SYSTEMIQ

Circular PET and Polyester

A circular economy blueprint for packaging and textiles in Europe

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About this report

This report is the second in a series exploring circular economy pathways for PET/polyester in Europe.

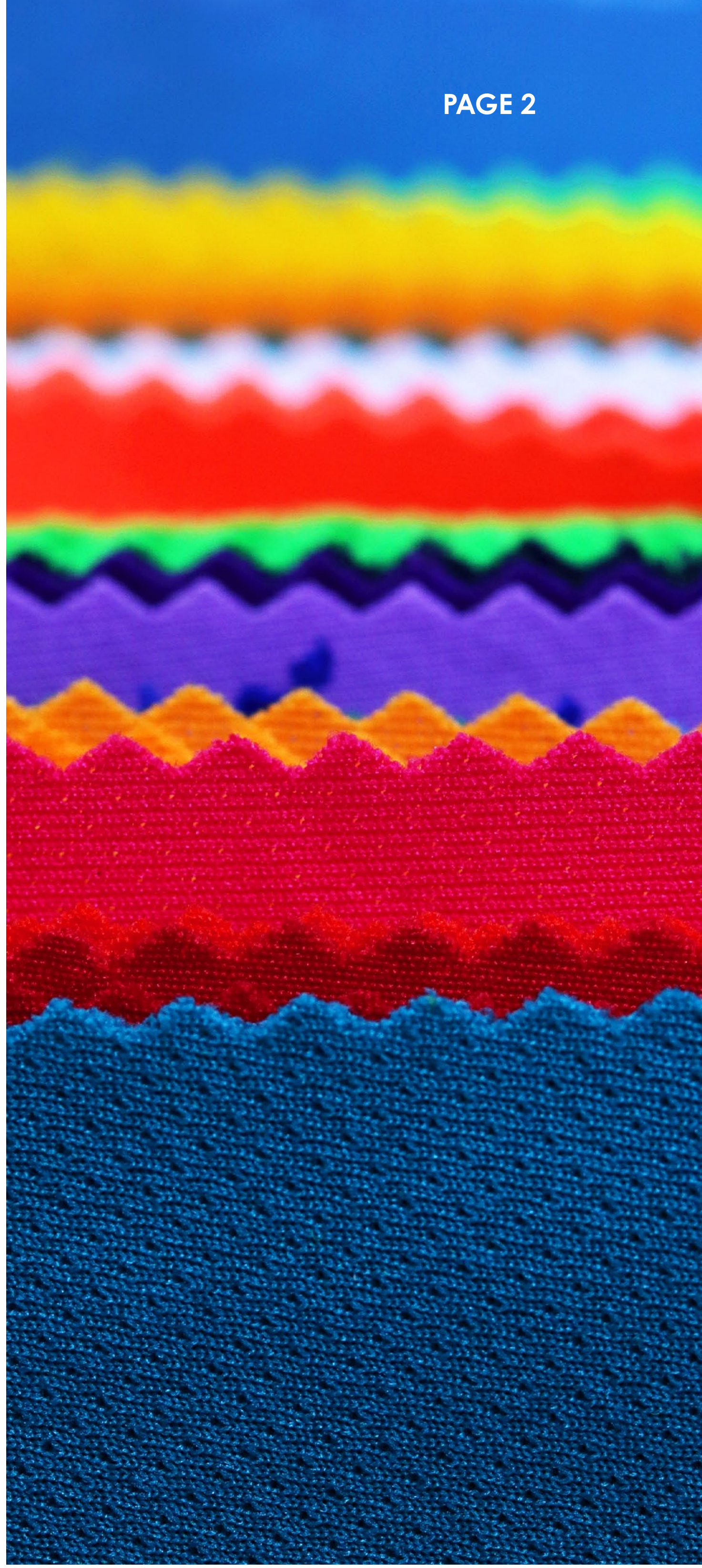
The study was commissioned by **Eastman** and financed by Eastman and **Interzero**. It provides a new evidence base, exploring the future potential for complementarity between reuse, mechanical recycling and chemical PET recycling of PET/polyester in Europe under different scenarios, as well as the role that demand reduction strategies could play. It quantifies material flows and environmental impacts of each scenario, and in doing so helps to answer some of the key gaps in existing research, identified in the **previous paper** in this series. Scenario modelling has been used to chart these possible futures for the system, with data and assumptions drawn from a combination of existing published reports and expert input, validated together with the oversight of the project Steering Group. The study team would welcome questions, challenges, relevant data points and information about published or ongoing studies that are not referenced in this paper. Please contact us at **plastic@systemiq.earth**.

About Systemiq

Systemiq was founded in 2016 to drive the achievement of the Paris Agreement and the UN Sustainable Development Goals, by transforming markets and business models in four key systems: land use, circular materials, clean energy and sustainable finance. A certified B Corp, Systemiq works to unlock economic opportunities that benefit business, society and the environment; it does so by partnering with industry, financial and government institutions, and civil society. In 2020, Systemiq and The Pew Charitable Trusts published "**Breaking the Plastic Wave: A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution**" – a first-of-its-kind model of the global plastics system that describes how to radically reduce ocean plastic pollution. In 2022, Systemiq published "**ReShaping Plastics**", outlining pathways to a circular, climate-neutral plastics system in Europe. Find out more at **www.systemiq.earth/**.

Disclaimer

This report was prepared by Systemiq with strategic guidance from an independent Steering Group, which provided input on all major project decisions, reviewed all assumptions and provided input into the approach. The steering group had representation from the public sector, civil society and industry, and we are deeply grateful to all the organisations and individuals that contributed their unique perspectives. While the report was financed by Eastman and Interzero, the Steering Group helped ensure its independence and unbiased nature. Responsibility for the information and views set out in this publication lies with the author. Steering Group members or funders endorse the overall project approach and findings, although not all statements in this publication necessarily represent the views of all individuals or the organisations they represent, and they cannot be held responsible for any use which may be made of the information contained or expressed therein.



Preface

The benefits of plastics have made them a key material in many sectors. Achieving circularity requires the engagement of actors from different countries and sectors. This is true for polyethylene terephthalate (PET), the plastic type that is the basis for bottles, trays and other packaging as well as a whole industry outside of packaging, namely polyester textiles. Beverage bottle PET is by far the most collected and recycled plastic, while non-bottle PET packaging and textiles still have a long way to go to achieve circularity. These applications face more difficulties in closing the loop of their products based on current practices in mechanical recycling; and to incorporate recycled content, they typically utilise high-quality recyclates from beverage bottle recycling. So, while it may seem unusual to those in the packaging industry to take polyester from textiles into a single system model together with packaging PET, this inter-change is already happening in reality.

Currently, chemical recycling technologies are emerging and depolymerisation in particular is fit for application to PET, due to its polycondensate nature. One of the main questions today concerns the role that chemical recycling can play as a complementary technology alongside mechanical recycling. The system modelling presented in this report highlights that only a complementarity scenario can truly increase circularity – a scenario in which all solutions are scaled up and all sectors, including the textile industry, contribute to the availability of recyclates. Without this, we face a 'right pocket, left pocket' reality, in which recycling routes change but overall recycling rates stagnate because the same feedstock is envisaged.

The modelling also highlights that recycling is just one part of the solution to achieve sustainability. Revaluing plastics as long-lasting materials with new business models, reuse, and generally longer lifetimes is key. This is valid for packaging (transition from single-use to reusable packaging models where appropriate), but also especially relevant for the textile industry, with its trend of high-consumption fast-fashion business models.

This report is a unique effort that objectively calculates the significant sustainability benefits that could be gained by moving away from fast fashion and from single-use packaging where possible, together with grasping the opportunities of expanding recycling infrastructure and applying chemical PET recycling as a complementary technology. Only by combining these systemic changes can we triple the recycling rate of PET/polyester from 23% to 67% and reduce greenhouse gas emissions by half.

We are grateful for the strong engagement of stakeholders from different industries, research and policy fields for their contribution to this report. Based on this broad input and the diligent work of the system modelling team, this report provides an excellent blueprint to move forwards to PET/polyester circularity in Europe.

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Executive summary

Polyethylene terephthalate (PET) is used extensively across many industries – in particular, consumer packaging and textiles, where it is known as polyester.

The PET plastic molecule is used to manufacture beverage bottles, packaging trays and containers, and synthetic textiles used in the apparel, built environment, automotive, hygiene and industrial sectors. In total, PET/polyester comprises around one-quarter of all plastic packaging and the majority of synthetic textiles sold in Europe.

The PET/polyester system is mostly linear today.

PET bottles benefit from one of the most mature collection, sorting and recycling value chains in Europe, underpinned by an increasingly supportive legislative environment. Although around half of PET bottles are mechanically recycled, the recycling rates for all other PET/polyester product applications are low or non-existent. As a result, only 25% of PET/polyester is recycled, with the remainder largely ending up in landfill or incineration (energy recovery). Of the PET/polyester that is recycled, two-thirds is used to make products which do not have a clear recycling path today, the largest of these being polyester textiles. The lack of recycling paths for most non-bottle PET/polyester applications, combined with demand for recycled PET from multiple industries, puts growing pressure on recycled PET supply.

PET/polyester's abundant circularity potential has not yet been realised.

New technology developments and circular economy innovations are now emerging. These include further scale-up and development of mechanical recycling alongside new solutions such as chemical PET recycling; advanced waste sortation; re-commerce and rental models in the fashion sector; and packaging reuse or new delivery models for products with no or low packaging. The product applications and chemical properties of PET/polyester mean that it can be well suited to different circular economy approaches including reuse, mechanical recycling and chemical recycling via depolymerisation. Chemical PET recycling produces virgin-like recycled PET suitable for contact-sensitive – or 'food-grade' – applications. It also has lower greenhouse gas (GHG) emissions and higher material-to-material yields compared to thermochemical recycling technologies (eg, pyrolysis) typically used for chemical recycling of other plastic types in the municipal waste system.

These new circular economy approaches have not yet been combined in a system model and scenario assessment to evaluate their full potential for system circularity. With support from an independent multi-stakeholder Steering Group, Systemiq has carried out new quantitative system modelling, exploring the material flows and environmental implications of future scenarios for a high-circularity, low-emissions European PET/polyester system. This work has revealed four key insights, outlined in the following pages, on the current trajectory of this system, as well as what is required to achieve a high-circularity, low-emissions future.

Key insights

1

Ambitious application of known circular economy solutions could reduce landfill and incineration by 70% and halve greenhouse gas emissions in 2040.

Modelling shows that all solutions are needed together to achieve the system changes required to hit circularity targets (reduction, reuse, mechanical recycling and chemical PET recycling). This ‘complementarity’ approach would apply these different circular economy approaches to different product applications based on environmental outcomes and technology suitability. The approach – defined in an ‘Ambitious Complementarity Scenario’ – has the potential to achieve high levels of circularity by 2040. When compared to a continuation of historical trends, it could:

- **Reduce PET/polyester consumption by one-third**, by expanding the reuse of packaging and textiles and reducing avoidable PET/polyester usage.
- **Reduce PET/polyester sent to landfill and incineration by ~70%** (a reduction of 5.9 million tonnes (Mt) per year), by expanding separate waste collection, sortation, mechanical recycling and chemical PET recycling infrastructure. Average recycling rates could reach 67% across all applications.
- **Halve system-level GHG emissions** (reducing emissions by ~18Mt of carbon dioxide equivalent (CO_2e) per year by 2040).
- **Increase the supply of recycled PET suitable for new PET/polyester packaging and textiles to 4.7Mt/year**, such that proposed requirements for recycled content in the draft EU Packaging and Packaging Waste Regulation (PPWR) can be met and the volume of recycled PET/polyester (rPET) being used for textiles can be maintained or increased (the PPWR requires 2.8Mt/year of recycled content at projected PET packaging consumption rates to meet recycled content targets). The simultaneous application of both mechanical and chemical PET recycling technologies is needed to meet or exceed the proposed targets.

On top of these environmental outcomes, the estimated socio-economic co-benefits of this system change in Europe would include 28,000 net new jobs by 2040 and an additional €5.5 billion per year in revenues for recycling industries, compared to €2.5 billion in 2020.

Further research is needed into the release of micro-plastics during the life cycle of PET/polyester products and the accumulation and migration of substances of concern during reuse and recycling loops (for all materials, not only PET/polyester). These two potential system risks and their impacts on human health and natural ecosystems were not studied in this report and are highlighted as a research priority.

2

To build this high-circularity, low-emissions PET/polyester system, improvements are needed in every part of the system. Six priority actions are identified:

Three 'upstream' actions aim to slow the growth in demand for PET/polyester through business model changes and to design products for circularity:

- **Expand reuse to extend product lifetimes for packaging and textiles, and promote new delivery models for products to reduce packaging demand:** Examples include re-commerce in the fashion sector and a transition from single-use food and drink packaging to reusable containers. Scale-up requires a step change in industry investment, building on learnings from pilot initiatives, alongside clarity from policy-makers on important considerations such as safety, hygiene and liability standards; methods for the assessment of the environmental and social impacts of new models; and public financing support.
- **Reverse trends of high-consumption business models in the fashion sector ('fast fashion'):** Between 2000 and 2015, the number of times clothes were worn before disposal fell by 36%.[1] Faster turnaround of seasonal collections also contributes to unsold stock, which may be sent to landfill or incineration. The Ambitious Complementarity Scenario[a] presented in this report models a steady slowdown in polyester textile demand growth and stabilisation by 2040. This will require action from industry and consumers, together with new policies such as an ambitious extended producer responsibility scheme for textiles to transfer the cost and responsibility of waste management to producers and provide economic incentives to reduce overconsumption.
- **Standardise product design to improve reuse and recycling economics:** In many cases, shifts in bottle designs, such as from coloured/opaque to clear, and a transition from multimaterial to monomaterial packaging[b] and to less complex textiles, may be easy wins to increase recyclability and improve the quality and value of recycled PET. Design for recycling rules that consider chemical PET/polyester recycling are needed, alongside existing rules covering design for mechanical recycling. Some design shifts, such as from coloured/opaque to clear bottles for light-sensitive products, may no longer be required if chemical PET recycling scales up. This would allow for continuation of opaque/coloured PET usage for light-sensitive products and mitigate the risk that design modifications such as shrink sleeves on clear PET bottles interfere with sorting or recycling processes.

a. The Ambitious Complementarity Scenario refers to a PET/polyester system performing at or near the peak, as defined by the current best-in-class for every stage of the system. This includes measures to slow PET consumption, design for recyclability, mechanical and chemical PET recycling, as well as increases in waste collection and sortation rates.

b. Some coloured/opaque and multi-material formats will still be required for specific product applications.

Three ‘downstream’ actions aim to put in place the complementary mechanical recycling and chemical PET recycling systems needed to deliver significant increases in recycling rates and availability of recycled PET/polyester suitable for new packaging and textiles:

- **Secure long-term demand for recycled PET/polyester:**

  In the Ambitious Complementarity Scenario, the supply of recycled PET in 2040 would be three times higher than in 2020. To ensure that demand for recycled PET/polyester drives the system to its full circularity potential, recycled content requirements are recommended across all end-use applications, including textiles. Companies using PET/polyester should enter into long-term offtake agreements with recyclers, ensuring long-term offtake security and de-risking investments for the recycling sector.

  Imports of recycled PET (or PET plastic waste for recycling) into Europe should be carefully assessed to ensure that this trend does not affect confidence in the safety of recycled PET or undermine investment in collection and recycling infrastructure in Europe.

- **Develop sufficient high-quality feedstock flows for recyclers by improving collection and sorting:**

  To achieve a ~75% (2.6Mt) increase in PET/polyester collected for recycling in the Ambitious Complementarity Scenario, effective deposit return schemes for bottles and separate collections for after-use textiles will be needed across Europe. The development of proportionate waste sortation capacity will also be required to ensure this waste is of appropriate quality for recyclers.

  Collection policies should be paired with policies to reduce waste to landfill or incineration (eg, banning the destruction of unsold or returned textiles and the incineration of recyclable packaging). The public and private sectors should collaborate to design and enact principles for the complementarity of mechanical and chemical PET recycling to ensure favourable environmental outcomes and build investor confidence in feedstock supplies.

- **Scale up recycling infrastructure and optimise performance:**

  The Ambitious Complementarity Scenario would see mechanical recycling volumes increase by two-thirds, from 2.0Mt in 2020 to 3.3Mt in 2040. Chemical PET recycling will need to bring 2.1Mt of capacity online by 2040 (including 0.4Mt ‘announced’ capacity that is not yet online in Europe today).[2] Scale-up of chemical PET recycling would enable the conversion of harder-to-recycle PET/polyester waste (eg, textiles, trays, coloured/opaque bottles and waste from mechanical PET recycling) into a contact-sensitive, virgin-like material. This has the effect of ‘recharging’ the system with virgin-like recycled PET without the need for fossil-based feedstocks.

  Complementary development of mechanical and chemical PET recycling could also serve to make the system more resilient – for example, to a failure to reduce overall PET/polyester consumption – or to achieve a large-scale transition from coloured/opaque to clear bottles, as required under design-for-recycling rules.

  The current lack of clarity in the regulatory treatment of recycling technologies (including controlled blending and mass balancing approaches) is a significant barrier to investment in new infrastructure. In the case of chemical PET recycling, the planning and construction timeline can often stretch to many years, putting at risk the achievement of regulatory targets. Recycling capacity will need to scale quickly to achieve targets set out in the EU Single Use Plastics Directive. This includes the provision of enough rPET to meet 2025 and 2030 recycled content targets and enough capacity to process a beverage bottle collection-for-recycling rate requirement of 90% by 2029. The public sector will need to facilitate conditions for investment in both mechanical and chemical PET recycling by providing policy certainty as quickly as possible and accelerating necessary permitting processes for related projects.

3

Further efforts and technology/ system innovations will be required beyond this Ambitious Complementarity Scenario to close the remaining gap on circularity and align with Europe's net-zero commitment by 2050.

Even in the Ambitious Complementarity Scenario, 2.8Mt of non-recycled PET/ polyester waste and 17.5Mt CO_2e of GHG emissions will still be generated per year. Further reductions in the levels of non-recycled waste and GHG emissions could be achieved through greater improvements in textile waste collection and sortation; carbon capture on waste incineration plants; electrification of petrochemicals facilities used for virgin PET/polyester production; and replacement of remaining fossil-based feedstocks with captured carbon, green hydrogen and biomass. These additional levers have not been modelled in this study.

4

Achieving the circularity potential of PET/polyester in Europe requires action from policy-makers and industry.

Additional regulatory clarity is still required to build investor confidence and unlock the multibillion-euro investments that will be required to bring these system changes to life – for example, on recycled content calculations under the Single Use Packaging Directive and Packaging and the PPWR, and on fair and practical principles for feedstock allocations between mechanical and chemical recycling.

With these additions alongside enactment of an ambitious PPWR and EU Textiles Strategy, investors can have confidence that circularity of PET/polyester is an investible business opportunity for the coming decade. Given the timelines for infrastructure developments, there is now great urgency for the new investments, actions, value chain building approaches and public-private collaborations that are required to bring this circular economy vision to life.

Fast facts

2040 AMBITIOUS COMPLEMENTARITY SCENARIO:

Combined scale-up of circular economy approaches (reduction, reuse, mechanical recycling, chemical PET recycling)

REDUCING AND REDESIGNING UPSTREAM

- EXPAND REUSE
- SLOW DOWN FAST FASHION
- DESIGN FOR MECHANICAL AND CHEMICAL RECYCLING

INCREASING RECYCLING DOWNSTREAM

- SECURE LONG-TERM DEMAND FOR RECYCLED PET/POLYESTER
- EXPAND COLLECTION AND SORTATION
- SCALE MECHANICAL AND CHEMICAL RECYCLING INFRASTRUCTURE

THE BENEFITS

Relative to a continuation of historical trends, 2040 could see:

- 1/3 LESS PET/POLYESTER CONSUMPTION
- 70% LESS PET/POLYESTER TO LANDFILL AND INCINERATION
- 50% LOWER GHG EMISSIONS

Socio-economic benefits could also be significant:

- 28,000 NEW JOBS[a]
- €5.5 BILLION ADDITIONAL RECYCLING REVENUES[b]

a. Net new jobs across the PET/polyester value chain compared to 2020. Accounts for job losses in the waste management sector outside recycling.

b. Estimated revenue figures only account for the sale of recycled PET produced by the system. They do not account for other additional revenues in the PET/polyester supply chain or lost revenues – for example, in landfill and incineration.