of the votes were for the 0 – 10% range, during discussions, stakeholders did not disagree with the presented range and there were no stakeholders who commented on the range being closer to the 0% end of the range. As such these votes were understood to likely lie towards the middle or upper end of the range. Therefore, a range of 5 – 20% is suggested for the maximum level of efficiency within the packaging sector.

As packaging applications make up 34% of UK plastic consumption,[334] this range is multiplied by 34% to give a range of approximately 2 – 7% across sectors.

Automotive

One study found that there is currently little happening in the way of reuse of refurbished plastic components in the automotive sector, but by developing more standardised modular component designs and creating resale channels, the total plastic demand in the automotive

[332] Ellen MacArthur Foundation (2022). Global Commitment 2021 Progress Report, p. 21
[333] SystemIQ (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe
[334] Plastics Europe (2023). Circular Economy for Plastics: United Kingdom – 2020.

sector could reduce by 6% by 2050.[335] Working back linearly, this gives a 2.7% reduction within the sector by 2035 from 2023.

Stakeholders were presented with the 2.7% maximum level of efficiency within the automotive sector during the workshop. Stakeholders generally agreed with this figure, with two participants voting for a range of 1 – 5% with medium confidence, and one stakeholder voting for <1% with medium confidence. This stakeholder noted that the modular components needed to facilitate reuse within the automotive industry would be difficult to guarantee and maintain quality control over, resulting in the relatively low rate of uptake. Therefore, a range of 1 – 5% is suggested for the maximum level of efficiency within the automotive sector.

As automotive applications make up 11% of UK plastic consumption,[336] this range is multiplied by 11% to give a range of approximately 0 – 0.5% across sectors.

The percent reduction across the sector is estimated from reductions within each industry which have been added to produce the final level of efficiency. The 2 – 7% reduction within the packaging sector and the 0 – 0.5% reduction within the automotive industry results in a presented level of efficiency of 2 – 8% with the majority of the reduction driven by the packaging sector. The evidence RAG rating for this efficiency level is amber, reflecting the small number of sources found in the literature and low level of stakeholder engagement, despite general consensus between stakeholders and the figure found in the literature.

6.4.3 Business-as-usual in 2035

Similar to the approach taken in the maximum level of efficiency, this research focused on levels of efficiency within the packaging and automotive industries. The findings were then multiplied by the market share of these industries to get the BAU level of efficiency across the entire plastics sector.

No existing literature data were found regarding BAU levels of efficiency for this measure. Stakeholders were also unable to provide quantitative efficiency levels during the interviews due to a lack of expertise in reusable markets. As a result, the levels of efficiency presented above were identified solely through stakeholder participation in the workshop.

Packaging & Household Goods

Stakeholders were first asked to vote for BAU levels of efficiency within the packaging sector. Three participants voted for a range between 0 – 10% all with medium confidence. One stakeholder voted that the level of efficiency was >20% with low confidence and did not provide a specific figure after being prompted. As a result, this vote was given less weight given the self-reported low confidence in the figure and the inability to follow-up with more

[335] SystemIQ (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe
[336] Plastics Europe (2023). Circular Economy for Plastics: United Kingdom – 2020.

information during the discussion. Therefore, a range of 0 – 10% is suggested for the BAU level of efficiency within the packaging sector.

As packaging applications make up 34% of UK plastic consumption,[337] this range is multiplied by 34% to give a range of approximately 0 – 3% across sectors.

Automotive

Three stakeholders voted for a BAU level of efficiency of <1%, two with medium confidence and one with low confidence. As a result, a <1% level of efficiency is suggested for the BAU level of efficiency within the automotive sector.

As automotive applications make up 11% of UK plastic consumption,[338] this figure is multiplied by 11% to give a BAU level of approximately 0 – 0.1% across sectors.

As in the maximum level of efficiency, the percent reduction across the sector is estimated from reductions within each industry which have been added to produce the final level of efficiency. The 0 – 3% reduction within the packaging sector and the 0 – 0.1% reduction within the automotive sector results in a presented level of efficiency of 0 – 3% with the majority of the reduction driven by the packaging sector. The evidence RAG rating for this efficiency level is red, reflecting the overall lack of data available in the literature and low confidence amongst stakeholders despite the consensus.

[337] Plastics Europe (2023). Circular Economy for Plastics: United Kingdom – 2020.
[338] Ibid.

7.0 Measure 7 – Recycling of Post-Consumer Plastics

7.1 Plastics resource efficiency measure

7.1.1 Description

The proportion of plastic materials recovered and recycled from municipal (i.e., household and commercial) waste.

Once plastic products reach the end of their useable lifetime, as much of the material as possible should be recycled to avoid resource loss through landfill or incineration and reduce carbon emissions from plastic use. For example, in Europe, mechanical recycling can save between 1.1 – 3.6 tonnes of CO_2e per tonne of plastic waste recycled instead of sent to incineration or landfill as plastics recycling is less carbon-intensive compared to virgin plastic production.[339]

It is important to recognise that there is significant variation in the terms and processes within the plastics recycling industry, and some of these deliver greater resource efficiency savings than others. For example, the term 'closed-loop recycling' is often used to describe the production of plastic recyclate of similar quality to the input material for use in applications with the same technical demands. In the resource efficiency context, any situation where recycled material replaces the use of virgin material will deliver resource efficiency savings. However, the literature review and stakeholder interviews revealed that maximising closed-loop recycling is an important part of this measure as it will enable greater resource efficiency savings across all sectors over time. This links with Measure 4 (recycled content in plastic products) whereby the recycled material should be suitable for inclusion in the same product. If there are technical reasons why this is not possible, overcoming these should be prioritised.

While the recycling rate varies between industries, this measure is applicable to all industries as plastics in all industries are, to some degree, sent for recycling.

Table 30: List of industries applicable to measure 7

Packaging & Household Goods	Construction	Automotives	Textiles	Electronics
Applicable	Applicable	Applicable	Applicable	Applicable

[339] European Commission, Joint Research Centre (2021). Environmental effects of plastic waste recycling.

Mechanical Recycling

Mechanical recycling is the most common way to recycle plastic in the UK. These processes physically break down plastic waste into smaller pieces which can then be separated from contaminants, cleaned and be melted and reprocessed into new plastic products. While mechanical recycling is the most energy efficient recycling process for plastics today, it has its limitations. Not all plastic waste streams can be effectively mechanically recycled due to differences in polymer properties such as in thermoset plastics, additives such as fire retardants and contamination issues. Repeated exposure to heat cycles through mechanical recycling can degrade the quality of the material, limiting its usability for certain high-performance applications such as packaging and mechanical recycling can result in some plastic being lost as microplastic. Furthermore, achieving a high level of purity in the recycled material is crucial to maintaining its quality and usability as contaminants can lead to issues with durability or aesthetics in the final products.

Chemical Recycling

Chemical recycling processes break down plastic waste into its constituent monomers or further into light hydrocarbons. These processes offer the potential to handle a wider range of mixed plastic waste, including those that are difficult to recycle using mechanical methods, such as multi-layered or contaminated plastics. However, there is generally still a requirement that the input feedstock is as clean and homogeneous as possible to maximise yields.

It might also help address some of the limitations of mechanical recycling, such as the degradation of plastic properties during repeated recycling cycles as these technologies have the potential to produce recyclate that is equivalent to virgin polymers. However, chemical recycling is not without its own challenges, including the need for efficient, economically viable processes and managing the energy requirements to ensure the environmental impact of the process is positive overall. Decarbonisation measures such as electrification may need to be applied in order for chemical recycling technologies to operate on a trajectory to net zero. Additionally, only plastic-to-plastic technologies should be considered recycling, as plastic-to-fuel chemical recycling is equated more closely with energy recovery processes.

Chemical recycling is a family of processes that includes several techniques, each with its own advantages and disadvantages. These technologies have different yields, emissions factors, costs, outputs and tolerances to feedstock impurities and contamination. The three main classifications of these processes are described below.

- *Depolymerisation:* Depolymerisation involves breaking down plastics into monomers, which can then be repolymerised to create new plastics identical to virgin materials. This process can help maintain the quality of recycled plastics.
- *Pyrolysis:* In pyrolysis, plastics are heated in the absence of oxygen to break down the long polymer chains into smaller hydrocarbon molecules, with various gaseous, liquid, and wax outputs. These products can then be further refined to produce feedstocks for new plastics or other chemicals.

- *Gasification:* Gasification is similar to pyrolysis, but the heating takes place in the presence of oxygen. It converts mixed waste (which can include, but not exclusively contain plastic) into a synthetic gas— mixture of carbon monoxide and hydrogen—(syngas) which can be used for various purposes including energy generation or chemical production.

Finally, there are also some emerging technologies that do not fit into the definitions of either mechanical or chemical recycling, because they might use chemicals, but no chemical reaction takes place. The process is entirely *physical*:

- *Dissolution:* solvents are used to dissolve plastics, allowing for the separation of various contaminants and additives. The resulting solution can then be processed to recover original polymer. These technologies still tend to produce an output that is not quite virgin grade, but can be used where mechanical recycling cannot be, for example, to remove fire retardants from polystyrene insulation.

Depolymerisation and dissolution are less energy intensive than pyrolysis and gasification and yield monomers or polymers, thus avoiding the thermal treatments to produce feedstock for monomers. However, these technologies are currently unable to accept mixed plastic waste streams. Gasification and pyrolysis, on the other hand, have a high tolerance for plastic waste that is currently harder to recycle. Pyrolysis has been of particular interest for plastics as the output product, pyrolysis oil, is a relatively straightforward replacement for naphtha (a commonly used fraction of crude oil) in steam crackers within the existing fossil-based system. However, both pyrolysis and gasification have significant process losses that cannot be used directly in polymer production and are typically used to produce fuels.

7.1.2 Measure indicator

The indicator selected to measure the plastics recycling rate was **'percent UK post-consumer recycling rate'** which is derived by dividing the mass of material recycled by the mass of material placed on market each year. It should be noted that in some literature sources recycling rate was reported in the literature in a way that was inconsistent or vague with regards to the point of measurement. For example, in some cases recycling rate was reported as 'mass of plastic waste collected' divided by 'mass of material placed on the market.' These data are conceptually relevant enough to not be discounted from the literature review and any information describing the measurement point, where available, is reported below.

Other indicators that were identified but not selected included:

- Percent recycling process yield.

This indicator, which measures the mass of output of the recycling process compared to the mass of input, was not selected because it does not identify data that provides actual material resource efficiency data for the current market, but rather acts as an indicator of the effectiveness of the recycling process, which is linked to the overall recycling rate (i.e., the preferred indicator).

7.1.2 Examples in practice

Construction

The key challenge facing increasing mechanical recycling of construction plastics are the technical limits associated with recycling materials that were put on the market several decades ago. For example, the long use-phase of the plastics can lead to a degradation in polymer quality and the presence of legacy additives such as cadmium and lead, which are no longer permitted for use, can be difficult for current systems to handle. However, the economics of recycling construction plastic waste streams benefit from the material typically being present in large volumes with a relatively homogenous composition.

The most impactful lever to driving recycling rates of plastics within the construction sector is separate collection. Plastic makes up less than 1% of total construction and demolition waste, and as such is very difficult to recover without source segregation.[340] Additionally, systems such as the REWINDO initiative in Germany can help improve recycling through the recovery of specific construction materials and recycling them in a closed loop[341]. Technological improvements such as digitised building passports and robotic sorting along with revised demolition practices can help to further improve the economics of plastics recycling in the construction sector. Design measures to improve recyclability of construction plastics are likely to have little impact on recycling rates within the sector before 2035, or indeed 2050, due to the longevity of the material use. However, design improvements are still needed to drive recycling rate increases as soon as possible.

Automotive

Historically, the focus within the automotive sector has been on the recycling of metals, particularly steel, as they are generally present in large volumes and are easier to recycle than plastics. The main challenge facing plastics recycling in the automotive sector is waste stream separation as plastic materials are often incorporated into composite components, resulting in logistical challenges with dismantling and sorting. Additionally, the recent increase in use of reinforced plastic containing fillers and additives has made recycling automotive plastics difficult if not impossible. Potential options to overcome these challenges include increased investment in post-shredding technologies as well as improved design for recycling of plastic components in vehicles and the development of an EPR scheme for end-of-life vehicles. Notably, in some cases, design for recycling changes might increase a vehicle's emissions during its use-phase. As such, a full life cycle analysis is required to determine which design changes result in an overall reduction in carbon emissions on a case-by-case basis.

Textiles

Plastics recycling within textiles is currently quite low due to a lack of separate collection systems, an increase in poor quality clothing in circulation, and the highly inefficient sorting and preparation of textiles for recycling due to a lack of automated sorting technologies. In

[340] Bio Intelligence Service (2011). Service contract on management of construction and demolition waste.
[341] Rewindo Fenster-Recycling-Service (n.d.). Available at: https://rewindo.de/

particular, there are insufficient sorting processes that are able to identify material according to specifications that are critical to recycling such as fibre types or applied chemical treatments. Textile waste is also particular in that it often contains elements such as trims and attachments that can be disruptive to recycling. There are few commercial-scale recycling facilities that allow for fibre-to-fibre recycling that deliver high-quality outputs that can replace virgin textile fibres. This is discussed in further detail in the “Unlocking Resource Efficiency: Phase 2 Textiles Report.” Additionally, the fibre-to-fibre recycling processes that do exist have strict input requirements, which makes issues around aggregation of sufficient and consistent quantities of a particular textile feedstock from sorters difficult. As a result, a significant proportion of textile waste is disposed of as residual waste or exported for ‘reuse’ before ultimately being disposed due to a lack of accountability.[342] [343]

7.2 Available sources

7.2.1 Literature review

The literature review identified 51 sources, used in this report, that discussed recycling of post-consumer plastics. This comprised:

- sixteen industry reports[344] [345] [346] [347] [348] [349] [350] [351] [352] [353] [354] [355] [356] [357];

[342] WRAP, Valpak, Verde Research & Consulting, and RECOUP (2018). PlasticFlow 2025: Plastic Packaging Flow Data Report
[343] WRAP (2021). Plastics Market Situation Report 2021.
[344] WWF (2018). A Plastic Future: Plastics Consumption and Waste Management in the UK.
[345] Circular Plastics Alliance (2020). Circular Plastics Alliance - State of Play on Collection and Sorting: Electronics and Electrical Equipment. Working Group.
[346] Plastics Europe (2022). Plastics – The Facts 2022.
[347] Circular Plastics Alliance (2020). Circular Plastics Alliance - State of Play on Collection and Sorting: Construction Working Group.
[348] Plastics Europe (2019). The Circular Economy for Plastics.
[349] Wrap (2022). The UK Plastics Pact Annual Report 2021-2022.
[350] BPF (2021). British Plastics Federation Recycling Roadmap.
[351] Green Alliance (2021). Completing the circle: Creating effective UK markets for recovered resources.
[352] Plastics Europe (2022). The Circular Economy for Plastics: A European Overview.
[353] Oakdene Hollins (2021). Driving change: A circular economy for automotive plastic
[354] Ellen MacArthur Foundation (2017). The New Plastics Economy: Rethinking the Future of Plastics & Catalysing Action
[355] Systemiq (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe.
[356] European Commission, Circular Plastics Alliance (2020). Circular Plastics Alliance - State of Play on Collection and Sorting: Automotive Working Group
[357] European Commission, Circular Plastics Alliance (2020). Circular Plastics Alliance – State of Play on Collection and Sorting: Packaging Working Group.

- sixteen academic papers[358] [359] [360] [361] [362] [363] [364] [365] [366] [367] [368] [369] [370] [371] [372] [373];
- five policy documents[374] [375] [376] [377] [378];
- five technical studies[379] [380] [381] [382] [383]; and
- nine website articles[384] [385] [386] [387] [388] [389] [390] [391] [392].

The relevant sources were generally considered of medium applicability when assessed against the data assessment framework, which recognises the relevance of the sources and the strength of the methodology within each. The sources exhibited an average IAS of 3.9 (out

[358] Watkins et al (2020). Support to the Circular Plastics Alliance in establishing a work plan to develop guidelines and standards on design-forrecycling of plastic products.
[359] Letcher, T. (2020). Plastic Waste and Recycling: Environmental Impact, Societal Issues, Prevention, and Solutions. Elsevier Academic Press. ISBN:978-0-12-817880-5.
[360] Lubongo and Alexandridis (2022). Assessment of Performance and Challenges in Use of Commercial Automated Sorting Technology for Plastic Waste. Recycling. 7(2), pp1-26.
[361] Allison et al. (2022). Reducing plastic waste: A meta-analysis of influences on behaviour and interventions. Journal of Cleaner Production. 380, pp1-18.
[362] Antonopoulos, I., Faraca, G. & Tonini, D. (2021). Recycling of post-consumer plastic packaging waste in the EU: Recovery rates, material flows, and barriers.
[363] Roy et al. (2022). Barriers to recycling plastics from the perspectives of industry stakeholders: a qualitative study. Journal of Integrative Environmental Sciences. 20(1), pp1-15.
[364] Burgess et al. (2021). The future of UK plastics recycling: One Bin to Rule Them All. Resources, Conservation & Recycling. 164, pp1-9.
[365] Roithner and Rechberger (2020). Implementing the Dimension of Quality into the Conventional Quantitative Definition of Recycling Rates. Waste Management. 105, pp586-593.
[366] Domenech et al. (2020). How circular are plastics in the UK?: Findings from Material Flow Analysis.
[367] Klotz et al. (2023). Potentials and limits of mechanical plastic recycling.
[368] Hahladakis et al. (2018). Post-consumer plastic packaging waste in England: Assessing the yield of multiple collection-recycling schemes.
[369] Drewnoik et al. (2023). What to Do about Plastics? Lessons from a Study of United Kingdom Plastics Flows
[370] Mehta et al. (2021). Using regional material flow analysis and geospatial mapping to support the transition to a circular economy for plastics
[371] Lase et al. (2023). How Much Can Chemical Recycling Contribute to Plastic Waste Recycling in Europe? An Assessment Using Material Flow Analysis Modelling
[372] Ragaert et al. (2017). Mechanical and chemical recycling of solid plastic waste.
[373] Eriksen et al. (2020). Dynamic Material Flow Analysis of PET, PE, and PP Flows in Europe: Evaluation of the Potential for Circular Economy.
[374] European Commission, Joint Research Centre (2021). Environmental effects of plastic waste recycling.
[375] The Packaging Waste (Data Reporting) (England) Regulations 2023
[376] DEFRA (2022). Extended Producer Responsibility for Packaging: Summary of Consultation Responses and Government Response. 26 March 2022.
[377] Waste (Miscellaneous Amendments) (EU Exit) Regulations 2019
[378] EU Packaging and Packaging Waste Directive (2018/852)
[379] RECOUP (2022). Plastic Packaging Recyclability By Design 2023. Version 10: Updated 2022.
[380] Viridor (2022). Bridging the Gap: Ending Britain's Reliance on Plastic Waste Export.
[381] WRAP (2023). Behaviours, Attitudes and Awareness: Recycling Tracker Survey in the UK – Spring 2023.
[382] Systemiq (2020). Breaking the Plastic Wave Thought Partners: Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution.
[383] Louise Smith (2022). Plastic waste.
[384] Rewindo Fenster-Recycling-Service (n.d.). Available at: https://rewindo.de/
[385] Greenpeace (2022) How Fast Fashion is using the Global South as a dumping ground for textile waste.
[386] Let's Recycle (2021). OPRL Adds In-Store Recycling Labels to Crisp Packets. 16 November 2021.
[387] Flexible Plastic Fund (2022). Household collections with FPF FlexCollect.
[388] Circular Plastics (2018). The European Plastics Industry Voluntary Commitments.
[389] The Green Tractor Scheme (2023). The Green Tractor Scheme: About Us.
[390] The Guardian (2019). War on plastic waste faces setback as cost of recycled material soars.
[391] Financial Times (2022). Recycled plastic prices double as drinks makers battle for supplies.
[392] OPRL (2023). On-Pack Recycling Label: About OPRL.

of 5), with 32 sources exhibiting a score of 4 or above. Of the literature reviewed for this measure, 22 sources were UK-specific and 21 were relevant to the European market. Additionally, all sources were published over the past ten years.

7.2.2 Interviews

Stakeholders considered recycling of post-consumer plastics to be an important measure for resource efficiency within the plastics sector. However, it was noted that this measure has significant overlap with ‘Measure 4 – Recycled content in plastic products’ given that recycled content cannot be incorporated without recycling processes in place to provide the necessary materials.

The indicator presented during the interviews was ‘percent recycling rate’ and this did not change throughout the research process. Three stakeholders engaged with this measure qualitatively and two provided quantitative feedback on the levels of efficiency. However, the low engagement with this measure was mostly due to the current levels of efficiency already being covered extensively in the literature and stakeholder comments were broadly consistent with what was found in the literature review.

7.2.3 Workshop

Stakeholders agreed that recycling is a key component of resource efficiency within the plastics sector. However, it was noted that this measure is a key area in which there are interdependencies with other elements within the plastics sector such as the introduction of biodegradable polymers and the scaling up of reuse systems. These interdependencies are explored further in ‘Section 8.0 – Interdependencies.’

The level of engagement in the workshop was as follows:

- All six stakeholders were active on the mural board and three stakeholders actively contributed to verbal discussion.

7.3 Drivers & Barriers

The drivers and barriers influencing this measure were identified through a combination of the literature review, stakeholder interviews and sector workshop.

7.3.1 Drivers

Table 31 below shows the main drivers for Measure 7. The most significant drivers are shown in bold as voted for by stakeholders in the workshop.

Table 31: Drivers for plastics sector measure 7

Description	PESTLE	COM-B
Regulatory requirements	**Legal**	**Capability – psychological**
Demand for recycled content	**Technological**	**Opportunity – physical**
Separate collection & high-quality sorting	**Environmental**	**Capability – physical**
Consumer awareness and behaviour	Social	Opportunity – social
Design for recycling (D4R) guidance	Political	Capability – psychological
Voluntary commitments	Political	Capability – psychological

Regulatory requirements

Government regulations that promote recycling and set recycling targets can drive the plastic recycling industry's growth. For instance, Extended Producer Responsibility (EPR) for packaging is an example of a legislative mechanism that incentivises the uptake of recyclable packaging. Among other requirements, EPR for packaging in the UK charges obligated packaging producers for the management of packaging waste, based on the weight and type of packaging placed on the UK market each year.[393] Whilst the eco-modulated fee structure under the UK's EPR for packaging aims to be introduced from October 2025, the intention of eco-modulated fees is to charge producers more for non-recyclable packaging and less for recyclable packaging.[394] This incentivises producers to use recyclable packaging materials, which should (provided consumer recycling behaviour is adopted) increase recycling rates. This is an approach used in other countries, such as France, whereby the packaging weight and material composition determines the eco-modulated fee.

Another example is the requirements and recycling targets set out in the UK's Waste Regulations. These regulations follow closely with the requirements and targets set out in the EU Waste Framework Directive. The UK's Waste Regulations sets recycling targets for the preparation for reuse and recycling of municipal waste, set at 55% by 2025, 60% by 2030 and 65% by 2035.[395] Achieving these recycling targets will require a combination of products being

[393] The Packaging Waste (Data Reporting) (England) Regulations 2023
[394] DEFRA (2022). Extended Producer Responsibility for Packaging: Summary of Consultation Responses and Government Response. 26 March 2022.
[395] Waste (Miscellaneous Amendments) (EU Exit) Regulations 2019

designed for recycling, consumer recycling behaviour and effective recycling infrastructure, for products made from plastic and other materials.

The UK's Plastic Packaging Tax is another regulatory example of incentivising higher plastic recycling rates. The Plastic Packaging Tax places a tax (currently at just over £200 per tonne) on plastic packaging and certain other plastic items which contain less than 30% recycled plastic content. This tax financially incentivises producers to incorporate recycled plastic content into their plastic packaging and certain other plastic products. This also drives demand for recycled plastic content, and therefore investment into plastic recycling infrastructure, throughout the supply-chain.[396] Supplying this recycled plastic content requires sufficient recycled plastic feedstock, requiring higher recycling rates.

Demand for recycled content

As outlined in section 4.3.2, there is demand for recycled plastic content, and especially high-quality food-grade plastic. As such, organisations such as the Circular Plastics Alliance has undertaken research and stakeholder engagement surrounding potential sources of recycled plastic content for the likes of packaging[397], electrical and electronic equipment[398], automotive[399] and construction[400] sectors in order to increase plastic recycling rates.

Separate collection & high-quality sorting

The separation of recyclable plastic waste into dedicated household and commercial recycling bins, sacks or skips is important to maximise recycling rates of the plastic material. Plastic recycling rates in Europe are reported to be 13 times higher when plastic waste is collected separately compared to as part of mixed recycling collection (e.g., plastic, metal and glass), compared with plastic waste being placed in general/residual waste streams.[401] The use of separate or mixed recycling collection systems from households and businesses increases not only the quantity, but also the quality of the output recycled plastic content. This is largely due to less contamination from other waste material, such as food, drink and other non-plastic material. Although much of the UK's household plastic recycling collections is for certain rigid plastic packaging (such as plastic bottles, trays and tubs), some retail stores, recycling centres and recycling points accept soft plastic packaging for recycling (such as plastic film, bags and wrappers).[402] Furthermore, with the upcoming requirement for soft plastics to be accepted in UK household kerbside recycling collections from 2027, a three-year "FlexCollect" pilot project is being introduced in certain council areas of the UK. This pilot project will test and develop

[396] Letcher, T. (2020). Plastic Waste and Recycling: Environmental Impact, Societal Issues, Prevention, and Solutions. Elsevier Academic Press. ISBN:978-0-12-817880-5.
[397] Circular Plastics Alliance (2020). Circular Plastics Alliance - State of Play on Collection and Sorting: Packaging Working Group.
[398] Circular Plastics Alliance (2020). Circular Plastics Alliance - State of Play on Collection and Sorting: Electronics and Electrical Equipment. Working Group.
[399] Circular Plastics Alliance (2020). Circular Plastics Alliance - State of Play on Collection and Sorting: Automotive Working Group.
[400] Circular Plastics Alliance (2020). Circular Plastics Alliance - State of Play on Collection and Sorting: Construction Working Group.
[401] Plastics Europe (2019). The Circular Economy for Plastics.
[402] Lets Recycle (2021). OPRL Adds In-Store Recycling Labels to Crisp Packets. 16 November 2021.

processes for including soft plastics in existing kerbside recycling systems. There are currently six participating councils involved in the scheme.[403] .

Along with separate collections of recyclable plastic waste, improved sorting processes in sorting facilities can further increase the quality of the input plastic waste. To achieve this, various processes are employed at the sorting facilities. These include the use of manual picking-lines, mechanical sorting equipment which sorts material by weight and size and also state-of-the-art digital technologies such as near-infrared (i.e., optical sorters) scanners. These scanners can identify the polymer of each plastic waste item on the conveyor belt, and automatically sorts the recyclable from the non-recyclable plastic waste. Although there are some types of plastic waste that are difficult to sort using optical sorting (e.g., black plastic or mixed polymer plastic), there are technical advances for the optical sorter equipment and plastic designs which can improve the sorting of plastic waste for recycling. Additionally, the integration of artificial intelligence (AI) and robotic sorting equipment in sorting facilities can further improve sorting efficiencies of plastic waste, with the ability to continuously "learn" and make effective decisions under various situations. [404]

Consumer awareness and behaviour

Growing awareness of the environmental impact of plastic waste, including marine plastics highlighted in the media, has increased the motivation to recycle plastic waste. For instance, one study reviewing literature on consumer behaviour surrounding waste found that consumers who were aware of the environmental impacts of plastic pollution were more likely to be motivated to recycle plastic waste than those who were not. The study added that recycling was often regarded as habitual, often motivated by emotion and morals.[405] Although consumer motivation to recycle plastic is a driver for increasing plastic recycling rates, the risk of increasing contamination from so-called "Wishcycling" whereby consumers attempt to recycle a material that is not recyclable in practice, poses a possible risk.

Design for Recycling (D4R) guidance

Product design plays an integral role in determining the recyclability of a product. For example, avoiding the use of certain pigments, additives, adhesives and multi-materials can increase the recyclability and quality of the plastic waste and recycled plastic content. Clear guidance on 'Design For Recycling' standards (e.g., RECOUP's 'Recyclability by Design'[406] guidance for plastic packaging) can help packaging producers and brand-owners to develop packaging that is more easily sorted, recycled and produces higher quality recycled content. For example, widespread adoption of design for recycling for vehicle parts is estimated to reduce mechanical recycling losses from 27% to 15%.[407]

---

[403] Flexible Plastic Fund (2022). Household collections with FPF FlexCollect.
[404] Lubongo and Alexandridis (2022). Assessment of Performance and Challenges in Use of Commercial Automated Sorting Technology for Plastic Waste. Recycling. 7(2), pp1-26.
[405] Allison et al. (2022). Reducing plastic waste: A meta-analysis of influences on behaviour and interventions. Journal of Cleaner Production. 380, pp1-18.
[406] RECOUP (2022). Plastic Packaging Recyclability By Design 2023. Version 10: Updated 2022.
[407] Antonopoulos, I., Faraca, G. & Tonini, D. (2021). Recycling of post-consumer plastic packaging waste in the EU: Recovery rates, material flows, and barriers.

Voluntary commitments

Setting plastic recycling targets through voluntary commitments, such as the UK Plastics Pact, is another driver for encouraging packaging producers to implement recyclable packaging. The UK Plastics Pact has set a 70% recycling/composting target by 2025. In 2021/22, 50% of packaging produced by the UK Plastic Pact members was recycled or composted, compared with 44% in 2018.[408] Additionally, Circular Plastics' "European Plastics Industry Voluntary Commitments" was established by six European plastic associations, with an overarching plastic recycling and reuse target of 50% by 2040 for Europe, with a 70% recycling and reuse target for plastic packaging by 2040.[409] A final voluntary commitment example is the UK's "The Green Tractor Scheme". This sets the ambitious target of recycling all agricultural plastic waste by 2030, along with ambitions to avoid unnecessary plastics in the supply-chain. Established in 2020, the commitment has over 20 signatories, including companies in the agricultural, retail and waste sectors.[410]

7.3.2 Barriers

Table 32 below shows the main barriers for Measure 7. The most significant barriers are shown in bold as voted for by stakeholders in the workshop.

Table 32: Barriers for plastics sector measure 7

Description	PESTLE	COM-B
Lack of domestic recycling infrastructure	**Technological**	**Capability – physical**
Volatile markets	**Economic**	**Opportunity – physical**
Lack of regulatory drivers and investment	**Economic / Political**	**Capability – psychological**
Technical limitations	Technological	Capability – physical
Consumer understanding and behaviour	Social	Opportunity – social
Data quality & definitions of recycling	Technological	Capability – physical
Contamination of plastic waste streams	Technological	Opportunity – physical

408 WRAP (2022). The UK Plastics Pact Annual Report 2021-2022.
409 Circular Plastics (2018). The European Plastics Industry Voluntary Commitments.
410 The Green Tractor Scheme (2023). The Green Tractor Scheme: About Us.

Lack of domestic recycling infrastructure

It is estimated that the UK exports around 19% of its plastic waste to other countries for recycling. This is higher than the estimated 16% of plastic waste being recycled in the UK using mechanical recycling and <1% using chemical recycling.[411] Plastic waste tends to be exported due to a lack of plastic recycling infrastructure in the UK, combined with low costs offered for recycling plastic in other countries. According to stakeholders interviewed, export of plastic waste in some cases is destined to low-income countries that lack sufficient recycling infrastructure. This reduces confidence in the exported plastic waste being handled appropriately and recycled.[412] Along with the potential of lost value of unrecycled plastic, negative environmental and human health impacts from exported plastic waste can also arise. For instance, these countries may be more prone to processing plastic waste in ways that have negative impacts on the environment, or the processes used can pose health and safety risks, contribute to climate change from open-air burning and damage ecosystems from chemicals leaching into surrounding soils and waterbodies.[413] Until more plastic recycling capacity is established in the UK, the export of plastic waste for recycling poses a barrier to the confidence and efficiency of plastic recycling.

Volatile markets

The cost difference between recycled plastic and virgin plastic can vary depending on supply and demand, energy costs and the market price of fossil-based resources.[414] The increasing demand for recycled plastic for packaging across Europe, for instance, has resulted in rising recycled plastic prices, with some recycled plastic costing more than virgin plastic.[415] Additionally, rising electricity prices have recently increased recycled plastic costs. Plastic Recyclers Europe reported that, before the energy price rises in 2022, the European plastic recycling facilities' operating costs were mostly for energy, labour and maintenance, with energy accounting for roughly 15-20%. However, the increase in energy prices in 2022 meant that energy costs now account for around 70% of operating costs. Some facilities have suspended operations because of these high costs.[416] As such, fluctuating costs may pose a barrier to the consistent use of recycled plastic content.

Lack of regulatory drivers and investment

During interviews, stakeholders noted that the lack of recycling infrastructure and volatile plastics markets are a result of a lack of sufficient regulation to drive investment towards the recycling market. Currently, the plastic recycling capacity in the UK is limited, leading to exports of some of the UK's plastic waste for recycling in other countries. [417] Investing in plastic recycling infrastructure in the UK could increase the UK's plastic recycling rate, and increase

[411] BPF (2021). British Plastics Federation Recycling Roadmap.
[412] Viridor (2022). Bridging the Gap: Ending Britain's Reliance on Plastic Waste Export.
[413] Letcher, T. (2020). Plastic Waste and Recycling: Environmental Impact, Societal Issues, Prevention, and Solutions. Elsevier Academic Press. ISBN:978-0-12-817880-5.
[414] The Guardian (2019). War on plastic waste faces setback as cost of recycled material soars.
[415] Financial Times (2022). Recycled plastic prices double as drinks makers battle for supplies.
[416] Lets Recycle (2022). High energy costs put plastic recycling 'at risk'.
[417] Green Alliance (2021). Completing the circle: Creating effective UK markets for recovered resources.

assurance that plastic destined for recycling is in fact recycled. It has been estimated that an additional 45 plastic recycling facilities could be feasibly introduced in the UK to increase domestic plastic recycling. This would require significant additional investment which could be met through private and public investments.[418] Funding avenues through private and/or public investments would be required, including financial incentives such as tax breaks.[419]

Technical limitations

Mechanical recycling is the predominant recycling process used for plastic waste in the UK (estimated at around 750kt in 2020), with chemical recycling being used to a lesser extent (estimated at 5kt in 2020).[420] Whilst mechanical recycling is an effective recycling process for many plastic polymer types, it is not suitable for certain plastic polymer types, such as products made of mixed polymer types and thermosets. This is where chemical recycling can be used to recycle such plastic waste that is unsuitable for mechanical recycling.[421] However, currently, recycling capacity in the UK is limited, meaning certain plastic waste is exported for recycling or treated as residual waste.

The other barrier associated with plastic recycling is related to the quality of recycled plastic content. Specifically, a plastic product can only be mechanically recycled a certain number of times before it loses its mechanical properties. The material must then be used for less demanding applications, and eventually must be dealt with through alternate pathways such as landfill and incineration. This is not currently a major problem, as recycling rates are relatively low, but as recycling rates increase it could become a limiting factor. Downgraded recycling plastic content can be used for products requiring lower quality and value plastic, such as street furniture and drainpipes, limiting its suitability for high quality products. [422]

Additionally, some plastic products contain certain additives and colourants which make it difficult for optical sorters in sorting facilities to identify as being recyclable plastic waste. For instance, the presence of brominated flame retardants, carbon black pigments and use of mixed materials in plastic products are difficult to correctly identify, so this plastic material can end up being treated as residual waste.[423] Furthermore, the presence of large labels or sleeves made of a different material or polymer to that of the plastic product can be incorrectly sorted or rejected.[424] As such, the combination of plastic product design and technical limitations at sorting facilities poses a barrier to plastic recycling.

[418] Ibid.
[419] Ibid.
[420] BPF (2021). British Plastics Federation Recycling Roadmap.
[421] Letcher, T. (2020). Plastic Waste and Recycling: Environmental Impact, Societal Issues, Prevention, and Solutions. Elsevier Academic Press. ISBN:978-0-12-817880-5.
[422] Letcher, T. (2020). Plastic Waste and Recycling: Environmental Impact, Societal Issues, Prevention, and Solutions. Elsevier Academic Press. ISBN:978-0-12-817880-5.
[423] Lubongo and Alexandridis (2022). Assessment of Performance and Challenges in Use of Commercial Automated Sorting Technology for Plastic Waste. Recycling. 7(2), pp1-26.
[424] RECOUP (2022). Plastic Packaging Recyclability By Design 2023. Version 10: Updated 2022.

Consumer understanding and behaviour

Whilst recycling behaviour is considered a social norm and is a widely adopted behaviour in the UK, there is still confusion amongst some consumers as to what types of plastic waste can and cannot be recycled.[425] Part of this confusion in terms of household plastic waste is due to the different types of plastic waste accepted for recycling across the UK's local authorities.[426] Although there are recycling labels provided on many UK household packaging items (such as the On-Pack Recycling Label),[427] this is not currently a mandatory requirement. Furthermore, household packaging is one of many plastic product types. Consumer confusion surrounding plastic recycling can lead to contamination of recycling streams and the disposal of recyclable plastic waste in the residual waste stream. For instance, findings from a recycling survey of UK adults in 2023 discovered that some plastic waste items, such as plastic toys and plastic bags, were incorrectly recycled in their local authority area.[428]

Data quality & definitions of recycling

In order to improve recycling rates for certain plastic products (e.g., packaging, electrical and electronic equipment and construction pipes), a good understanding of the quantities and types of plastic is required. Such data can identify plastic products with particularly low recycling rates that require intervention – such as providing product design guidance, raising awareness to consumers, improving recycling infrastructure and setting targets. Although UK recycling data is available for plastic waste, it largely relies on data provided by producer compliance schemes as part of policy reporting requirements – such as packaging, waste electrical and electronic equipment and end-of-life vehicles. As such, data accuracy is limited. Data for waste electrical and electronic equipment, for instance, is limited as only one-third of appliances are recovered through appropriate recycling routes in Europe.[429] Waste treatment information for the remaining two-thirds is therefore not well understood, meaning that targets and progress are difficult to monitor.

Also relating to data, the definition of "recycling" varies between literature, policies and the waste industry. Specifically, the point at which plastic waste is reported as being "recycled" can be either the material collected for recycling, the sorted material that is sent for recycling or the plastic that enters pelletisation and extrusion processes. For instance, the 2018 update to the EU Packaging and Packaging Waste Directive[430] changed the stage at which packaging waste can be reported as being recycled. The update requires Member States to record sorted outputs (i.e., excluding losses and non-recycled material) as recycled packaging, rather than packaging waste entering the recycling process.[431] Due to this change, plastic packaging

[425] Roy et al. (2022). Barriers to recycling plastics from the perspectives of industry stakeholders: a qualitative study. Journal of Integrative Environmental Sciences. 20(1), pp1-15.
[426] Burgess et al. (2021). The future of UK plastics recycling: One Bin to Rule Them All. Resources, Conservation & Recycling. 164, pp1-9.
[427] OPRL (2023). On-Pack Recycling Label: About OPRL.
[428] WRAP (2023). Behaviours, Attitudes and Awareness: Recycling Tracker Survey in the UK – Spring 2023.
[429] Circular Plastics Alliance (2020). Circular Plastics Alliance - State of Play on Collection and Sorting: Electronics and Electrical Equipment Working Group.
[430] EU Packaging and Packaging Waste Directive (2018/852)
[431] Roithner and Rechberger (2020). Implementing the Dimension of Quality into the Conventional Quantitative Definition of Recycling Rates. Waste Management. 105, pp586-593.

recycling rates in Europe in 2020 were estimated to be 46% using the old calculation method, or 32% using the new calculation method.[432] As such, comparing recycling rates between plastic product types and monitoring progress can be challenging. Limited plastic waste recycling data combined with varying recycling calculation methods therefore poses a barrier to effective monitoring and targeting of plastic recycling rates.

Contamination of plastic waste streams

Even when plastic waste is collected separately, it can consist of polymers that are not accepted for recycling, additives and non-plastic material such as food residue, paper labels and adhesives. Contamination can reduce the quality of recycled plastic content, which can result in some plastic waste being rejected and treated as residual waste. For example, even a small amount of PLA in PET recycled material can cause yellowing, agglomeration and reduction in technical performance. This can render the recycled material unsuitable for many end products.[433] As such, contamination poses a barrier to plastic recycling rates and recycled content quality.

7.4 Levels of efficiency

Table 33: Levels of efficiency for plastics sector measure 7

Indicator: % UK post-consumer recycling rate			
Level of efficiency	Current	Maximum in 2035	Business-as-usual in 2035
Value	27 – 41%	50 – 60%	40 – 50%
Evidence RAG	Amber-green	Green	Red-amber

7.4.1 Current level of efficiency

The level of efficiency was determined through a review of eight different literature sources, many of which focus on the European market more broadly but likely with general applicability to the UK market. An industry report by BPF which measured the recycling rate in the UK as input volume to mechanical and non-mechanical recycling, excluding the mass exported for recycling, estimated the recycling rate as between 32 – 41%.[434] A 2020 study by SystemIQ reported a 37% collection rate for plastic waste within the UK[435] while BPF reported a 37% collection rate in 2022. One research paper calculated recycling rate by subtracting tonnages

[432] Plastics Europe (2022). The Circular Economy for Plastics: A European Overview.
[433] Letcher, T. (2020). Plastic Waste and Recycling: Environmental Impact, Societal Issues, Prevention, and Solutions. Elsevier Academic Press. ISBN:978-0-12-817880-5.
[434] BPF (2021). British Plastics Federation Recycling Roadmap.
[435] Systemiq (2020). Breaking the Plastic Wave Thought Partners: Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution.

of plastic disposed/lost and tonnages exported for recycling from tonnage of plastic consumed in the UK, arriving at a recycling rate of 27%[436] while another material flows analysis of UK plastic including packaging, construction, textiles, EEE and automotive reported a 34% collection rate.[437] Finally, WWF reported a plastics collection rate for 2018 in the UK at 31%.[438] It should be noted that collection rate and recycling rates are two different definitions however they are both still relevant to this measure. In high level analyses, collection rate has been used as a proxy for recycling rate which indicates how closely linked the two definitions are.

Stakeholder votes were generally consistent with the level of efficiency found in the literature, although stakeholders tended to vote for values slightly lower, with three participants voting for a current level of efficiency between 10 – 20% (one with high confidence, two with medium confidence). Two participants voted for a maximum level of efficiency between 21 – 30% with medium confidence. However, given the difficulty in estimating recycling rates offhand and the high quality of data found during the literature review, more weight has been given to the figures found in the literature review when arriving at the final level of efficiency. As such, the average recycling rate across plastics products in all sectors in the UK is estimated to be between 27 – 41%. The evidence RAG rating for this efficiency level is amber-green, reflecting the high quality of literature available.

As recycling rate varies by industry, a summary of the current recycling rate within particular industries is found in Appendix E. These rates were not used in calculating the current level of efficiency but are useful in providing context to the variation in recycling rate across industries.

7.4.2 Maximum level of efficiency in 2035

The literature review yielded ten sources that discussed maximum projected recycling rates. However, most of these sources only discussed maximum levels within certain industries (e.g., packaging). A report by the British Plastics Federation suggests the maximum level of efficiency within the UK could reach 57% by 2030, including both mechanically and chemically recycled material and excluding material exported for recycling.[439] Another report focusing on Europe as a whole suggested a similar figure, with a maximum level of efficiency reaching 61% by 2030.[440] These reports lay out the key strategic elements that would need to be in place in order to achieve these rates, including the scaling of chemical recycling technologies, EPR and other legislative drivers in place, EfW capacity remaining stable, an increase in efficiency in existing facilities, standardised collection and allowing only high quality material to be exported for recycling (which effectively removes an outlet for low quality material, incentivising higher domestic recycling capacity).

The levels of efficiency found in the literature were generally validated by stakeholders during the workshop. Six participants voted for a maximum level of efficiency between 50 – 60% (one high confidence, five medium confidence) and one participant voted for a maximum level of

[436] Green Alliance (2021). Completing the circle: Creating effective UK markets for recovered resources.
[437] Domenech et al. (2020). How circular are plastics in the UK?: Findings from Material Flow Analysis.
[438] WWF (2018). A Plastic Future: Plastics Consumption and Waste Management in the UK.
[439] British Plastics Federation (2021). British Plastics Federation Recycling Roadmap.
[440] Lase et al. (2023). How Much Can Chemical Recycling Contribute to Plastic Waste Recycling in Europe? An Assessment Using Material Flow Analysis Modelling

efficiency between 40 – 50% (medium confidence). Two stakeholders noted that the 50 – 60% recycling rate could only be achieved by utilising chemical recycling in addition to mechanical recycling, which was an assumption also used for the figures found in the literature. As such, the maximum level of efficiency was estimated to be between 50 – 60%. The evidence RAG rating for this measure is green reflecting the high quality of literature available and consensus between the stakeholder input and the supporting literature.

7.4.3 Business-as-usual in 2035

The BAU level of efficiency was identified solely through stakeholder participation in the workshop as BAU level of efficiency was not found in the literature for this measure. All six participants who voted in the workshop indicated a BAU level of efficiency between 40 – 50% (two high confidence, four medium confidence). Three stakeholders noted that this BAU level of efficiency also includes chemical recycling, although at a lower rate than the maximum level of efficiency given policy development is expected to be slow and limit the rate of impact. As a result, the BAU level of efficiency was estimated to be between 40 – 50%. The evidence RAG rating for this measure is red-amber given the lack of available literature data and relatively low level of confidence between stakeholders who participated in the voting exercise.

8.0 Interdependencies

This report has discussed each of the measures identified for the plastics sector and presented estimates for the maximum and BAU level of efficiency they could achieve independently, that is, not considering any interdependencies or interactions between measures.

However, in practice these measures are likely to occur in tandem, and the levels of efficiency that are reached in each will depend on progress against other measures. The precise nature of these interdependencies should be considered when using any of the level of efficiency estimates from this report in further research or modelling exercises that attempt to produce an estimate of the cumulative impact of these measures over time.

A summary of the key interactions/interdependencies between the measures in this report with other measures in the sector, and with measures in other sectors is presented below.

Note, the estimates for the current level of efficiency will by their nature reflect the interactions and interdependencies between measures as they currently occur.

8.1 Interdependencies within the sector

Measures 1 & 4

- Measure 1 – Lean design of plastic products
- Measure 4 – Recycled content in plastic products

When recycled content is incorporated within a product, the product often requires a greater mass of material due to the lower functional performance of recycled plastic in products.

Measures 1 & 6

- Measure 1 – Lean design of plastic products
- Measure 6 – Reuse of plastic products

Reusable products are often designed for longer lifespans, which can result in greater use of material in order to promote longevity.

Measures 1 & 7

- Measure 1 – Lean design of plastic products
- Measure 7 – Recycling of post-consumer plastics

Stakeholders noted that some elements of lightweighting have become so extreme that products that were previously recyclable are becoming unrecyclable (e.g., PET bottles becoming more like films, which are more difficult to recycle than blow moulded PET).

Measures 2 & 6

- Measure 2 – Material substitution with non-plastic products
- Measure 6 – Reuse of plastic products

Material substitution can, in some cases, promote the reuse of products (e.g., plastic to glass) or make reuse more difficult (e.g., plastic to paper).

Measures 3 & 7

- Measure 3 – Feedstock substitution with bio-based feedstocks
- Measure 7 – Recycling of post-consumer plastics

While drop-in polymers should technically be able to run through the same recycling processes as fossil-based plastics, the development of novel polymers will require separate treatment from the existing polymers. This complicates recycling systems and may result in a decrease in recycling rate overall.

Measures 4 & 7

- Measure 4 – Recycled content in plastic products
- Measure 7 – Recycling of post-consumer plastics

The incorporation of recycled content within plastic products is contingent on having the available feedstock. Recycling of post-consumer plastics directly provides the feedstock for recycled content in plastic products. Thus, without plastics recycling there can be no recycled content.

Measures 6 & 7

- Measure 6 – Reuse of plastic products
- Measure 7 – Recycling of post-consumer plastics

A shift towards reusable business models will have an impact on waste generation. While this would be positive for resource efficiency within the plastics sector as a whole, it is likely that the composition of waste generated will also shift. This could have the outcome of creating waste streams that are either more or less difficult to recycle. In either case this would have an impact on the recycling rate of post-consumer plastics.

8.2 Interdependencies with other sectors

Chemicals Sector

The plastics sector is deeply interconnected with the chemicals sector. The chemicals sector serves as the primary producer for all plastics products and, as indicated in the introduction of this report, the two sectors share a value chain. Consequently, many of the measures implemented in the plastics sector will have a ripple effect upstream on the chemicals sector and vice versa. For example, if products are designed to be lighter, it will result in lower consumption of chemicals and, subsequently, a reduction in overall material extraction within that sector. Additionally, if recycling rates within the plastics sector increase, the extraction demand for the chemicals to produce these polymers can be expected to decrease. Indeed, every measure that results in a resource efficiency improvement within the plastics sector will have the knock-on effect of decreasing demand for fossil-based plastics feedstocks from the chemical sector. Therefore, it is crucial to consider not only the plastics sector itself but the chemicals sector in tandem as the chemicals sector plays a significant role in the plastics supply chain and can significantly contribute to overall efforts aimed at achieving resource efficiency.

Food and Drink

Plastic is often utilised as a packaging material for food and drink products. This packaging can have an impact on resource efficiency within the food and drink sector as it offers protection and preservation of perishable products, extending shelf-life and reducing food waste. However, there is often a trade-off in terms of the GHG emissions associated with plastic packaging, as packaging that utilises more material can also have higher embedded GHG emissions associated with production and transportation. Resource efficiency measures within the plastics sector may result in the deterioration of the packaging’s ability to preserve food and drink products. Additionally, improvements in packaging to reduce food waste (e.g., packaging for longer life, resealable packaging, or smaller portion sizes) may require the use of additional plastic material.

Material Substitution Sectors (paper, glass, steel)

The aim of this project is to explore resource efficiency within the plastics sector while delivering equivalent utility, rather than a reduction in overall consumption. As such, a reduction in plastic use through material substitution will result in an increase in consumption of those materials being used to replace plastic products. This includes materials from other sectors within scope of this project (e.g., paper, glass, steel) and those outside of scope of this project (e.g., aluminium, cotton). Technological advancements made within plastics and alternate material markets might drive material substitution either away from or towards plastic. For example, the development of electric arc furnace technology leading to the decarbonisation of steel could drive material use away from single-use plastic and towards reusable steel within packaging, as suggested by stakeholders during this study. When considering the impact of material substitution on resource use, it is important to consider the many factors that determine whether materials should be substituted including LCAs, specific requirements of the product and contextual factors to the company manufacturing them. It is therefore a complex system and difficult to estimate the net impacts on each sector and material.

Sectors that Utilise Plastic Products (textiles, construction, electronics, vehicles)

Although plastics are most commonly used as a packaging material, plastics are also widely used to produce products themselves. These products are utilised across many sectors evaluated over the course of the “Unlocking Resource Efficiency” project such as textiles (e.g., polyester), construction (e.g., pipes), electronics (e.g., buttons, casings), and vehicles (e.g., dashboards, bumpers). This results in substantial overlap between the plastics materials sector and the industries in which these materials are applied. For example, efforts to lightweight products within the construction or vehicles sectors might serve as a driver of material substitution away from steel and towards plastics. Additionally, materials selected for recyclability might be informed by the capacity of the UK market to reliably capture and recycle plastic materials. As a result, an increase in plastics recycling capacity may result in an increase in the use of plastic materials across these industries. These industries may also exhibit an interdependent relationship with each other with regard to the use of recycled plastics as this will rely on a large enough supply of recycled material to be available for each industry to increase its recycled content according to its targets.

Glossary and abbreviations

B2B	Business-to-business
BAU	Business-as-usual
BPF	British Plastics Federation
D4R	Design for recycling
EMF	Ellen MacArthur Foundation
EPR	Extended producer responsibility
FTY	First time yield
GHG	Greenhouse gas
HDPE	High density polyethylene
IAS	Indicative applicability score
MORE	Monitoring Recyclates for Europe
MRF	Material recovery facility
PE	Polyethylene
PEF	Polyethylene furanoate
PET	Polyethylene terephthalate
PHA	Polyhydroxyalkanoates
PLA	Polylactic acid
PP	Polypropylene
PPWR	Packaging and Packaging Waste Regulation
PRE	Plastic Recyclers Europe
PRN	Packaging recovery note
PS	Polystyrene
PTT	Polytrimethylene terephthalate
PUR	Polyurethane

PVC	Polyvinyl chloride
RE	Resource efficiency
SUPD	Single-Use Plastic Directive

Appendix A: IAS Scoring Parameters

Table 34: Methodology for the calculation of the IAS

Number of ‘high’ criteria	Number of ‘low’ criteria	IAS
Indifferent	3 or more	1
<= 1	2	2
>= 2	2	3
<= 2	1	3
>= 3	1	4
<= 1	None	3
2	None	4
>= 3	None	5

Table 35: IAS Scoring Parameters

Criteria	High	Medium	Low
Geography	Specific to UK	Non-UK but applicable to the UK	Non-UK and not applicable to the UK
Date of publication	< 10 years	10 to 20 years	> 20 years
Sector applicability	Sector and measure-specific, discusses RE and circularity	Sector and measure-specific, focus on decarbonisation	Cross-sector
Methodology	Research methodology well defined and deemed appropriate	Research methodology well defined but not deemed appropriate / Minor description of research methodology	No research methodology
Peer Review	Explicitly mentioned peer review	Not explicitly mentioned, but assumed to have been peer reviewed	Unknown

Appendix B: Search strings

- Measure 1 – Lean Design of Plastic Products:
    - (plastic OR polymer) AND (light weight* OR light-weight* OR lightweight*)
    - ("uk" OR "united kingdom" OR "great britain") AND (plastic OR polymer) AND (light weight* OR light-weight* OR lightweight*)
- Measure 2 – Material Substitution with Non-Plastic Materials:
    - (plastic OR polymer) AND (alternative OR substitute) AND (circular* OR environment* OR resource efficien* OR sustainab*)
    - ("uk" OR "united kingdom" OR "great britain") AND (plastic OR polymer) AND (alternative OR substitute) AND (circular* OR environment* OR resource efficien* OR sustainab*)
    - (plastic OR polymer) AND (alternative OR substitute) AND (circular* OR environment* OR resource efficien* OR sustainab*) AND (carbon OR CO2* OR emissions OR lifecycle OR life-cycle OR "life cycle" OR LCA)
    - ("uk" OR "united kingdom" OR "great britain") AND (plastic OR polymer) AND (alternative OR substitute) AND (circular* OR environment* OR resource efficien* OR sustainab*) AND (carbon OR CO2* OR emissions OR lifecycle OR life-cycle OR "life cycle" OR LCA)
- Measure 3 – Feedstock Substitution with Bio-Based Plastic:
    - (plastic OR polymer) AND (biodegrad* OR bio-degrad* OR compost*)
    - ("uk" OR "united kingdom" OR "great britain") AND (plastic OR polymer) AND (biodegrad* OR bio-degrad* OR compost*)
    - (plastic OR polymer) AND (biodegrad* OR bio-degrad* OR compost*) AND (carbon OR CO2* OR emissions OR lifecycle OR life-cycle OR "life cycle" OR LCA)
    - ("uk" OR "united kingdom" OR "great britain") AND (plastic OR polymer) AND (biodegrad* OR bio-degrad* OR compost*) AND (carbon OR CO2* OR emissions OR lifecycle OR life-cycle OR "life cycle" OR LCA)
    - (plastic OR polymer) AND (biobased OR bio-based)
    - ("uk" OR "united kingdom" OR "great britain") AND (plastic OR polymer) AND (biobased OR bio-based)
    - (plastic OR polymer) AND (biobased OR bio-based) AND (carbon OR CO2* OR emissions OR lifecycle OR life-cycle OR "life cycle" OR LCA)
    - ("uk" OR "united kingdom" OR "great britain") AND (plastic OR polymer) AND (biobased OR bio-based) AND (carbon OR CO2* OR emissions OR lifecycle OR life-cycle OR "life cycle" OR LCA)

- Measure 4 – Recycled Content in Plastic Products:
    - (plastic OR polymer) AND ("recycled content" OR "recycled material" OR "consumer content")
    - ("uk" OR "united kingdom" OR "great britain") AND (plastic OR polymer) AND ("recycled content" OR "recycled material" OR "consumer content")
- Measure 5 – Waste Reduction in Product Manufacturing:
    - (plastic OR polymer) AND (low* OR reduc* OR minim*) AND (manufactur* OR process* OR produc*) AND waste
    - ("uk" OR "united kingdom" OR "great britain") AND (plastic OR polymer) AND (low OR reduction OR minim*) AND (manufactur* OR process* OR production) AND waste
    - (plastic OR polymer) AND (low OR reduction OR minim*) AND (manufactur* OR process* OR production) AND (efficient OR efficiency)
    - ("uk" OR "united kingdom" OR "great britain") AND (plastic OR polymer) AND (low OR reduction OR minim*) AND (manufactur* OR process* OR production) AND (efficient OR efficiency)
- Measure 6 – Reuse of Plastic Products:
    - (plastic OR polymer) AND (shar* OR leas* OR hir*)
    - ("uk" OR "united kingdom" OR "great britain") AND (plastic OR polymer) AND (shar* OR leas* OR hir*)
    - (plastic OR polymer) AND (circular* OR environment* OR resource efficien* OR sustainab*) AND (demand OR uptake)
    - ("uk" OR "united kingdom" OR "great britain") AND (plastic OR polymer) AND (circular* OR environment* OR resource efficien* OR sustainab*) AND (demand OR uptake)
    - (plastic OR polymer) AND (durab* OR reuse OR re-use OR refill OR re-fill OR repair* OR lifespan OR life-span OR "life span" OR extend* OR modular*)
    - ("uk" OR "united kingdom" OR "great britain") AND (plastic OR polymer) AND (durab* OR reuse OR re-use OR refill OR re-fill OR repair* OR lifespan OR life-span OR "life span" OR extend* OR modular*)
- Measure 7 – Plastics Recycling Rate:
    - (plastic OR polymer) AND (recycl* OR reprocess* OR re-process* OR remanufactur* OR re-manufactur*) AND (post-consumer OR "post consumer")
    - ("uk" OR "united kingdom" OR "great britain") AND (plastic OR polymer) AND (recycl* OR reprocess* OR re-process* OR remanufactur* OR re-manufactur*) AND (post-consumer OR "post consumer")
    - (plastic OR polymer) AND (recycl* OR reprocess* OR re-process* OR remanufactur* OR re-manufactur*) AND (post-industrial OR "post industrial")

  - ("uk" OR "united kingdom" OR "great britain") AND (plastic OR polymer) AND (recycl* OR reprocess* OR re-process* OR remanufactur* OR re-manufactur*) AND (post-industrial OR "post industrial")
- Additional search terms to capture literature relating to plastic and resource efficiency:
  - (plastic OR polymer) AND (circular* OR environment* OR resource efficien* OR sustainab*)
  - ("uk" OR "united kingdom" OR "great britain") AND (plastic OR polymer) AND (circular* OR environment* OR resource efficien* OR sustainab*)
  - (plastic OR polymer) AND (circular* OR environment* OR resource efficien* OR sustainab*) AND (carbon OR CO2* OR emissions OR lifecycle OR life-cycle OR "life cycle" OR LCA)
  - ("uk" OR "united kingdom" OR "great britain") AND (plastic OR polymer) AND (circular* OR environment* OR resource efficien* OR sustainab*) AND (carbon OR CO2* OR emissions OR lifecycle OR life-cycle OR "life cycle" OR LCA)
  - (plastic OR polymer) AND (circular* OR environment* OR resource efficien* OR sustainab*) AND (design* OR "eco-design" OR "eco design" OR "ecodesign")
  - ("uk" OR "united kingdom" OR "great britain") AND (plastic OR polymer) AND (circular* OR environment* OR resource efficien* OR sustainab*) AND (design* OR "eco-design" OR "eco design" OR "ecodesign")
  - (plastic OR polymer) AND (mono-material OR "mono material" OR recyclability)
  - ("uk" OR "united kingdom" OR "great britain") AND (plastic OR polymer) AND (mono-material OR "mono material" OR recyclability)
  - (plastic OR polymer) AND (alternative OR substitute) AND (circular* OR environment* OR resource efficien* OR sustainab*) AND (polymer OR resin)
  - ("uk" OR "united kingdom" OR "great britain") AND (plastic OR polymer) AND (alternative OR substitute) AND (circular* OR environment* OR resource efficien* OR sustainab*) AND (polymer OR resin)
  - (plastic OR polymer) AND (recycl* OR reprocess* OR re-process* OR remanufactur* OR re-manufactur*)
  - ("uk" OR "united kingdom" OR "great britain") AND (plastic OR polymer) AND (recycl* OR reprocess* OR re-process* OR remanufactur* OR re-manufactur*)
  - (plastic OR polymer) AND (sort* OR captur* OR detect* OR mrf OR "near infrared" OR "near infra-red" OR " near infra red")
  - ("uk" OR "united kingdom" OR "great britain") AND (plastic OR polymer) AND (sort* OR captur* OR detect* OR detecting OR mrf OR "near infrared" OR "near infra-red" OR " near infra red")
  - (plastic OR polymer) AND (biodegrad* OR compost* OR anaerobic* OR ad OR ivc OR windrow)

- ("uk" OR "united kingdom" OR "great britain") AND (plastic* OR polymer*) AND (biodegrad* OR compost* OR anaerobic* OR ad OR ivc OR windrow)

Appendix C: Literature sources

Table 40 below lists the literature sources for the plastics sector.

Table 36: List of literature sources for the plastics sector

Title	URL	Author	Year	IAS
Biobased building blocks and polymers in the world: capacities, production, and applications–status quo and trends towards 2020	https://www.researchgate.net/publication/277901567_2nd_edition_Bio-based_Building_Blocks_and_Polymers_in_the_World_Capacities_Production_and_Applications_-_Status_Quo_and_Trends_Towards_2020	Aeschelmann, F. & Carus, M.	2015	**4**
An extended life cycle analysis of packaging systems for fruit and vegetable transport in Europe	https://link.springer.com/article/10.1007/s11367-013-0590-4	Albrecht et al.	2013	**4**
Reducing plastic waste: A meta-analysis of influences on behaviour and interventions	https://www.sciencedirect.com/science/article/pii/S095965262204433X	Allison et al.	2022	**4**
Quality Improvement in Plastic Injection Molding Industry: Applying Lean Six Sigma to SME in Kuwait	https://ieomsociety.org/ieom2018/papers/666.pdf	Alshammari et al.	2018	**2**
Recycling of post-consumer plastic packaging waste in the EU: Recovery rates, material flows, and barriers	https://www.sciencedirect.com/science/article/pii/S0956053X21001999	Antonopoulos et al.	2021	**5**
Recycling of post-consumer plastic packaging waste in the EU: Recovery rates, material flows, and barriers.	https://www.sciencedirect.com/science/article/pii/S0956053X21001999	Antonopoulos, I., Faraca, G. & Tonini, D.	2021	**5**
Product Environmental Report: iPhone 14 Pro Max	https://www.apple.com/environment/	Apple	2022	**1**
Reducing plastic waste through voluntary agreements. Learning from the EU Green Deal implementation	https://www.eeas.europa.eu/sites/default/files/documents/2023/EU%20Project%20in%20Canada%20-%20Green%20Deals%20Policy%20Brief%20January%20%202023_0.pdf	Bauer et al.	2023	**5**
Does biobased polymer achieve better environmental impacts than fossil polymer? Comparison of fossil HDPE and	https://www.sciencedirect.com/science/article/abs/pii/S0961953415301860	Belboom and Leonard	2016	**5**

Title	URL	Author	Year	IAS
biobased HDPE produced from sugar beet and wheat				
Key metrics to measure the performance and impact of reusable packaging in circular supply chains	https://www.frontiersin.org/articles/10.3389/frsus.2022.910215/full	Betts et al.	2022	**4**
Service contract on management of construction and demolition waste	https://www.btbab.com/wp-content/uploads/documentos/legislacion/UE-BIO_Construction_and_demolition_waste_final_report_09022011.pdf	Bio Intelligence Service	2011	**4**
Plastics: Recycling and Sustainability	https://www.bpf.co.uk/Sustainability/Plastics_and_Sustainability.aspx	BPF	N.D.	**1**
The impact of plastic packaging on life cycle energy consumption and greenhouse gas emissions in Europe	https://plasticseurope.org/wp-content/uploads/2021/10/2011-Denkstatt-Summary-E-GHG_Packaging.pdf	Brandt and Pilz	2011	**4**
About The British Plastics Industry	About The British Plastics Industry (bpf.co.uk)	British Plastics Federation	N.D. (website accessed 2023)	**3**
British Plastics Federation Recycling Roadmap	Recycling Roadmap (bpf.co.uk)	British Plastics Federation	2021	**5**
British Plastic Federation: Plastic Recycling	https://www.bpf.co.uk/Sustainability/Plastics_Recycling.aspx#s4	British Plastics Federation	2022	**3**
Recycled content used in plastic packaging applications	https://www.fdf.org.uk/globalassets/resources/publications/bpf-recycled-content-used-plastic-packaging-applications-july-2020-revision.pdf	British Plastics Federation	2020	**3**
Welcome to our Interim Life Cycle Analysis of British Recycled Plastic – 29 July 2022	https://britishrecycledplastic.co.uk/interim-life-cycle-analysis-of-british-recycled-plastic-29-july-2022/	British Recycled Plastic	2022	**3**
The Unintended Side Effects of Bioplastics: Carbon, Land, and Water Footprints	https://www.sciencedirect.com/science/article/pii/S2590332220303055	Brizga et al.	2020	**5**
The future of UK plastics recycling: One Bin to Rule Them All.	https://www.sciencedirect.com/science/article/pii/S0921344920305085	Burgess et al.	2021	**5**
Chemical Recycling: Delivering recycled content to meet the EU's circular economy	https://cefic.org/app/uploads/2022/12/Chemical-Recycling-Delivering-recycled-content-to-meet-the-EUs-	CEFIC	2022	**5**

Title	URL	Author	Year	IAS
ambitions - the Single Use Plastics Directive Implementing Act and the Packaging and Packaging Waste Directive revision.	circular-economy-ambitions-—-the-Single-Use-Plastics-Directive-Implementing-Act-and-the-Packaging-and-Packaging-Waste-Directive-revision.pdf			
Global Markets and Technologies for Bioplastics	https://www.bccresearch.com/market-research/plastics/global-markets-and-technologies-for-bioplastics.html	Chen J.	2019	**4**
Supporting evidence Environmental performance of beverage cartons	https://www.beveragecarton.eu/wp-content/uploads/2021/03/20-011-Circular-Analytics_ACE-Full-report_2021-03-11.pdf	Circular Analytics	2020	**4**
The European Plastics Industry Voluntary Commitments	https://www.circularplastics.org/	Circular Plastics	2018	**3**
Circular Plastics Alliance - State of Play on Collection and Sorting: Electronics and Electrical Equipment Working Group	https://ec.europa.eu/docsroom/documents/43694	Circular Plastics Alliance	2020	**3**
Circular Plastics Alliance - State of Play on Collection and Sorting: Construction Working Group	https://ec.europa.eu/docsroom/documents/43694	Circular Plastics Alliance	2020	**4**
Sustainability of Reusable Packaging – Current Situation and Trends	https://www.sciencedirect.com/science/article/pii/S2590289X20300086	Coelho et al.	2020	**3**
Guidance on applying the Waste Hierarchy	https://assets.publishing.service.gov.uk/media/5a795abde5274a2acd18c223/pb13530-waste-hierarchy-guidance.pdf	Defra	2011	**3**
Extended Producer Responsibility for Packaging: Summary of Consultation Responses and Government Response	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1063589/epr-consultation-government-response.pdf	Defra	2022	**5**
The Sustainable Consumer 2023	https://www2.deloitte.com/uk/en/pages/consumer-business/articles/sustainable-consumer.html?ref=charterworks.com	Deloitte	2023	**2**
How circular are plastics in the UK?: Findings from Material Flow Analysis	https://discovery.ucl.ac.uk/id/eprint/10117315/3/Domenech%20Aparisi_Domenech_Teresa_HowCircularAre	Domenech et al.	2020	**5**

Title	URL	Author	Year	IAS
	PlasticsintheUK_submitted.pdf#:~:text=This%20paper%20aims%20to%20contribute%20to%20a%20comprehensive,and%20fibres%20to%20consumption%20and%20end%20of%20life.			
Carbon footprint analysis in plastics manufacturing	https://www.sciencedirect.com/science/article/abs/pii/S095965261300019X	Dormer et al.	2013	**4**
What to Do about Plastics? Lessons from a Study of United Kingdom Plastics Flows	https://pubs.acs.org/doi/pdf/10.1021/acs.est.3c00263	Drewnoik et al.	2023	**5**
Too Good To Be True? A Study of Green Claims On Plastic Products	https://ecostandard.org/wp-content/uploads/2021/07/ECOS-RPa-REPORT-Too-Good-To-Be-True.pdf	ECOS	2021	**4**
The New Plastics Economy: Rethinking the Future of Plastics & Catalysing Action	https://emf.thirdlight.com/file/24/RrpCWLER-yBWPZRrwSoRrB9KM2/The%20New%20Plastics%20Economy%3A%20Rethinking%20the%20future%20of%20plastics%20%26%20catalysing%20action.pdf	Ellen MacArthur Foundation	2017	**4**
Upstream Innovation: a guide to packaging solutions.	https://ellenmacarthurfoundation.org/upstream-innovation/overview	Ellen MacArthur Foundation	2020	**3**
Reuse – rethinking packaging	https://ellenmacarthurfoundation.org/reuse-rethinking-packaging	Ellen MacArthur Foundation	2019	**1**
Global Commitment 2021 Progress Report	https://ellenmacarthurfoundation.org/global-commitment-2021/overview	Ellen MacArthur Foundation	2022	**3**
Global Commitment 2022	https://www.ellenmacarthurfoundation.org/global-commitment-2022/overview	Ellen MacArthur Foundation	2022	**3**
Dynamic Material Flow Analysis of PET, PE, and PP Flows in Europe: Evaluation of the Potential for Circular Economy	https://pubs.acs.org/doi/full/10.1021/acs.est.0c03435	Eriksen et al.	2020	**5**
Bioplastics - Facts and Figures	https://docs.european-bioplastics.org/publications/EUBP_Facts_and_figures.pdf	European Bioplastics	2023	**3**

Title	URL	Author	Year	IAS
Fact Sheet: Bioplastics – Industry Standards & Labels	https://docs.european-bioplastics.org/publications/fs/EUBP_FS_Standards.pdf	European Bioplastics	2023	3
A European Strategy for Plastics in a Circular Economy	Eu-plastics-strategy-brochure.pdf (europarc.org)	European Commission	2018	3
Biobased plastics: Sustainable Sourcing & Content	https://op.europa.eu/en/publication-detail/-/publication/06d4f39d-70c9-11ed-9887-01aa75ed71a1/language-en	European Commission	2022	5
EU Packaging and Packaging Waste Directive (2018/852)	https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32018L0852	European Commission	2018	5
Circular Plastics Alliance - State of Play on Collection and Sorting: Automotive Working Group	https://ec.europa.eu/docsroom/documents/43694	European Commission, Circular Plastics Alliance	2020	5
Circular Plastics Alliance - State of Play on Collection and Sorting: Packaging Working Group	https://ec.europa.eu/docsroom/documents/43695	European Commission, Circular Plastics Alliance	2020	5
Environmental effects of plastic waste recycling	https://publications.jrc.ec.europa.eu/repository/handle/JRC122455	European Commission, Joint Research Centre	2021	5
Recycled plastic prices double as drinks makers battle for supplies	https://www.ft.com/content/122e7584-c837-44bc-9965-9fd37d7c03ca	Financial Times	2022	1
Household collections with FPF FlexCollect	https://flexibleplasticfund.org.uk/flexcollect	Flexible Plastic Fund	2022	1
Alternatives to single-use plastics in food packaging and production	https://www.food.gov.uk/print/pdf/node/20076	Food Standards Agency	2023	5
Development of an integrated sustainability matrix to depict challenges and trade-offs of introducing bio-based plastics in the foodpackaging value chain	https://www.researchgate.net/publication/347334181_Development_of_an_integrated_sustainability_matrix_to_depict_challenges_and_trade-offs_of_introducing_bio-based_plastics_in_the_food_packaging_value_chain	Gerassimidou et al.	2021	5
Closing the Plastics Circularity Gap: Full Report	https://www.gstatic.com/gumdrop/sustainability/closing-plastics-gap-full-report.pdf	Google and AFARA	2022	4

Title	URL	Author	Year	IAS
An attractive and sustainable solution	https://www.grahampackaging.com/solutions/lightweighting/active-base	Graham packaging	N.D.	**1**
Fixing the system: Why a circular economy for all materials is the only way to solve the plastic problem. (Including Methodology)	https://green-alliance.org.uk/wp-content/uploads/2021/11/Fixing_the_system.pdf	Green Alliance	2020	**5**
Completing the circle: Creating effective UK markets for recovered resources	https://green-alliance.org.uk/publication/completing-the-circle-creating-effective-uk-markets-for-recovered-resources/	Green Alliance	2021	**3**
How Fast Fashion is using the Global South as a dumping ground for textile waste	https://www.greenpeace.org/static/planet4-international-stateless/2022/04/9f50d3de-greenpeace-germany-poisoned-fast-fashion-briefing-factsheet-april-2022.pdf	Greenpeace	2022	**2**
Comparative cradle-to-grave life cycle assessment of bio-based and petrochemical PET bottles	https://www.sciencedirect.com/science/article/pii/S0048969721037141	Gursel et al.	2021	**5**
Post-consumer plastic packaging waste in England: Assessing the yield of multiple collection-recycling schemes	https://www.sciencedirect.com/science/article/pii/S0956053X18300758?via%3Dihub	Hahladakis et al.	2018	**5**
Plastic Waste and Recycling: Environmental Impact, Societal Issues, Prevention, and Solutions. Chapter 5: Biodegradable Plastics	https://www.researchgate.net/profile/Mohanraj-Chandran/publication/339905534_Conversion_of_plastic_waste_to_fuel/links/5e982e474585150839e08d12/Conversion-of-plastic-waste-to-fuel.pdf#page=121	Havstad	2020	**4**
From single-use to reuse: development of a decision support tool for FMCG packaging	https://essay.utwente.nl/89731/1/Hesseling_MA_ET_2.pdf	Hesseling	2022	**2**
How circular are plastics in the EU?: MFA of plastics in the EU and pathways to circularity	https://www.sciencedirect.com/science/article/pii/S2666789420300040	Hsu et al.	2021	**5**
The impact of nature documentaries on public environmental preferences and willingness to pay: entropy balancing and the	https://www.tandfonline.com/doi/full/10.1080/09640568.2020.1828840	Hynes et al.	2020	**5**

Title	URL	Author	Year	IAS
blue planet II effect. Journal of Environmental Planning and Management. 64:8. pp1428-1456.				
Biopolymers facts and statistics: 2022 - Production capacities, processing routes, feedstock, land and water use	https://www.ifbb-hannover.de/files/IfBB/downloads/faltblaetter_broschueren/f+s/Biopolymers-Facts-Statistics-einseitig-2022.pdf	IfBB - Institute for Bioplastics and Biocomposites	2023	**4**
Resource efficiency and climate change: material efficiency strategies for a low-carbon future.	https://www.unep.org/resources/report/resource-efficiency-and-climate-change-material-efficiency-strategies-low-carbon	International Resource Panel	2020	**4**
ISO 16620:2015 Plastics – Biobased Content	https://www.iso.org/standard/63766.html	ISO	2015	**3**
ISO 14021:2016(en) Environmental labels and declarations — Self-declared environmental claims (Type II environmental labelling).	https://www.iso.org/standard/66652.html	ISO	2016	**3**
Plastic Waste and Recycling: Environmental Impact, Societal Issues, Prevention, and Solutions. Chapter 4: Biobased Plastics	https://www.researchgate.net/profile/Mohanraj-Chandran/publication/339905534_Conversion_of_plastic_waste_to_fuel/links/5e982e474585150839e08d12/Conversion-of-plastic-waste-to-fuel.pdf#page=89	Kabasci	2020	**4**
Sustainability management in plastics processing	https://www.bpf.co.uk/Publications/sustainability-management-in-plastics-processing.aspx	Kent, R.	2022	**5**
Potentials and limits of mechanical plastic recycling	https://onlinelibrary.wiley.com/doi/pdf/10.1111/jiec.13393	Klotz et al.	2023	**5**
Reusable plastic crate or recyclable cardboard box? A comparison of two delivery systems	https://www.researchgate.net/publication/261187569_Reusable_plastic_crate_or_recyclable_cardboard_box_A_comparison_of_two_delivery_systems	Koskela et al.	2014	**5**
Potential trade-offs between eliminating plastics and mitigating climate change: An LCA perspective on Polyethylene Terephthalate (PET) bottles in Cornwall	Potential trade-offs between eliminating plastics and mitigating climate change: An LCA perspective on Polyethylene Terephthalate (PET) bottles in Cornwall - ScienceDirect	Koulompis et al.	2020	**5**

Title	URL	Author	Year	IAS
How Much Can Chemical Recycling Contribute to Plastic Waste Recycling in Europe? An Assessment Using Material Flow Analysis Modelling	https://www.sciencedirect.com/science/article/pii/S0921344923000538#:~:text=This%20paper%20uses%20prospective%20material%20flow%20analysis%20%28MFA%29,would%20improve%20plastic%20recycling%20rate%20up%20to%2080%25.	Lase et al.	2023	**5**
The Environmental Protection (Plastic Plates etc. and Polystyrene Containers etc.) (England) Regulations 2023	https://www.legislation.gov.uk/uksi/2023/982/contents/made	Legistlation.gov.uk	2023	**5**
The Environmental Protection (Single-use Plastic Products) (Scotland) Regulations 2021	https://www.legislation.gov.uk/ssi/2021/410/contents/made	Legistlation.gov.uk	2023	**5**
The Environmental Protection (Single-use Plastic Products) (Wales) Act 2023	https://www.legislation.gov.uk/en/asc/2023/2/contents/enacted	Legistlation.gov.uk	2023	**5**
The Packaging Waste (Data Reporting) (England) Regulations 2023	https://www.legislation.gov.uk/uksi/2023/219/contents/made	Legistlation.gov.uk	2023	**5**
Waste (Miscellaneous Amendments) (EU Exit) Regulations 2019	https://www.legislation.gov.uk/uksi/2019/620/made	Legistlation.gov.uk	2019	**5**
Plastic Waste and Recycling: Environmental Impact, Societal Issues, Prevention, and Solutions.	https://www.researchgate.net/profile/Mohanraj-Chandran/publication/339905534_Conversion_of_plastic_waste_to_fuel/links/5e982e474585150839e08d12/Conversion-of-plastic-waste-to-fuel.pdf#page=89	Letcher	2020	**4**
High energy costs put plastic recycling 'at risk'	https://www.letsrecycle.com/news/high-energy-costs-putting-plastic-recycling-at-risk/	Lets Recycle	2022	**2**
OPRL Adds In-Store Recycling Labels to Crisp Packets.	https://www.letsrecycle.com/news/oprl-adds-in-store-recycling-labels-to-crisp-packets/	Lets Recycle	2021	**3**
A Perspective on PEF Synthesis, Properties, and End-Life	https://www.frontiersin.org/articles/10.3389/fchem.2020.00585/full	Loos et al.	2020	**3**
Plastic waste	https://commonslibrary.parliament.uk/research-briefings/cbp-8515/	Louise Smith	2022	**5**
Assessment of Performance and Challenges in Use of	https://www.mdpi.com/2313-4321/7/2/11	Lubongo and Alexandridis	2022	**3**

Title	URL	Author	Year	IAS
Commercial Automated Sorting Technology for Plastic Waste				
Sustainable packaging: the role of materials substitution.	https://materialeconomics.com/publications/publication/sustainable-packaging	Material Economics	2018	3
The potential impact of reusable packaging	https://www.mckinsey.com/industries/packaging-and-paper/our-insights/the-potential-impact-of-reusable-packaging	McKinsey & Company	2023	3
The changing nature of life cycle assessment	https://www.sciencedirect.com/science/article/pii/S0961953415001609	McManus and Taylor	2015	3
Using regional material flow analysis and geospatial mapping to support the transition to a circular economy for plastics	https://pureadmin.qub.ac.uk/ws/portalfiles/portal/273381368/Revised_manuscript_Clean_version_R2.pdf	Mehta et al.	2021	5
Six Sigma Methodology In A Plastic Injection Molding Industry: A Case Study	http://irphouse.com/ijiet/ijietv7m1_03.pdf	Mishra et al.	2015	2
Carbon and energy footprints of high-value food trays and lidding films made of common bio-based and conventional packaging materials	https://www.sciencedirect.com/science/article/pii/S2666789421000507	Nejad et al.	2021	5
Driving change: A circular economy for automotive plastic	https://static1.squarespace.com/static/5a60c3cc9f07f58443081f58/t/61953204084ffd6e6fa89480/1637167623043/Circular+economy+for+automotive+plastics+-+Sept+2021_Final.pdf	Oakdene Hollins	2021	3
OECD Global Plastics Outlook to 2060	https://www.oecd-ilibrary.org/sites/aa1edf33-en/1/3/1/index.html?itemId=/content/publication/aa1edf33-en&_csp_=ca738cf5d4f327be3b6fec4af9ce5d12&itemIGO=oecd&itemContentType=book#section-d1e841	OECD	2022	3
On-Pack Recycling Label: About OPRL	https://oprl.org.uk/about-oprl/	OPRL	2023	3
Plastic IQ Methodology Document	https://plasticiq.org/resources/	Plastic IQ	2021	3

Title	URL	Author	Year	IAS
The Massive Dumping of Discarded Clothing in Ghana and Chile Must Stop	https://www.plasticsoupfoundation.org/en/2022/03/the-massive-dumping-of-discarded-clothing-in-ghana-and-chile-must-stop/	Plastic Soup Foundation	2022	**1**
The Circular Economy for Plastics	https://plasticseurope.org/knowledge-hub/the-circular-economy-for-plastics-a-european-overview-2/	Plastics Europe	2022	**5**
Plastics - The Facts 2022	https://plasticseurope.org/wp-content/uploads/2023/03/PE-PLASTICS-THE-FACTS_FINAL_DIGITAL-5.pdf	Plastics Europe	2022	**3**
Circular Economy for Plastics: United Kingdom - 2020	https://plasticseurope.org/wp-content/uploads/2023/02/PlasticsEurope-National_ALL.pdf	Plastics Europe	2023	**3**
Plastics - The Facts 2023	https://plasticseurope.org/knowledge-hub/plastics-the-fast-facts-2023/	Plastics Europe	2023	**3**
2021 RecoTrace Data Collection Results	Not public	PolyRec	2021	**3**
Environmental benefits of material-efficient design: A hybrid life cycle assessment of a plastic milk bottle	https://www.sciencedirect.com/science/article/abs/pii/S2352550922000252?via%3Dihub	Pomponi et al.	2022	**5**
Mechanical and chemical recycling of solid plastic waste	https://www.sciencedirect.com/science/article/abs/pii/S0956053X17305354	Ragaert et al.	2017	**5**
Plastic Packaging Recyclability By Design 2023	https://www.recoup.org/research-and-reports/recoup-recyclability-by-design-2023/	RECOUP	2023	**5**
Realising Reuse: The Potential for Scaling Up Reusable Packaging and Policy Recommendations.	https://rethinkplasticalliance.eu/wp-content/uploads/2021/07/Realising-Reuse-Final-report-July-2021.pdf	Rethink Plastic	2021	**3**
Rewindo Fenster-Recycling Service	https://rewindo.de/	Rewindo	n.d.	**3**
Implementing the Dimension of Quality into the Conventional Quantitative Definition of Recycling Rates.	https://www.sciencedirect.com/science/article/abs/pii/S0956053X20300921	Roithner and Rechberger	2020	**4**
Bioplastics for a circular economy	https://www.nature.com/articles/s41578-021-00407-8	Rosenboom et al.	2022	**4**

Title	URL	Author	Year	IAS
Barriers to recycling plastics from the perspectives of industry stakeholders: a qualitative study.	https://www.tandfonline.com/doi/full/10.1080/1943815X.2023.2190379	Roy et al.	2023	**4**
Beyond recycling: An LCA-based decision-support tool to accelerate Scotland's transition to a circular economy	https://www.sciencedirect.com/science/article/pii/S2667378922000074	Salembdeeb et al.	2022	**5**
Bioplastic production in terms of life cycle assessment: A state-of-the-art review	https://www.sciencedirect.com/science/article/pii/S2666498423000194	Samir Ali et al	2023	**5**
Supplemental Criteria for Electrical and Electronic Equipment: SCS-103 Recycled Content Standard Annex A	https://www.scsstandards.org/standards/recycled-content-standard-annexA#:~:text=The%20SCS-103%20Annex%20A%20sets%20a%20minimum%20threshold,in%20products%20with%20higher%20levels%20of%20recycled%20content.	SCS Standards	2023	**2**
SCS Certification Standard for Biobased Content SCS-114 Biobased Content Standard	https://cdn.scsstandards.org/files/2023-03/SCS%20Standard_114_FS_V1.0%20%282023%29_0.pdf	SCS Standards	2023	**3**
Plastics in the context of the circular economy and sustainable plastics recycling: Comprehensive review on research development, standardization and market	https://www.sciencedirect.com/science/article/pii/S2666682021000633	Shamsuyeva and Endres	2021	**4**
Rethinking and Optimizing plastic waste management under COVID-19 pandemic: Policy solutions based on redesign and reduction of single-use plastics and personal protective equipment	https://www.researchgate.net/publication/342551974_Rethinking_and_optimising_plastic_waste_management_under_COVID-19_pandemic_Policy_solutions_based_on_redesign_and_reduction_of_single-use_plastics_and_personal_protective_equipment	Silva et al.	2020	**3**
Plastic Futures and their CO2 Emissions	https://www.nature.com/articles/s41586-022-05422-5	Stegmann et al.	2021	**4**
Bio-based plastics: status, challenges and trends	https://www.researchgate.net/publication/265433282_Bio-based_plastics_status_challenges_and_trends	Storz, H. and Vorlop, K. D.	2013	**4**

Title	URL	Author	Year	IAS
ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe	https://plasticseurope.org/wp-content/uploads/2022/04/SYSTEMIQ-ReShapingPlastics-April2022.pdf	SystemIQ	2022	4
Breaking the Plastic Wave Thought Partners: Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution	https://www.pewtrusts.org/-/media/assets/2020/07/breakingtheplasticwave_report.pdf	Systemiq et al.	2020	3
Global Bioplastic Packaging Market 2019-2023	https://www.businesswire.com/news/home/20190314005330/en/Global-Bioplastic-Packaging-Market-2019-2023---Adoption-of-Innovative-Materials-for-Manufacturing-Bioplastic-Packaging-to-Boost-Growth---Technavio	Technavio	2019	4
Use. Reuse. Repeat. Sharing Learnings on Reusable Packaging. Tesco Reuse Report 2022.	https://www.tescoplc.com/media/759307/tesco-reuse-report.pdf	Tesco	2022	3
2025 Recycled Polyester Challenge: First Annual Report	https://textileexchange.org/app/uploads/2022/11/2025-Recycled-Polyester-Challenge_2022.pdf	Textile Exchange	2022	1
Can the UK Plastic Tax help decarbonise the packaging industry?	https://www.carbontrust.com/news-and-insights/insights/can-the-uk-plastic-tax-help-decarbonise-the-packaging-industry	The Carbon Trust	2022	5
The Green Tractor Scheme: About Us	https://www.thegreentractorscheme.co.uk/	The Green Tractor Scheme	2023	1
War on plastic waste faces setback as cost of recycled material soars	https://www.theguardian.com/environment/2019/oct/13/war-on-plastic-waste-faces-setback-as-cost-of-recycled-material-soars	The Guardian	2019	1
Plastics Tool	https://www.sustainablefutures.manchester.ac.uk/research/case-studies/one_bin_to_rule_them_all/plasticshierarchy/	The University of Manchester	N.D. (website accessed 2023)	2
Plastics and Sustainability: A Valuation of Environmental Benefits, Costs and Opportunities for Continuous Improvement	https://www.americanchemistry.com/better-policy-regulation/transportation-infrastructure/corporate-average-fuel-economy-cafe-emissions-compliance/resources/plastics-and-sustainability-a-valuation-of-environmental-benefits-costs-and-	Trucost, The American Chemistry Council	2016	3

Title	URL	Author	Year	IAS
	opportunities-for-continuous-improvement			
UK leads the way on ending plastic pollution	https://www.gov.uk/government/news/uk-leads-the-way-on-ending-plastic-pollution	UK Government	2022	4
Misleading environmental claims	https://www.gov.uk/government/collections/misleading-environmental-claims	UK Government	2023	3
Plastic Packaging Tax	https://www.gov.uk/government/collections/plastic-packaging-tax	UK Government	2023	5
Open consultation: Plastic Packaging Tax - chemical recycling and adoption of a mass balance approach	https://www.gov.uk/government/consultations/plastic-packaging-tax-chemical-recycling-and-adoption-of-a-mass-balance-approach	UK Government	2023	4
Understanding Business Requirements for Increasing the Uptake of Recycled Plastic: A Value Chain Perspective	https://www.mdpi.com/2313-4321/7/4/42	Van Der Vegt et al.	2022	4
Steps towards standardization of plastic reusable packaging: A preliminary study into standardization in the reuse sector.	https://www.meermetminderplastic.nl/nieuws/2023/Januari-23/Steps-towards-standardization-of-plastic-reusable-packaging-Rebel-January-2023.pdf	Vink and Blanksma	2023	2
Bridging the Gap: Ending Britain's Reliance on Plastic Waste Export	https://prod-cms.viridor.co.uk/media/liibyk1r/220629-uk-plastics-study-final-report.pdf	Viridor	2022	3
Examining Material Evidence: The Carbon Footprint	https://www.imperial.ac.uk/media/imperial-college/faculty-of-natural-sciences/centre-for-environmental-policy/public/Veolia-Plastic-Whitepaper.pdf	Voulvoulis et al.	N.D.	3
Support to the Circular Plastics Alliance in establishing a work plan to develop guidelines and standards on design-for recycling of plastic products	cpa_support_on_guidelines_for_dfr_final_report_2020_final2.pdf (researchgate.net)	Watkins et al	2020	5
Drivers of public plastic (mis)use — New insights from changes in single-use plastic usage during the Covid-19 pandemic	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9345657/	Winton et al.	2022	3

Title	URL	Author	Year	IAS
Future of Reusable Consumption Models: Platform for Shaping the Future of Consumption - Insight Report July 2021	https://www3.weforum.org/docs/WEF_IR_Future_of_Reusable_Consumption_2021.pdf	World Economic Forum	2021	**4**
Plastics Market Situation Report 2021	https://wrap.org.uk/resources/report/plastics-market-situation-report-2021#download-file	WRAP	2021	**5**
The UK Plastics Pact Annual Report 2021-2022	The UK Plastics Pact Annual Report 2021-22.pdf (wrap.org.uk)	WRAP	2022	**5**
Non-Technical Challenges to Non-Mechanical Recycling	https://wrap.org.uk/resources/report/non-technical-challenges-non-mechanical-recycling	WRAP	2021	**5**
Plastic Waste Hierarchy	https://wrap.org.uk/sites/default/files/2022-12/DEFRA_PLASTIC_WASTE_HIERARCHY%20v7.0%20%28002%29.pdf	WRAP	2022	**5**
The UK Plastics Pact: Plastics Definitions	https://wrap.org.uk/taking-action/plastic-packaging/initiatives/the-uk-plastics-pact/plastics-definitions	WRAP	n.d.	**1**
Textiles Market Situation report 2019	https://wrap.org.uk/resources/market-situation-reports/textiles-2019#download-file	WRAP	2019	**3**
Household Waste Prevention Hub: Reuse – Barriers to Re-Use	https://wrap.org.uk/resources/guide/re-use/barriers-re-use	WRAP	2015	**2**
Behaviours, Attitudes and Awareness: Recycling Tracker Survey in the UK – Spring 2023	https://wrap.org.uk/resources/report/recycling-tracker-survey-spring-2023	WRAP	2023	**3**
PlasticFlow 2025: Plastic Packaging Flow Data Report	PlasticFlow-2025.pdf (valpak.co.uk)	WRAP, Valpak, Verde Research & Consulting, and RECOUP	2018	**5**
A Plastic Future: Plastics Consumption and Waste Management in the UK	https://www.wwf.org.uk/sites/default/files/2018-03/WWF_Plastics_Consumption_Report_Final.pdf	WWF	2018	**5**
Impact of Microplastics and Nanoplastics on Human Health	https://www.mdpi.com/2079-4991/11/2/496#:~:text=Several%20in%20vitro%20and%20in%20vivo%20studies%20have,%5B%20108%2C%2	Yee et al.	2021	**4**

Title	URL	Author	Year	IAS
	0109%2C%20110%2C%20111%20%5D.%20Table%201.			
Most Brits support ban on harmful plastic packaging	https://yougov.co.uk/topics/consumer/articles-reports/2019/04/19/most-brits-support-ban-harmful-plastic-packaging	YouGov	2019	**5**
Reusable vs Single-Use Packaging: A Review of Environmental Impacts	https://zerowasteeurope.eu/wp-content/uploads/2020/12/zwe_reloop_report_reusable-vs-single-use-packaging-a-review-of-environmental-impact_en.pdf.pdf_v2.pdf	Zero Waste Europe	2020	**3**
Strategies to reduce the global carbon footprint of plastics	https://escholarship.org/content/qt78w7x36q/qt78w7x36q.pdf	Zheng and Suh	2019	**5**
Strategies to Reduce the Global Carbon Footprint of Plastics	https://www.nature.com/articles/s41558-019-0459-z	Zheng and Suh	2019	**4**
Strategies to Reduce the Global Carbon Footprint of Plastics. Nature Climate Change. 9, p374-378	https://www.polybags.co.uk/environmentally-friendly/strategies-to-reduce-the-global-carbon-footprint-of-plastics.pdf	Zheng, J. and Suh, S	2019	**5**
Packaging Design for the Circular Economy: A Systematic Review	https://www.sciencedirect.com/science/article/pii/S235255092200152X	Zhu et al.	2022	**4**
Consumer attitudes and willingness to pay for novel bio-based products using hypothetical bottle choice	https://www.sciencedirect.com/science/article/pii/S2352550922002895	Zwicker et al.	2023	**5**

Appendix D: List of discarded resource efficiency measures in the plastics sector

During the literature review, several measures were considered and discarded. These discarded measures are listed below in Table 41 alongside the reason for exclusion.

Table 37: List of discarded resource efficiency measures for the plastics sector

Theme	Sub-theme	Measure name	Measure indicator	Reason for De-prioritisation
Design	Material substitution	Material substitution with biodegradable / compostable plastics	% reduction in non-biodegradable plastic consumption	Biodegradable plastics do not provide an opportunity for resource efficiency as they are not recyclable and therefore the material cannot be preserved
End of Life	Recycling	Composting (including anaerobic digestion) of biodegradable plastic products	% of non-biodegradable plastics substituted with biodegradable plastics	See above
End of Life	Recycling	Pre-consumer in-process recycling	% pre-consumer recycling rate	In-process recycling is considered standard practice and plastic refeed is not considered a waste product

Appendix E: Recycled content and recycling rate by industry

Table 38: Current level of mechanically recycled content by industry

Application	Current level of efficiency
Automotive – All [441] [442] [443] [444] [445]	2 – 3%
Construction – All [446] [447] [448]	14 - 18%
Electronics – All [449] [450] [451]	2 – 3%
Packaging – All [452] [453] [454] [455] [456] [457]	5 – 13%
PET bottles[458]	15 – 18%
HDPE bottles[459]	20 – 25%
Film (food grade)[460]	7%
Film (non-food grade)[461]	12%

[441] Circular Plastics Alliance (2020). State of Play on Collection and Sorting: Electronics and Electrical Equipment Working Group.
[442] Plastics Europe (2022). The Circular Economy for Plastics.
[443] Plastics Europe (2022). Plastics – The Facts 2022.
[444] Plastics Europe (2023). Circular Economy for Plastics: United Kingdom – 2020.
[445] Oakdene Hollins (2021). Driving change: A circular economy for automotive plastic.
[446] Plastics Europe (2022). The Circular Economy for Plastics.
[447] Plastics Europe (2022). Plastics – The Facts 2022.
[448] Plastics Europe (2023). Circular Economy for Plastics: United Kingdom – 2020.
[449] Plastics Europe (2022). The Circular Economy for Plastics.
[450] Plastics Europe (2022). Plastics – The Facts 2022.
[451] Plastics Europe (2023). Circular Economy for Plastics: United Kingdom – 2020.
[452] Plastics Europe (2022). The Circular Economy for Plastics.
[453] Plastics Europe (2022). Plastics – The Facts 2022.
[454] Plastics Europe (2023). Circular Economy for Plastics: United Kingdom – 2020.
[455] WRAP (2021). Non-Technical Challenges to Non-Mechanical Recycling.
[456] British Plastics Federation (2021). British Plastics Federation Recycling Roadmap.
[457] Green Alliance (2020). Fixing the system: Why a circular economy for all materials is the only way to solve the plastic problem. (Including Methodology).
[458] British Plastics Federation (2021). British Plastics Federation Recycling Roadmap.
[459] Ibid
[460] Ibid.
[461] Ibid.

Rigids[462]	17 – 18%

Table 39: Maximum level of mechanically recycled content in 2035 by industry

Industry	Application	Maximum level of efficiency
Automotive[463] [464]	PE	80%
	PP	50%
	All	26%
Construction[465] [466]	PP	50%
	All	46%
Electronics[467] [468] [469]	PET	100%
	PE	80%
	PP	50%
	All	30 - 38%
Packaging[470] [471] [472]	Carrier bags	100%
	PET trays (food contact)	95%
	PET (non-food contact)	100%
	PE (food contact)	60%
	PE (non-food contact)	99%

462 Ibid.
463 Eriksen et al. (2020). Dynamic Material Flow Analysis of PET, PE, and PP Flows in Europe: Evaluation of the Potential for Circular Economy.
464 Lase et al. (2023). How Much Can Chemical Recycling Contribute to Plastic Waste Recycling in Europe? An Assessment Using Material Flow Analysis Modelling
465 Eriksen et al. (2020). Dynamic Material Flow Analysis of PET, PE, and PP Flows in Europe: Evaluation of the Potential for Circular Economy.
466 Lase et al. (2023). How Much Can Chemical Recycling Contribute to Plastic Waste Recycling in Europe? An Assessment Using Material Flow Analysis Modelling
467 Eriksen et al. (2020). Dynamic Material Flow Analysis of PET, PE, and PP Flows in Europe: Evaluation of the Potential for Circular Economy.
468 Lase et al. (2023). How Much Can Chemical Recycling Contribute to Plastic Waste Recycling in Europe? An Assessment Using Material Flow Analysis Modelling
469 SCS Standards (2023). Supplemental Criteria for Electrical and Electronic Equipment: SCS-103 Recycled Content Standard Annex A.
470 British Plastics Federation (2021). British Plastics Federation Recycling Roadmap.
471 Eriksen et al. (2020). Dynamic Material Flow Analysis of PET, PE, and PP Flows in Europe: Evaluation of the Potential for Circular Economy.
472 Lase et al. (2023). How Much Can Chemical Recycling Contribute to Plastic Waste Recycling in Europe? An Assessment Using Material Flow Analysis Modelling

	PP (food contact)	50%
	PP (non-food contact)	50%
	All	52%
Textiles[473]	PET	75%
	PE	80%

Table 40: BAU level of mechanically recycled content in 2035 by industry

Industry	Application	BAU level of efficiency
Automotive[474]	All	6-15%
Construction[475]	All	17-46%
Electronics[476]	All	3-11%
Packaging[477] [478]	All	6-18%
	PET	50%
	HDPE	45%
	Bottles (HDPE & PET)	30 – 50%

Table 41: Current recycling rate by industry

Industry	Current level of efficiency
Packaging [479] [480] [481] [482]	43 – 52%
Construction [483]	26%

[473] Eriksen et al. (2020). Dynamic Material Flow Analysis of PET, PE, and PP Flows in Europe: Evaluation of the Potential for Circular Economy.
[474] Lase et al. (2023). How Much Can Chemical Recycling Contribute to Plastic Waste Recycling in Europe? An Assessment Using Material Flow Analysis Modelling
[475] Ibid.
[476] Ibid.
[477] Lase et al. (2023). How Much Can Chemical Recycling Contribute to Plastic Waste Recycling in Europe? An Assessment Using Material Flow Analysis Modelling
[478] BPF (2020). Recycled content used in plastic packaging applications.
[479] Plastics Europe (2022). The Circular Economy for Plastics.
[480] WRAP, Valpak, Verde Research & Consulting, and RECOUP (2018). PlasticFlow 2025: Plastic Packaging Flow Data Report.
[481] WRAP (2021). Plastics Market Situation Report 2021.
[482] BPF (2022). British Plastic Federation: Plastic Recycling.
[483] Circular Plastics Alliance (2020). Circular Plastics Alliance – State of Play on Collection and Sorting: Construction Working Group.

Automotive[484]	30%
Electricals[485] [486]	23 – 44%

[484] British Plastics Federation (2021). British Plastics Federation Recycling Roadmap.
[485] Ibid.
[486] BPF (2022). British Plastic Federation: Plastic Recycling.

This publication is available from: www.gov.uk/government/publications/unlocking-resource-efficiency