SYSTEMIQ

NOVEMBER 2024

Transforming PET Packaging and Textiles in the United States

Systems Change Scenarios and Recommendations to Cut Waste, Create Jobs, and Mitigate Climate Change

Advisory Partners: CLOSED LOOP partners, eunomia, The Recycling Partnership SOLVING FOR CIRCULARITY

ABOUT REPORT

This report assesses the current state of circularity of PET packaging and polyester textiles in the U.S., uses detailed system modeling to quantify the impact of applying proven circular approaches (reduce, reuse, recycling) under different scenarios, and outlines recommendations for government and the private sector to achieve the benefits of an ambitious scenario.

The study was commissioned and financed by Eastman.

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Systemiq

Systemiq, the systems change company, was founded in 2016 to drive the achievement of the Sustainable Development Goals and the Paris Agreement by transforming markets and business models in five key systems: nature and food; materials and circularity; energy; urban areas; and sustainable finance. A certified B Corp, Systemiq combines strategic advisory services with high-impact, on-the-ground work, and partners with business, finance, policymakers and civil society to deliver systems change.

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ADVISORY PARTNERS

Closed Loop Partners

Closed Loop Partners is a firm at the forefront of building the circular economy, and is comprised of three key business segments: an investment arm, Closed Loop Capital Management; an innovation center, the Center for the Circular Economy; and an operating group, Closed Loop Builders. The Center for the Circular Economy executes research and analytics, unites organizations to tackle complex material challenges and implements systemic change that advances the circular economy. The Center's expertise spans circularity across the full lifecycle of materials, connecting upstream innovation to downstream recovery infrastructure and end markets.

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Eunomia is a global environmental consultancy with nearly 25 years of expertise, delivering science-based research and advisory services that challenge the status quo. Their work spans the circular economy, including sustainable material use and reuse, recycling, and waste management; carbon economy, including measuring and reducing carbon footprints, navigating offsets, and aligning with global standards; and natural economy, including enhancing ecological balance and developing nature-based investments. Eunomia provides innovative, unbiased solutions across policy, strategy and implementation for a sustainable future.

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Learn more at:
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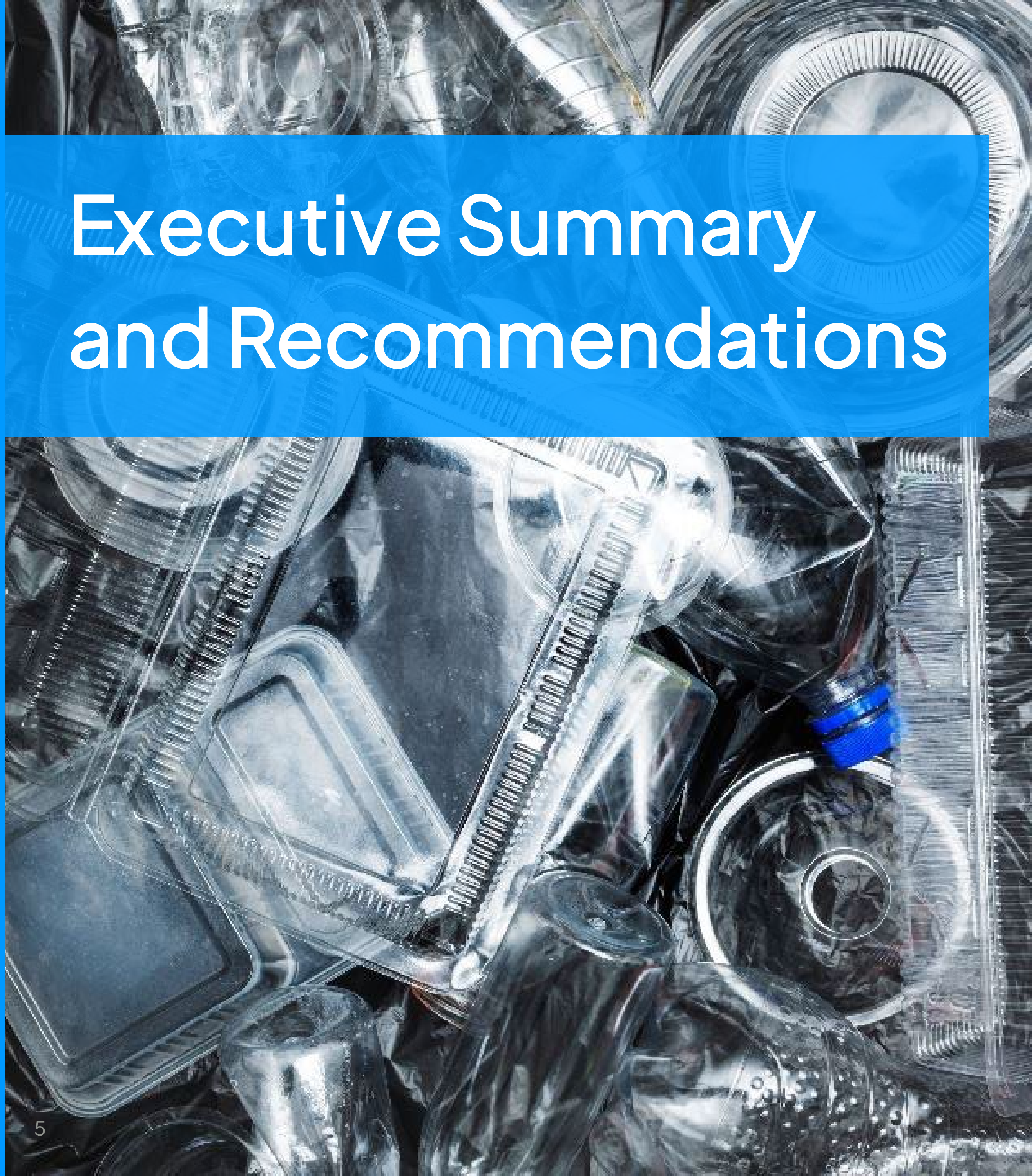
CONTENTS

Executive Summary and Recommendations



Packaging and textile materials account for one-third of the annual material waste footprint of a typical U.S. citizen.[a,1] PET/polyester makes up 30% of all plastic packaging and textiles[b,2,3], with demand growing faster than for other packaging and textile materials.

PET (polyethylene terephthalate) plastic – known as polyester when spun into fibers – is a versatile material and the building block for products that we use every day in our economy, particularly in packaging and textiles. PET packaging applications include plastic bottles for beverages and cleaning products, as well as food trays and clamshells. Polyester textiles applications include apparel, curtains, carpets, vehicles, upholstery and many industrial applications.

Thirty percent of all plastic packaging and textiles sold every year in the United States are made from PET/polyester, with consumption growing 2.3% year-over-year[c]. PET consumption totals 62 pounds per U.S. citizen every year, one of the highest in the world[d]. Each year over 100 billion PET bottles and 10 billion polyester garments are sold in the U.S.[e].

Notes **a.** Systemiq analysis based on EPA waste generation data. Note the EPA data is based on municipal solid waste (MSW); **b.** Systemiq analysis based on EPA waste generation data and U.S. Plastic Pact; **c.** Systemiq analysis based on Dow Jones; **d.** The U.S. produces the most plastic waste per person worldwide with an average of 287 pounds per person per year for all plastics (Statista 2023); **e.** Systemiq analysis

The PET/polyester system in the U.S. is mostly linear today.

PET/polyester products are predominantly made from fossil fuel-derived feedstocks and the system in the U.S. is mostly linear with ~90% sent to disposal after one use, and 10% mechanically recycled.

Production and disposal of PET/polyester uses 320,000 barrels per day of oil-equivalent fossil fuels (2% of U.S. demand)[a] and generates 120 million metric tons of GHG emissions per year (CO_2 equivalent) – similar to all annual emissions from the State of North Carolina[4].

The 7.9 million metric tons of PET/polyester packaging and textiles sent to landfill or incinerated each year would have an estimated financial value of around $7 billion[b] if they were recycled.

Circular Economy Potential for PET/Polyester

PET/polyester is a material with high potential for circular economy approaches, including reduction, reuse, and material-to-material recycling via mechanical recycling or depolymerization recycling.

PET/polyester has properties that offer high potential for circularity. For example, the amount of PET/polyester used can be reduced with lighter-weight packaging, given the material's strength and durability even at low thickness. Conversely, PET containers can also be made into thick-walled formats designed to be reused multiple times. Resale and rental of apparel, including items made of polyester, is a prevalent and growing example of a reuse economy[c]. Mechanical recycling approaches[d] are well established for clear bottles and emerging for other applications. In addition, PET/polyester has a lower life cycle climate impact when compared to some packaging materials, such as glass (see *Annex A1*).

For harder-to-recycle formats, the molecular structure of PET/polyester is also well-suited to depolymerization recycling, sometimes called "molecular recycling". Depolymerization recycling, a material-to-material technology, converts PET/polyester back into monomers (the building blocks of new plastics) and then combines them again to make virgin-quality recycled PET/polyester. In contrast, other commonly-used plastics (e.g. polypropylene and polyethylene) are made from strongly-linked molecules that are not suitable for depolymerization recycling.[e] Depolymerization recycling is now entering the U.S. market at commercial scale with support from apparel and packaged goods companies and the federal government.[f]

Circular economy approaches are already generating environmental and economic benefits in the U.S. The apparel resale industry for all materials generates annual revenues of $45 billion and is growing quickly at 12% year-over-year.[g,5,6,7,8] PET packaging recycling is an industry estimated to generate in the order of $1billion annually in recycling revenue,[h] despite PET packaging

Notes **a.** Barrels of oil equivalent; **b.** Based on U.S. rPET price end of Q1 2024 ($1130/metric ton) and assuming high recycling yields; **c.** Note that all upstream reduction assumptions are laid out in detail in the technical appendix to this report. The lightweighting potential is based on reduction progress that has already been achieved; **d.** Cleaning and re-melting at low temperature without changing the plastic chemical composition; **e.** These other plastics require energy-intensive thermal process (e.g. pyrolysis) to break down the plastics into oils and gases, which then need further steps to be converted into new plastics (see Box 2); **f.** The first large-scale plant (capacity of 110kt per year) became operational in 2024 (Eastman plant in Kingsport) and 4 industrial-scale PET/polyester depolymerization recycling plants have been announced in the U.S. (Eastman, Syre, Revalyu, Ambercycle). Many innovators continue to advance the technology (e.g., Reterra, Circularix); g. Systemiq analysis based on fmi (2023), PYMNTS (2023), Statista, ThredUp (2024); **h** Systemiq analysis recycling rates lagging behind comparable countries (23% in the U.S. vs. 42% in Canada)[9].

Textile circularity is a key challenge that requires systems-level change and new technology deployment in order to move away from reliance on recycling plastic bottles into textiles and towards textile-to-textile recycling at scale.

Polyester textile recycling has not yet achieved meaningful scale. As a result, recycled PET, used in both packaging and textiles, is only generated by recycling PET packaging ,and the vast majority of recycled polyester textiles today are derived from plastic bottles.

However, scaling up depolymerization recycling could offer a recycling solution for textiles with high polyester content. The virgin- quality recycled PET output from depolymerization could then be used to produce either packaging or textiles, resulting in a flexible system.

Scenario analysis carried out for this study examines the environmental and economic benefits that could be realized by scaling up proven circular economy approaches for both packaging and textiles. This analysis shows that accelerating the transition towards a circular economy could cut waste, reduce GHG emissions and create a significant number of U.S. jobs by 2040, with further improvements expected beyond that date.

The scenario analysis in the report shows that scaling up proven circular economy approaches for PET packaging and polyester textiles by 2040 could increase recycling rates for packaging to ~70% and for textiles to ~19% - a result that can only be achieved though the combination of mechanical and depolymerization recycling. This demonstrates strong progress towards a circular economy for PET/polyester and would provide the foundation for further systems change after 2040, particularly for textiles.

Virgin PET/polyester consumption could be reduced by almost half by 2040, relative to the continuation of current trends (from 13 to 7 million metric tons). Waste disposal could also be halved, from 12 to 6 million metric tons. GHG emissions from PET packaging could decrease by ~60%. If recycling solutions are localized in the U.S. and not outsourced to other locations, by 2040 the industry could generate about 46,000 more direct jobs in reuse and recycling than today (100,000–200,000 more when including indirect jobs) and $4.9 billion in additional revenue for recycling industries.

Accelerating the Transition to a Circular Economy for PET/Polyester

Acceleration of ambitious legislation, industry action, new technology scale-up and research is needed to address system challenges and scale PET/polyester circularity.

This report's analysis identifies a clear opportunity to reduce the environmental impact of PET/polyester consumption and unlock the economic, social and environmental benefits of a circular economy for these versatile and prevalent materials. There are some promising inroads towards PET/polyester circularity already in play, but there is a need for ambitious government and private sector action—as well as cross-sector collaboration and additional research—in order to address economic and structural barriers to circularity, and to achieve the benefits projected in this report.

RECOMMENDATIONS

FOR GOVERNMENT

Government policy makers at the state and federal levels have a critical role in setting ambitious legislation and program goals to create the enabling conditions for the transition from a linear economy to a safe and sustainable circular economy for PET/polyester.

A range of policy instruments, as well as implementation approaches, are required to work in parallel, with harmonization between states where possible. Well-designed Extended Producer Responsibility (EPR) legislation is highlighted as a particularly important policy instrument for both packaging and textiles. EPR is already in use in five states and has the potential to scale up circular economy approaches by creating financial incentives for sorting and recycling investments and improved product design[a].

Six recommendations are identified for government:

1 Adopt best practice policies and implementation approaches to reduce unnecessary consumption of textiles and single-use packaging. Examples include:

- **Restrictions and disclosure requirements** on the destruction of unsold apparel, alongside **policies to disincentivize "fast and ultra-fast fashion"** and **reduce the use of unnecessary packaging.**
- **Reuse/refill mandates or incentives** to support the transition from single-use to reusable packaging.
- **Collaborating with industry** to develop new circular systems for practical applications: for example, closed loop reuse systems for beverage containers at venues (e.g. malls, universities), events (e.g. sport stadiums), or city-level reuse/refill initiatives, including public water fountains.

Note a. In the past three years, Extended Producer Responsibility (EPR) legislation for packaging has been enacted in five states with ten other states considering EPR laws, in addition to Deposit Return Systems for beverage containers in ten states (Bottle Bills – a type of EPR legislation). The core of EPR is a financial mechanism that holds producer companies responsible for products at end-of-life and mobilizes industry financing to improve recycling economics compared to primary material production. Although lagging behind packaging, legislation to improve textiles circularity are now also gaining momentum and have been adopted in two states.

2 Introduce well-designed EPR legislation for both packaging and textiles,

seeking harmonization and convergence where possible within the U.S., building on lessons learned domestically and globally, and ensuring that EPR legislation is designed to support the key pillars of the PET/polyester circularity approach outlined in this study. For example, EPR legislation should:

- **Encourage and reward product design for circularity through eco-modulation°** (including durability, reuse, recycling, and low microplastic release);
- **Incentivize U.S. domestic infrastructure,** leveraging existing sorting and recycling systems and scaling up new ones, rather than large-scale imports of recycled materials. This will help increase U.S. recycling rates and reduce landfill volumes over time;
- **Consider high-yield material-to-material recycling technologies** as a responsible end-market to widen the scope of products that can be recycled into high-value outputs. Ensure that EPR system design allows for innovation of high-yield material-to-material recycling technologies and has the flexibility to adapt as technology, infrastructure and product design evolve;
- **Adopt differentiated strategy for textiles EPR** compared to packaging, taking into account different global supply chain configurations; supporting circular and durable design, apparel resale/recommerce and not only recycling; and considering the impact of EPR fees on export markets for apparel resale. Clarity on how markets for collected recyclables are defined and considered is particularly important for establishing textiles EPR, while accounting for full coverage of "net costs"[a] is required to incentivize investments in sorting and recycling infrastructure;
- **Be clear on which packaging and textiles products will be covered,** the recycling targets or KPIs that will be applied, and who is obligated to meet them, and ensure that EPR systems are interoperable across states;
- **Provide support for a broad range of interventions to enable circularity** including end-market development and research and development (R&D) funding via the Producer Responsibility Organization (PRO);
- **Encourage flows of recycled materials into high-value end products** with potential for multiple recycling loops rather than low-value non-recyclable products; this supports the economics of recycling and thus encourages investment in infrastructure;
- **Evaluate the benefits of integrating well-designed Deposit Return Systems** (DRS) for beverage containers (commonly referred to as Bottle Bills) on top of a curbside collection model for all other packaging and textiles; this analysis should take into account the proven potential for significantly higher recycling rates within DRS systems and the opportunity to prevent contamination versus the potential downside impacts of lower value of curbside packaging recycling streams when beverage containers are removed;

Note a. Net of recycling revenues

3

Enact policies to increase demand for post-consumer recycled content (rPET) to reduce market volatility. Examples include:

- Recycled content mandates in legislation;
- Variable EPR fees (known as eco-modulation);
- Incentives and public procurement rules promoting use of recycled materials from U.S. recyclers;
- Supporting the development of end-markets for recycled materials; and
- Implementation of credible mechanisms to account, trace, and ensure safe recycled content from plastic waste inputs to recycled plastic.

4

Set recycling targets by product type for both packaging and textiles, expand coverage of curbside recycling collection for all packaging types, and establish highly-localized drop-off points for textiles, combined with extensive public education campaigns.

5

Increase the price of sending waste to disposal through higher landfill and incineration fees to further boost reuse and recycling and disincentivize linear models.

6

" De-risk" private sector investments by increasing public investment into circularity infrastructure, technology, and research.

Public investment can be made as grants or loans from the federal through municipal level or incorporated into blended financing opportunities. Public sector investment can support a systems-change "tipping point" by catalyzing investment from the private sector into reuse and recycling infrastructure, including collection, sortation and high-yield material-to-material recycling. In addition, many of these infrastructure investments are capital-intensive, with longer payback periods, and so could benefit from "de-risking" from the public sector.

RECOMMENDATIONS

FOR INDUSTRY

PET/polyester producers and recyclers are investing in new technology innovation and scaling.

Consumer goods companies are making ambitious commitments to eliminate unnecessary packaging and reduce virgin plastic use, design products and packaging for reuse or recycling, and use post-consumer recycled content in packaging[a].

Commitments to use recycled polyester in apparel have also emerged across the fashion industry, currently almost fully reliant on mechanically-recycled PET from plastic bottles but with some companies aiming to prioritize textile-to-textile recycling[b].

These are all promising trends, but wider adoption and accelerated action is still required to support the transition to circularity. Five recommendations are identified for companies in the packaging and textiles value chain:

7 Reduce unnecessary consumption (and waste) of textiles and single-use packaging,

through reduction of material use, collaborating on deploying reuse/resale systems, reselling or donating unsold textiles, and moving away from "fast and ultra-fast fashion" business models.

8 Implement best practice design for circularity

through industry collaboration and alignment to enable durability and multiple reuse cycles, maximize recycling and the production of high-value rPET, and minimize microplastic release. Accelerating design for circularity while maintaining fitness for use is particularly necessary for polyester textiles, including shifting from blends to high-purity textiles, and will require value chain collaboration to align on best practices.

Notes a. PepsiCo commits to 100% rPET use for all bottles in the U.S. by 2030. Coca-Cola aims to have at least 25% of beverages by volume sold in refillable or returnable containers, 100% packaging recyclable and use at least 50% recycled content by 2030; b. Most brands' commitment on polyester is focused on rPET incorporation, but a few are also aiming to support textile-to-textile recycling (e.g. Patagonia, VF, Lululemon).

9 Maximize textile collection for reuse and recycling

by offering and incentivizing take-back programs and accessible collection points in apparel, homeware, and carpet stores and collaborating with existing collection programs. Collaboration on collection will lay the groundwork and gather brand/retailer momentum behind EPR policy for textiles.

10 Increase procurement of domestically-generated post-consumer recycled content from both packaging and textiles through long-term contracts

to reduce market volatility and boost domestic infrastructure investment. Reducing the textile industry's reliance on rPET from bottles is necessary in order to strengthen the circularity of both value chains.

11 Implement best industrial practices

to control microplastics generation, capture microplastics during use phase (e.g. washing machine filters) and during the recycling and handling process (e.g. dust and water controls).

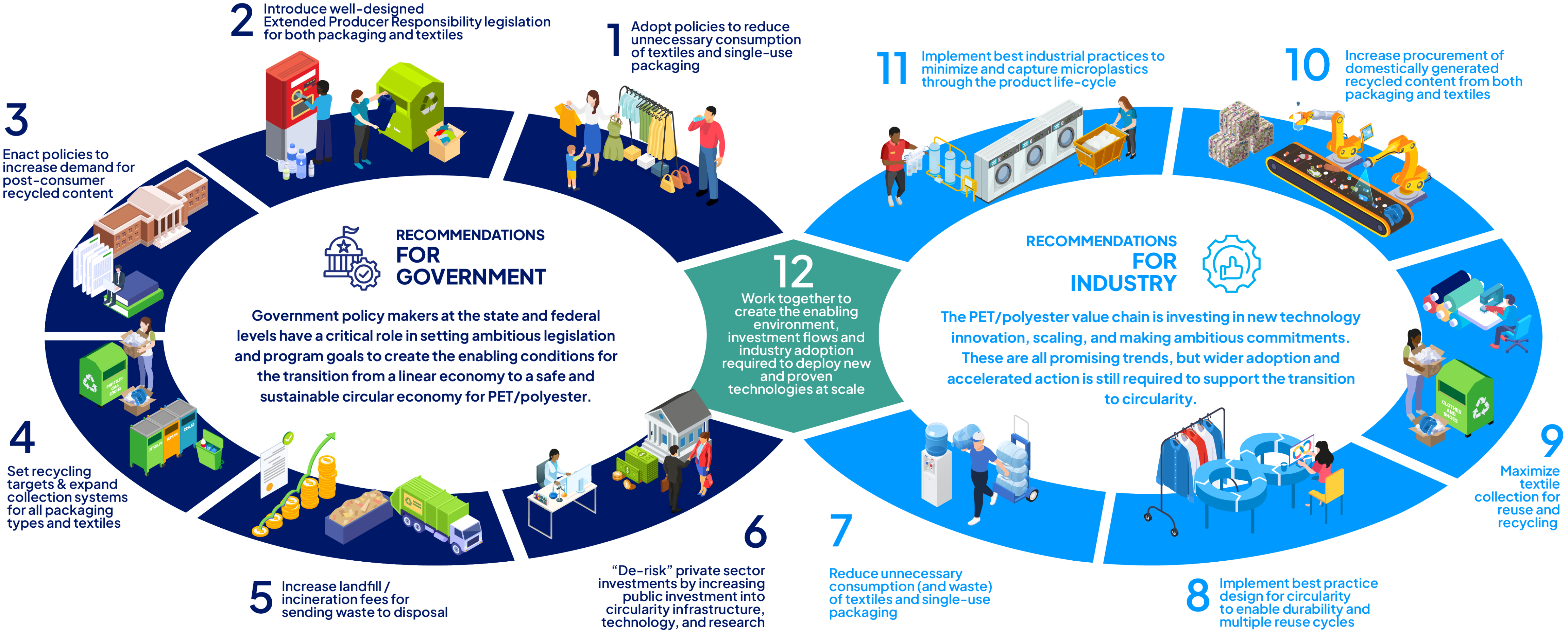
RECOMMENDATIONS FOR CROSS-SECTOR COLLABORATION

The study highlights the range of new and proven technologies that are now available to accelerate action across the full spectrum of circular economy approaches. Scaling up these technologies will require coordinated action from government, industry, investors and research institutions, as identified in the following recommendation:

12 Work together to create the enabling environment, investment flows and industry adoption required to deploy new and proven technologies at scale.

Examples include digital technologies to forecast demand and reduce unsold stocks in textiles, advanced sensor-based and AI-enabled sorting of packaging and textiles for resale, reuse or recycling, and deployment of advancements in both mechanical recycling and depolymerization recycling.

Twelve recommendations to address system challenges and scale PET/polyester circularity.



RECOMMENDATIONS FOR FUTURE RESEARCH

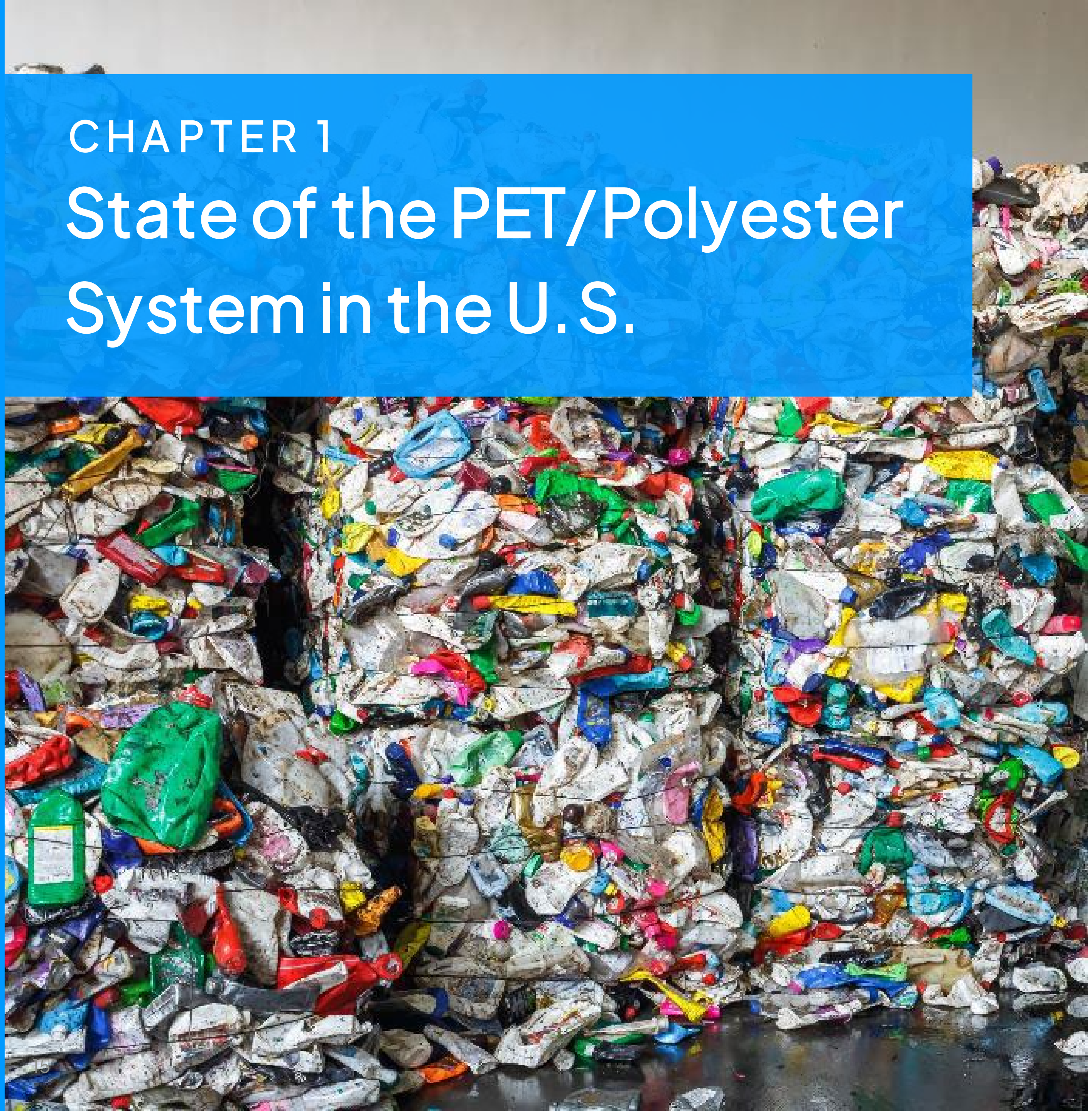
Key outstanding system questions and knowledge gaps have been identified in this study and are recommended for further research, including:

- **Strategies to unlock higher recycling rates for end-of-life textiles,** above and beyond the ambitious application of proven approaches in this study, where polyester textiles only reach 19% recycling rate by 2040. This includes research into consumer behaviors.
- **Further definition of principles for complementary mechanical and depolymerization recycling** based on environmentally- and economically-optimal feedstock allocation principles and practical approaches to implementing these principles.
- **Potential impacts of recycled PET imports on recycling industry growth and recycling rates in the U.S.** Imports currently account for around 20% of recycled PET use in the U.S. while domestic recyclers run below capacity[10].
- **Environmental justice and consumer health concerns, including the extent and impact of packaging and textile supply chains** contribution to microplastics pollution and exposure to chemicals of concern[11], and the most effective mitigation measures.
- **Optimal distribution of recycled PET from mechanical and depolymerization recycling to product applications,** including environmental, cost and logistics considerations. This can be impacted by rPET quality requirements (e.g. depolymerization generates virgin quality rPET), manufacturing locations (e.g. polyester textiles could be recycled in the U.S. , whereas the majority of production of new textile products occurs outside U.S.).
- **Environmental impact trade-offs between different material and system alternatives,** including comparing circularity and climate impacts of PET/polyester compared to other materials such as polypropylene and polyethylene with credible life cycle assessments at a granular product level and also between reuse and single use systems.

Conclusion

The quantitative modeling carried out for this study demonstrates **the potential for system innovations** in the packaging and textile sectors to achieve waste reduction, resource conservation and climate mitigation goals, and create green jobs. **The size of the prize is substantial.** Momentum is building through shifts in the EPR policy landscape, ambitious circularity commitments and action in the packaged goods and fashion sectors, and new technologies emerging at scale.

Coordinated and ambitious action is now required across industry value chains and multiple levels of government to unlock these benefits and create examples of circular and low-emissions PET/polyester value chains at scale that can be emulated by other material systems.



CHAPTER 1

State of the PET/Polyester System in the U.S.

Plastics have become a ubiquitous material in today's society and play a pivotal role in our daily needs, with uses ranging from food to healthcare, consumer products, textiles, automotive and construction. PET[a] is one of the most common types of plastic and primarily known for its widespread use in both PET packaging and polyester textiles. Each year over 100 billion PET bottles and over 10 billion polyester garments[b] are put on the United States market.

The plastics system also makes a significant and growing contribution to waste generation and greenhouse gas (GHG) emissions. Valuable and recyclable end-of-life plastics are landfilled or incinerated each year. Specifically for PET/polyester in the U.S. market, disposed materials are the equivalent of $7 billion per year in material sales if recycled.[c] Policy makers, companies and consumers are becoming increasingly aware of the environmental damage and missed economic opportunities of this linear system, while technology is emerging to help facilitate change.

This report quantifies how the current linear system for PET and polyester use in the United States could be transformed into a circular system by 2040, if proven approaches were adopted at scale, and the benefits this would bring for the economy, people and the planet. This chapter identifies the scale of the issue in its current state in the United States.

Notes **a.** Short for polyethylene terephthalate; **b.** Systemiq analysis; **c.** Based on rPET revenue that could be achieved when recycling material that is lost to landfill, incineration, and export. Does not take into account savings from avoiding disposal gate fees or reduced export revenues

PET and polyester have come to play pivotal roles in plastic packaging & textiles due to their unique combination of properties.

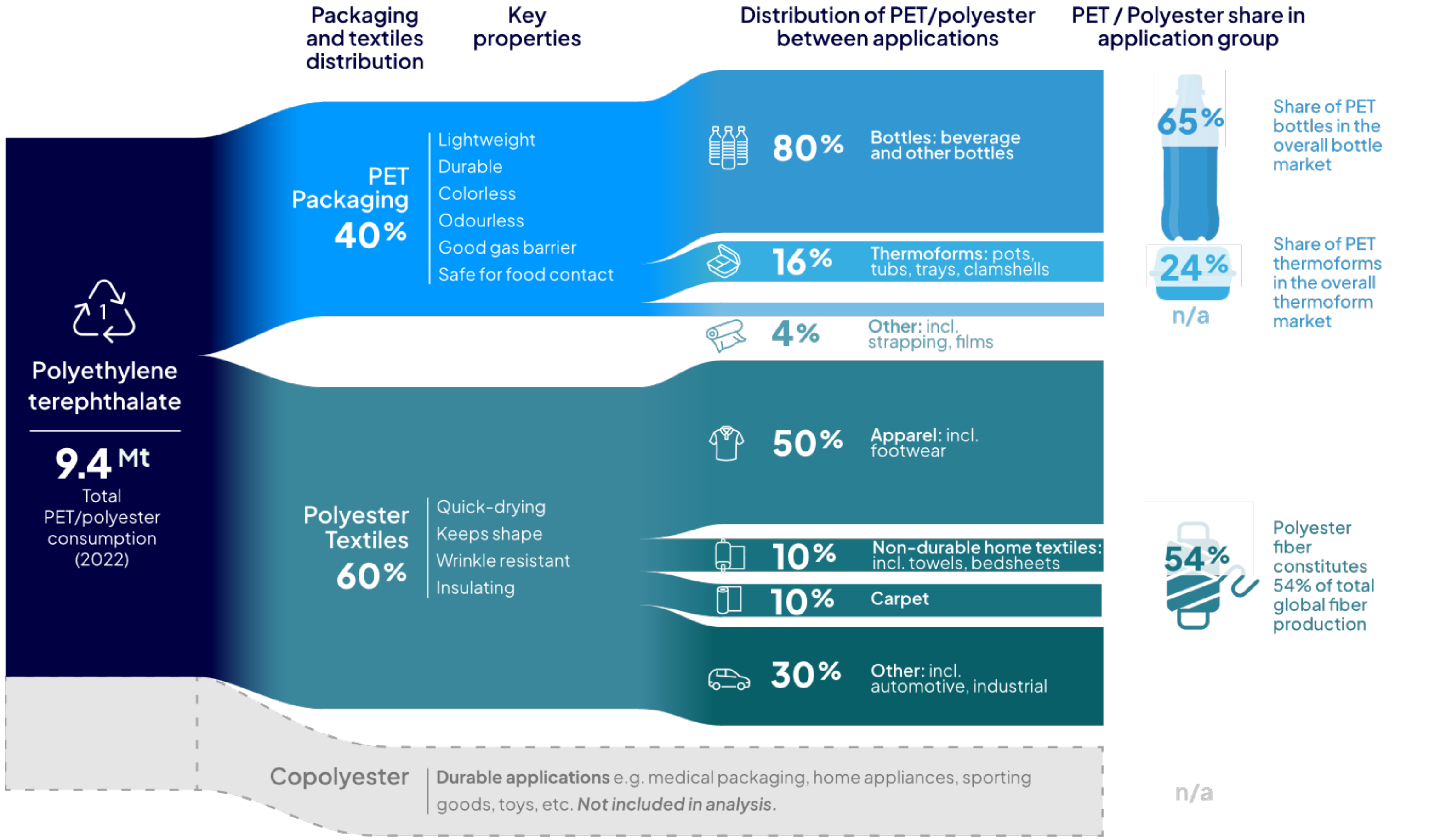
In 2022, the U.S. consumed 9.4 Mt[a] of PET/polyester.[b] Of this amount, 40% was used in packaging and 60% in textiles (*Exhibit 1*). In the packaging sector, around 80% of PET is used for bottles (for beverages and other uses), with the remaining 20% used for trays, tubs, clamshells, and other packaging applications such as strapping. In total, PET makes up about 25% of all plastic packaging in the U.S. .

For packaging applications (e.g. bottles and trays), PET is durable, lightweight, safe for food contact, and extends the shelf-life of food products. Polyester textiles are a versatile and affordable material that is easy to clean and maintains a stable shape. Polyester is commonly used in textiles for apparel, carpets, furniture and in automotive uses.

It is estimated that around half of polyester is used in apparel [c,12] (of which ~70% is used in pure polyester or high-purity polyester blends[d,13]), ~10% in non-durable home textiles (e.g. towels or bedsheets), and ~10% in carpets. The rest is used in other applications, such as automotive and industrial uses.

EXHIBIT 1 Applications and shares of both materials [e]

Based on data from 2019–2024



Sources Systemiq analysis based on U.S. Plastics Pact (2020), Adler, M., & Vellanki, D. (2024), Textile Exchange (2023), Cunningham and Miller (2022), and expert input

Notes **a.** In the report 'Mt' is U.S. ed as abbreviation for 'million metric tons'; **b.** 8.4Mt of virgin PET, 0.7Mt domestic rPET, 0.2Mt rPET import; **c.** Systemiq analysis based on Textile Exchange (2023) and expert input; **d.** High-purity polyester textiles are considered as having >80% polyester by weight; **e.** Copolyester is not in the scope of this study; **f** Strapping is used to secure large packaging formats or materials onto pallets.

PET and polyester consumption in the U.S. has been growing.

Between 2016 and 2023, the consumption of PET in packaging increased by 23% with a compound annual growth rate (CAGR) of ~3%[a]. While U.S. polyester textile consumption growth data is very limited, reported textiles waste generated between 2000 and 2018[b,14] increased by 80% (CAGR of ~3%), which is likely to be broadly indicative of polyester textile growth.

There is growing attention on the role of circular economy and "reduce-reuse-recycle" approaches to reduce environmental impacts and enhance economic benefits in industries that rely on PET/polyester.

In a circular system, PET packaging and polyester textiles are reduced, reused, and recycled to minimize waste and conserve resources (*Exhibit 2*). '**Upstream**' circular economy strategies slow the growth in demand for PET/polyester by changing business models, such as adopting reusable packaging and apparel rental or resale, and by improving product designs for both packaging and textile applications to eliminate unnecessary material use, enable reuse, and facilitate recycling. '**Downstream**' circular economy strategies ensure that PET/polyester waste streams are diverted from landfills into high-value safe reuse and recycling systems supported by efficient and economically viable waste collection and sorting systems.

Notes **a.** Systemiq analysis based on Dow Jones data; **b.** Percentage change in absolute tons, based on EPA waste generation data

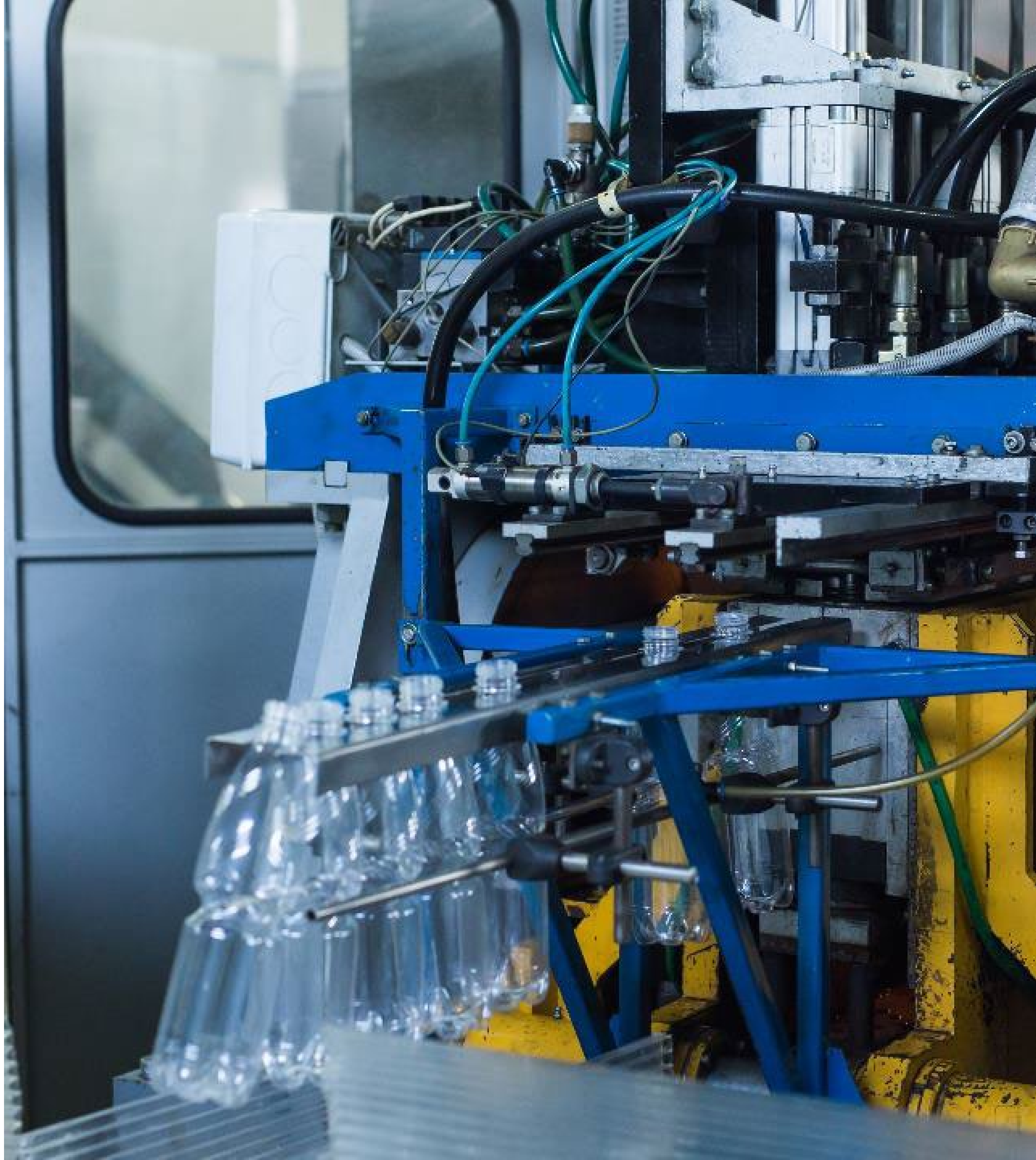
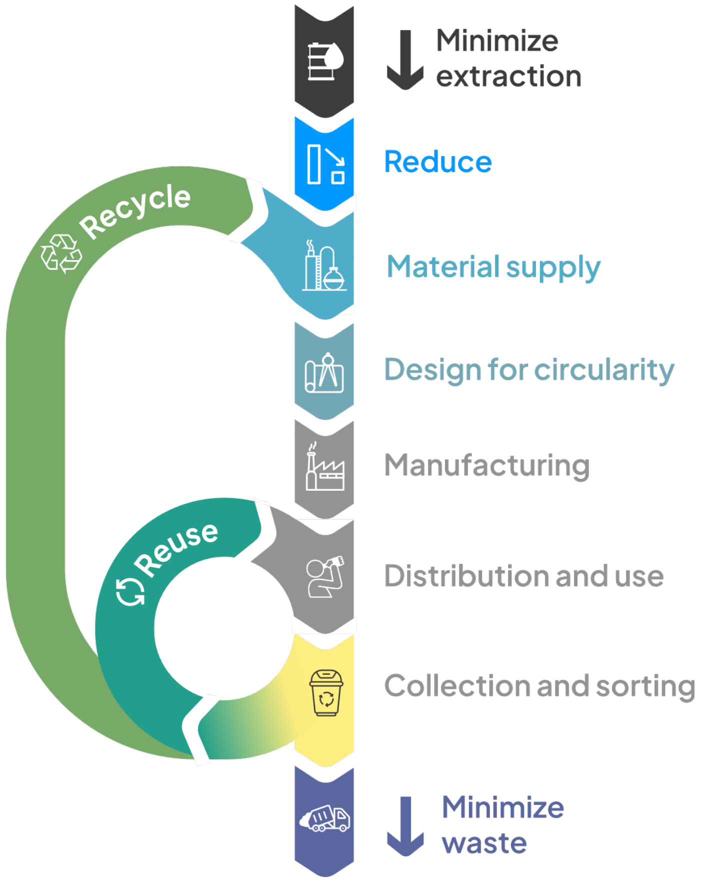


EXHIBIT 2 **Definitions of reduce, substitute, reuse and recycle in the context of PET/polyester**



Upstream | Downstream

Reduce

Minimize material usage by

- **Eliminating** unnecessary packaging and consumption of textiles
- **Optimizing** production efficiency, e.g. lightweighting
- **Substituting** PET/polyester with alternative materials with comparable performance at lower environmental impact

Reuse

Extend the lifespan of PET packaging and polyester textiles through

- Packaging **return and reuse**
- Packaging **refill**
- Textile **repurpose**[a]
- Textile **recommerce** e.g. through second-hand clothing.

Recycle

Divert PET packaging and polyester textiles from landfills and **keep materials in the loop by**

- **Improving collection** and **sorting** of waste
- **Increasing recycling capacities** and include technologies for harder-to-recycle materials

Design for circularity

Adopt designs for PET packaging and polyester textiles that enable reuse and/or recycling through

- **Design for reduction:** same or improved functionality with less material use
- **Design for reuse**: increase durability and repairability
- **Design for recycling**: use of recyclable materials, phase out of problematic materials and additives, shif from multilayers and blends to monomaterials

Notes a. We use the term "repurposing" to refer to textiles that are turned into anything else, typically via simpler processes that do not alter the fiber structure. Polyester textiles are repurposed into filament, stuffing, or shoddy for products like upholstery or building insulation

Environmental impacts from the plastics system and health concerns about plastics are gaining traction and strengthening the case for a circular economy transition.

Alongside increasing awareness of plastic pollution's impact on oceans and the export of plastic waste to the Global South, there are rising concerns about impacts and environmental justice issues within the U.S. These include the effects of plastic production on local communities as well as landfill expansion and the transport of waste across states borders because of exhausted landfill capacities[15].

The effect of microplastics on human health – a relatively new research field – has also become an important topic for the U.S. public: 66% of U.S. consumers indicate they are very concerned about the health impacts of microplastics[16]. Among the various sources of primary microplastics, those from PET/polyester primarily originate from textile wear and tear during use and wash, leakage from landfills and during manufacturing or recycling processes. [a, b, c, 17, 18]

In the U.S., the majority of PET/polyester follows a linear, rather than circular, system and is disposed of in landfills or incinerated.

As a result of limited reuse and low recycling rates, the PET/polyester system is reliant on significant virgin fossil fuel-based feedstock from oil and natural gas (*Exhibit 3*).

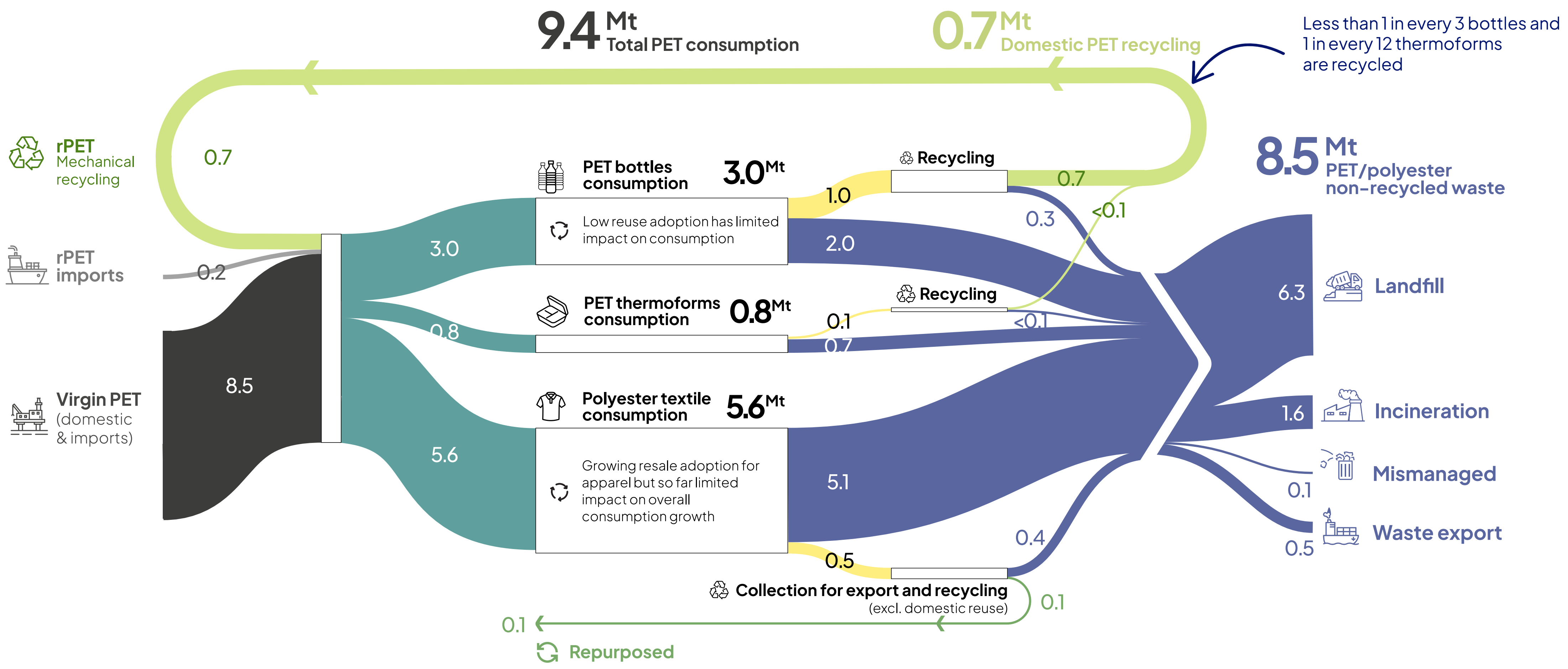
Recycled content supply is generated almost exclusively from PET bottles, with its distribution across applications driven by demand for recycled content[d,20]. With no recycling pathways at scale today for polyester textiles, PET packaging is often recycled into polyester textiles, but never the other way around. This limits the potential to meet corporate rPET commitments.

Alongside increasing awareness of plastic pollution's impact on oceans and the export of plastic waste to the Global South, there are rising concerns about environmental impacts and justice issues within the U.S

Notes **a.** A study found that the microplastic release in wastewater from mechanical recycling plant including filtration systems —considered a best practice-- amounted to 6% of the total plastic waste processed. This number can be as high as 13% without a filtration system in place; **b.** Microplastic release during the recycling process highlights the need to invest in microplastic reduction technology, in parallel with increasing recycling rates. Although PET/polyester microplastics account for a small share of global primary microplastic release (the large majority is from paints and tires), the scale of microplastic release is nonetheless significant and further research is needed to understand impacts; **c.** The referenced analysis excluded so-called "secondary microplastics" which originate from the breakdown of macroplastics; **d.** In 2022, approximately half of rPET was used to make bottles, a quarter for other PET packaging, and a quarter for polyester textiles.

PET packaging and polyester textiles primarily rely on virgin, fossil-fuel derived feedstock today. This is because recycling is limited to packaging, and only PET bottles are recycled at meaningful scale.

EXHIBIT 3 **2022 U.S. PET packaging and polyester textiles flows**



Notes a. Bio-PET is excluded; b. Sources are provided in the technical appendix; c. We use the term "repurposing" to refer to textiles that are turned into anything else, typically via simpler processes that do not alter the fiber structure. Polyester textiles are repurposed into filament, stuffing, or shoddy for products like upholstery or building insulation. d. PET thermoforms consumption includes a small share of other PET applications such as strapping and films (see Exhibit 1)

The economics of circularity has been a leading factor limiting its growth.

While a detailed economic analysis was not carried out for this study, the need to strengthen the economics of circular approaches for PET/polyester was highlighted by the Steering Group, expert interviews, and prior research. Other key structural barriers to PET/polyester circularity were also analyzed, drawing on insights from Steering Group members, expert interviews and prior research (*see Annex A4*).

For instance, today the economics of investing in recycling can be marginal. The cost of producing recycled PET is estimated to be 5–20% higher than virgin PET,[21] and recycling economics are affected by uncertain demand due to volatility of virgin PET prices and competition from imports of recycled PET.

rPET imports have increased in recent years, now accounting for approximately 20% of rPET supply[a,22,23,24,25]. At the same time, domestic mechanical PET recycling plants are running at an average of approximately 75% utilization[26], highlighting the challenge presented by imports.

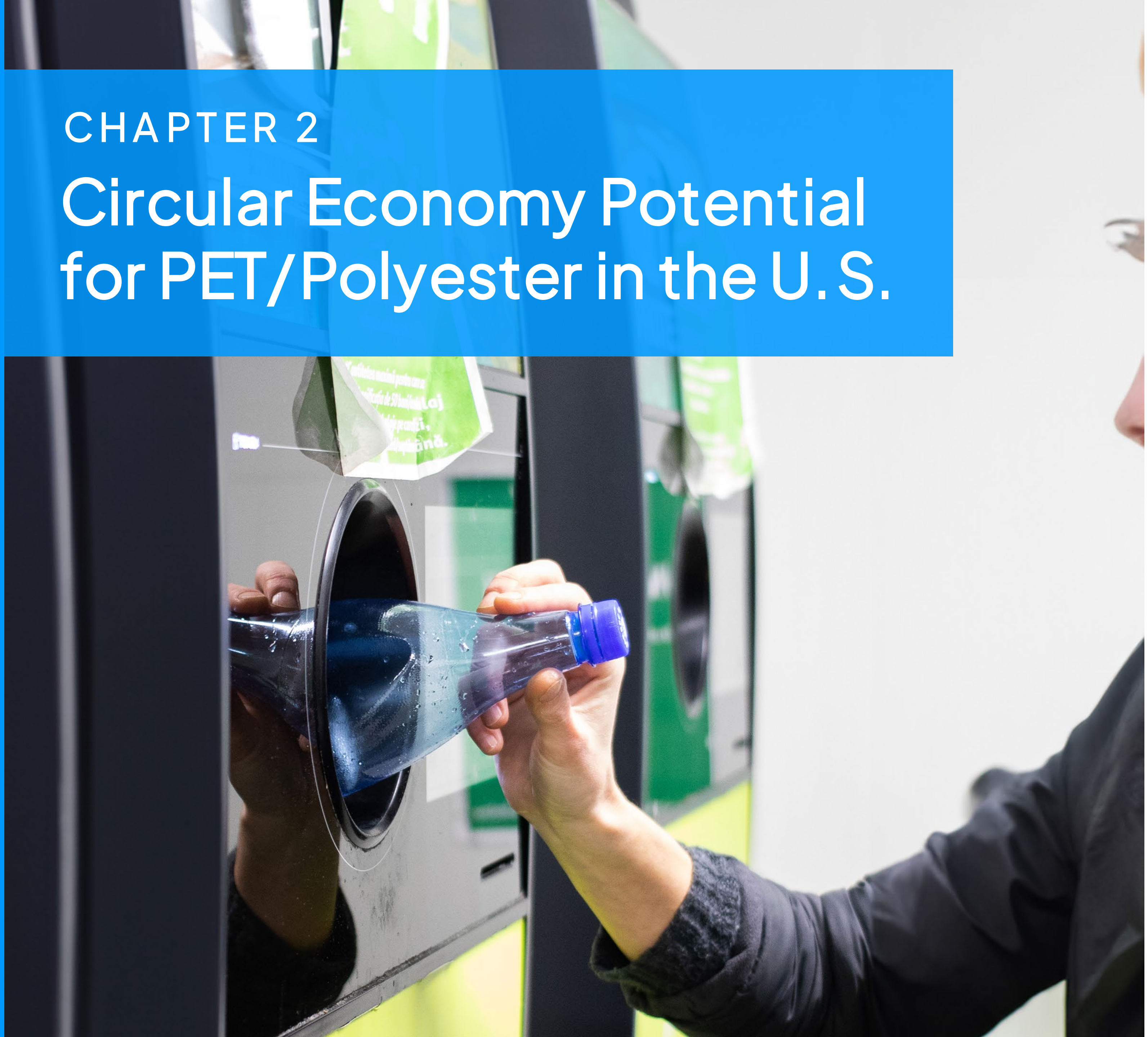
Improving the investment case to build new sorting and recycling infrastructure will require coordinated action from the public and private sectors . This is especially true for textile recycling, the infrastructure for which is much less well-developed than that for PET packaging.

Note a. Recent increases in demand for recycled PET (rPET) are being met predominantly through imports, predominantly from southeast Asia, Canada and Latin America, with imports often able to outcompete domestic rPET on price; b. Systemiq Analysis based on Steering Group insights. More details in Annex A4.

EXHIBIT 4 Long term economic barriers have limited the growth of " reduce-reuse-recycle" circular strategies [b]

CHAPTER 2

Circular Economy Potential for PET/Polyester in the U.S.



Corporate circularity commitments are well-established in the packaging and apparel sectors.

The number and ambition of voluntary commitments by brands is increasing with targets on reduction, recyclability and recycled content.[a] Examples are highlighted in *Exhibit 5*.

This is driven by a combination of consumer demand, market competition, and efforts to anticipate and shape emerging government policies. While leading companies have invested significantly into their circularity commitments, particularly those that relate to recycling and recycled content, in many cases progress has been slower than anticipated and commitments have not consistently translated into action[27].

Note a. In the New Plastics Economy Global Commitment, more than 250 businesses, representing 20% of plastic packaging globally, have aligned on ambitious 2025 targets ensuring 100% of plastic packaging is resuable, recyclable or compostable. In the 2025 Recycled Polyester Challenge, 72 of the 124 signatories commit to replacing 100% of virgin polyester with recycled content by 2025.

U.S. brands have set commitments to reduce virgin plastic use and increase recycled content

EXHIBIT 5 Examples of corporate commitments

Examples of packaging brands commitments

Coca-Cola	50% recycled PET in water bottles by 2030	↓20% virgin plastic reduction by 2025[a]
Danone	50% recycled PET in water bottles by 2025	↓30% virgin plastic reduction by 2030[a]
Nestlé	50% recycled PET in water bottles by 2025	↓33% virgin plastic reduction by 2025[ii]
PepsiCo	100% recycled PET in USA by 2030[i]	↓20% virgin plastic reduction by 2025[b]
Unilever	25% recycled plastic by 2025	↓40% virgin plastic reduction by 2028[a]

Leading brands with significant U.S. presence have set ambitious voluntary commitments to become more circular. Examples are highlighted here for virgin plastic reduction and recycled content.

Currently, the vast majority of recycled polyester textiles are made from recycled PET bottles. Depolymerization recycling to enable textiles-to-textiles recycling of polyester is now emerging.

Examples of textiles brands commitments

INDITEX, adidas, H&M Group, J.CREW

100% recycled polyester by 2025

Notes a. Baseline year between 2018–2020; b. Pepsi-branded products

Sources Ellen MacArthur Foundation (2023), Textile Exchange (2024), company websites

Government policies are in place in some states to support PET/polyester circularity in the U.S., with packaging leading the way and gaining momentum.

Bottle bills (also known as Deposit Return Systems, or DRS) were first introduced in 1972 and now exist in ten states to incentivize recycling of PET bottles by enforcing a deposit at point of purchase that is refunded when empty containers are returned[a]. Broader Extended Producer Responsibility (EPR) legislation for packaging has been passed in five states with ten others considering new EPR laws.[38] EPR requires producers to contribute to end-of-life costs of products placed on the market and provides incentives for reduction and design for increased circularity of products. Other policies impacting PET packaging, such as recycled content mandates, are also emerging *(Exhibit 6)*. Unlike packaging, textile policies have only recently started to emerge with legislation adopted in California and New York State.

While there is growing momentum to establish policies, our recommendations in Chapter 4 highlight key principles to follow to ensure these policies are well-designed, maximizing environmental impact and socio-economic benefits.

Note a. Bottle bills or Deposit Return Schemes are a type of EPR that, when well-designed, are proven to significantly increase recycling rates for beverage bottles.

EXHIBIT 6 **State-level packaging policies**

NOT EXHAUSTIVE

States with recycling policies	
Recycling targets	OR, CA, WA, ME, CT
Recycled content mandates on select products	OR, CA, WA, ME, CT, NJ
Deposit return systems or “Bottle Bills”	CA, CT, HI, IA, ME, MA, MI, NY, OR, VT
Extended producer responsibility	ME, OR, CO, CA, MN with distinct designs in each.

States with reuse policies	
Reuse targets	CA, OR
Deposit return scheme (DRS) incl. reuse	CA, MA

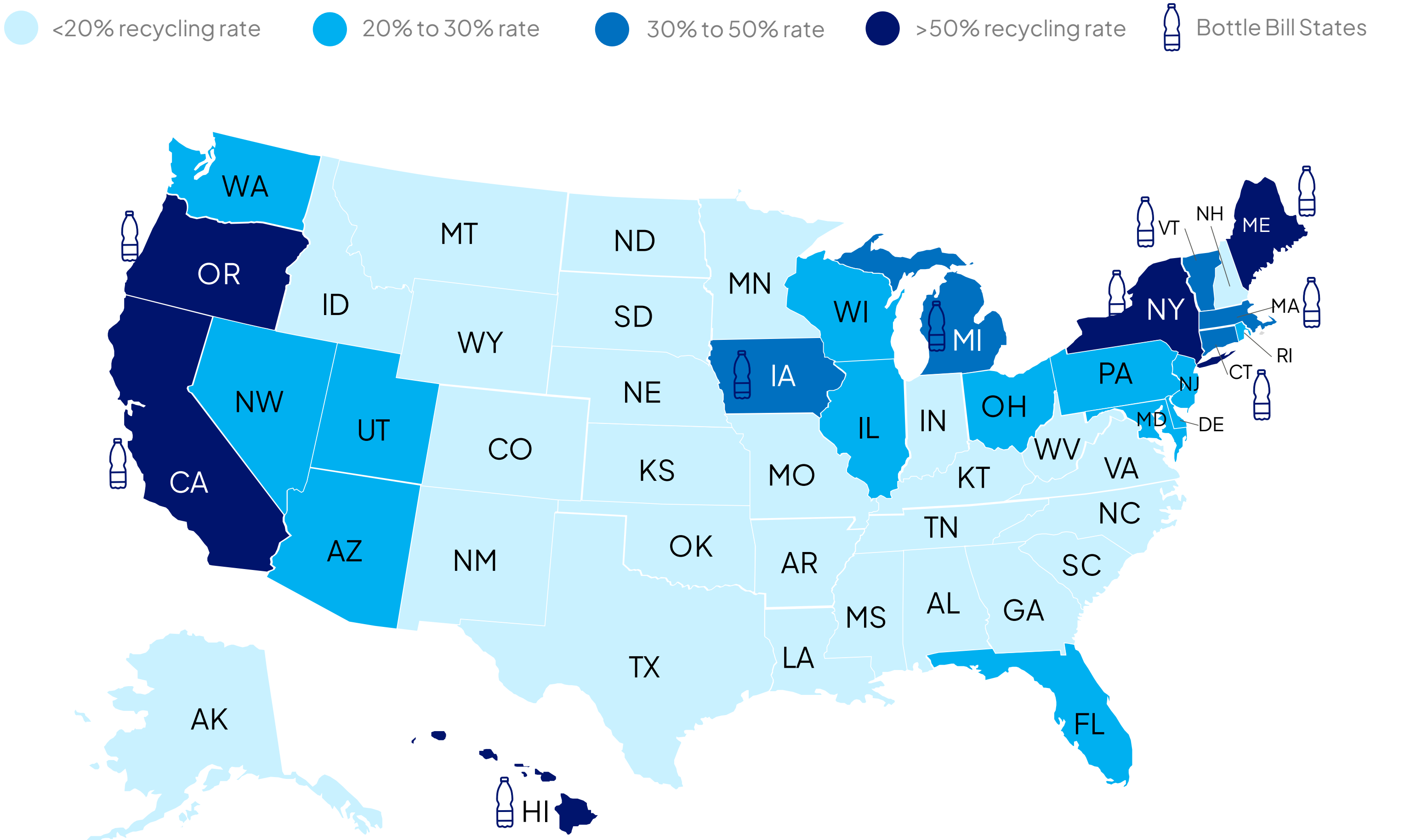
States with none of the recycling and reuse policies	
None of the policies covered	AL, AK, AZ, AR, DE, DC, FL, GA, ID, IL, IN, KS, KY, LA, MD, MS, MO, MT, NE, NV, NH, NM, NC, ND, OH, OK, PA, RI, SC, SD, TN, TX, UT, VA, WV, WI, WY

Policies have proven effective in boosting collection and recycling rates of PET bottles.

Policy has been shown to be effective in strengthening recycling performance. For example, the ten states with bottle bills achieve higher recycling rates for bottles (*Exhibit 7*). Despite covering only a quarter of the U.S. population, bottle bill states account for 60% of the PET bottles recycled in the U.S.[29]. All states with bottle bills have recycling rates above 30%, while at least five achieve rates above 50%.

The success of bottle bills is dependent on multiple factors including the level of deposit (e.g., 10 cents per container in Oregon[30], which achieves the highest bottle recycling rate of 75% and bottle collection for recycling rate of 90%) and the ease of participation.

EXHIBIT 7 PET bottle recycling rates and bottle bills by state



Source: The Recycling Partnership (2024), Systemiq analysis

New technologies and innovations are opening up new opportunities for circularity.

New technologies and innovations are emerging across the full spectrum of circular economy approaches *(Exhibit 8)*. These technologies and innovations are enabled by AI (e.g. for demand prediction), advanced sensors (e.g. for optical sortation), recycling technology (e.g. depolymerization for hard-to-recycle materials[a]), digital payment mechanisms (e.g. for deposit return systems), material innovation (e.g. lightweight packaging), and product innovation (e.g. concentrated cleaning products).

To address the current challenges in textile recycling, solutions for textile-to-textile recycling need be developed in order to reduce reliance on rPET sourced from PET bottles. Depolymerization offers a promising approach for recycling both polyester textile and hard-to-recycle PET packaging and generating virgin-quality rPET. This would enable a flexible system supporting both the packaging and textile systems.

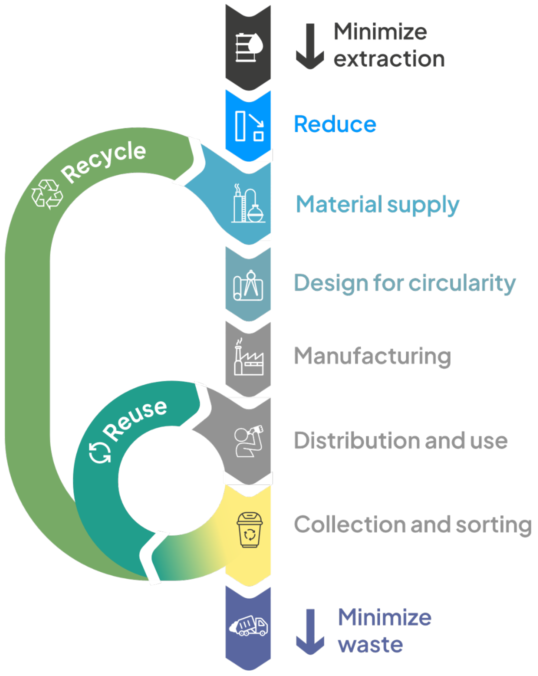
Depolymerization could offer a promising approach for recycling both polyester textile and hard-to-recycle PET packaging and generating virgin-quality rPET.

Note a. The technology will need to prove its effectiveness at scale to recycle both hard-to-recycle PET packaging and polyester textiles.

Photo credit: Eastman- Depolymerization plant, Kingsport, TN

Technology developments are opening new opportunities across the circular economy

EXHIBIT 8 **Examples of innovations enhancing circularity**



Reduce

- Next generation packaging and textiles materials to substitute for PET/polyester, where environmentally beneficially[a]
- Lightweighting of PET packaging
- New product delivery models, such as shift to concentrate products
- Enhanced apparel demand forecasting
- Optimized textile production to reduce offcuts
- Home carbonators and filtration systems

Reuse

- Online platforms for textiles resale [b]
- Reverse logistics technologies, including harmonized packaging[c] and traceability
- Digital packaging return for reuse
- Digital in-store refill[d]

Design for Circularity

- Mono-material packaging solutions to replace hard-to-recycle multi-material solutions
- Labelless bottles
- Adhesive formulation and design for easier label/absorbent pad removal
- Textile printing technology in the same material to increase recyclability

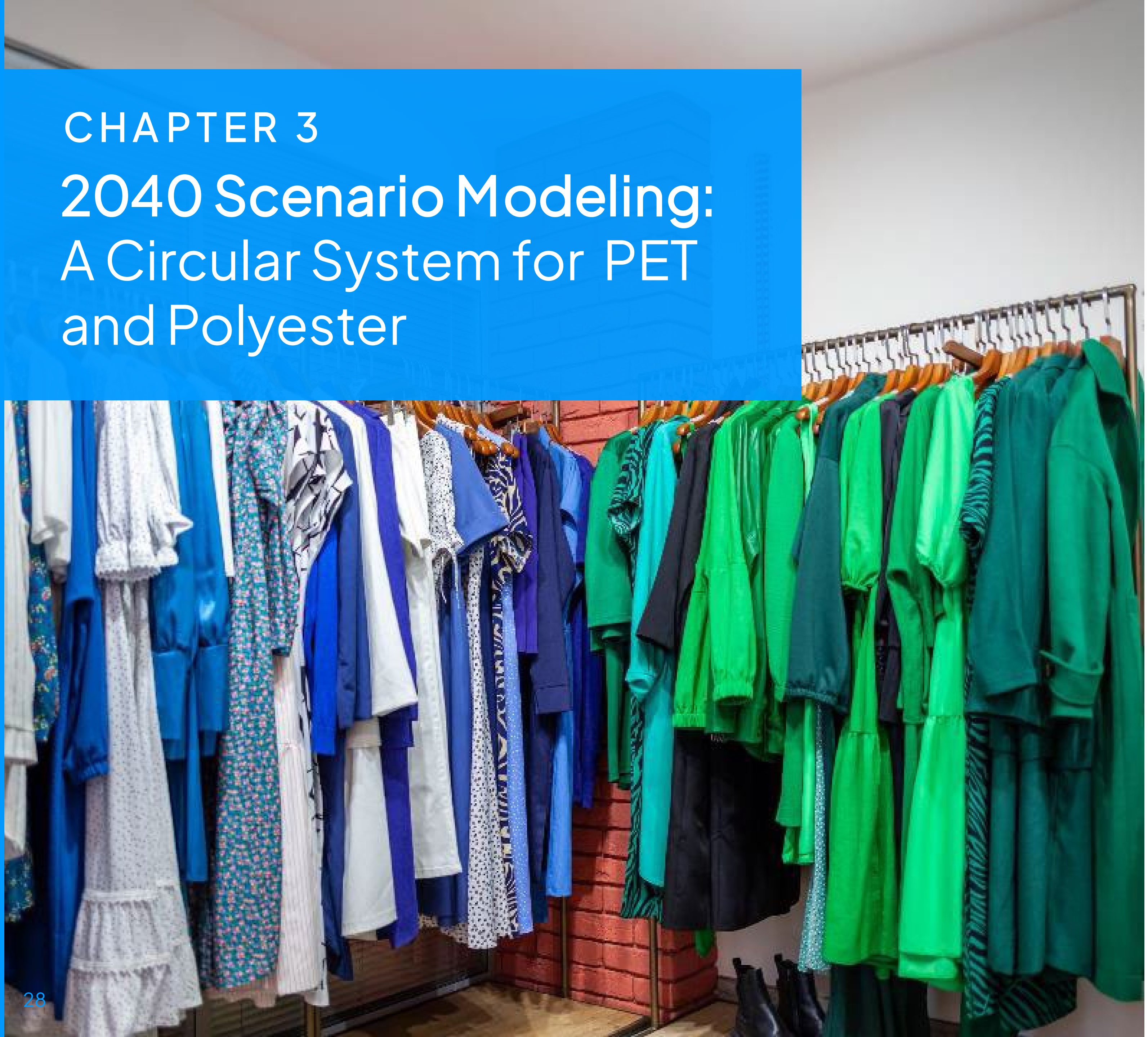
Collection & Sorting

- Digitally enabled deposit return systems for recycling
- AI driven optical sortation for packaging and textiles recycling[e]
- Remote sensors on textile collection bins
- Digitally enabled demand driven textiles collection[f]

Recycle

- Depolymerization recycling to process materials that are hard to mechanically recycle into virgin-quality PET/polyester
- Advances in mechanical recycling technology

Notes Illustrative examples: a. waste/byproduct plant, mycelium, microbe-derived, spider silk proteins; b. e.g., ThreadUp; Coca-Cola Universal bottle in South America; c. e.g., TOMRA reverse vending machine; d. e.g., Algramo; e. e.g.,Greyparrot; Sortile identification, sorting, and traceability technology for textile; TOMRA and Stadler automated textile sorting plant; f. e.g., Trashie Take Bake Bags, Retrievr;
Sources: Innovation in Textiles (2021); Adler, M., & Vellanki, D. (2024) ; Fraunhofer Institut (2015).



CHAPTER 3

2040 Scenario Modeling: A Circular System for PET and Polyester

Two alternative 2040 scenarios are outlined in this chapter: a Current Trends Scenario and an Ambitious Circularity Scenario.

> **The Current Trends Scenario** projects a continuation of recent PET/polyester consumption trends and end-of-life disposal/recycling pathways.

> **The Ambitious Circularity Scenario** quantifies the impact of applying proven circular economy solutions at scale across the PET/polyester supply chain, in line with best practices in the U.S. today *(Exhibit 10)*.

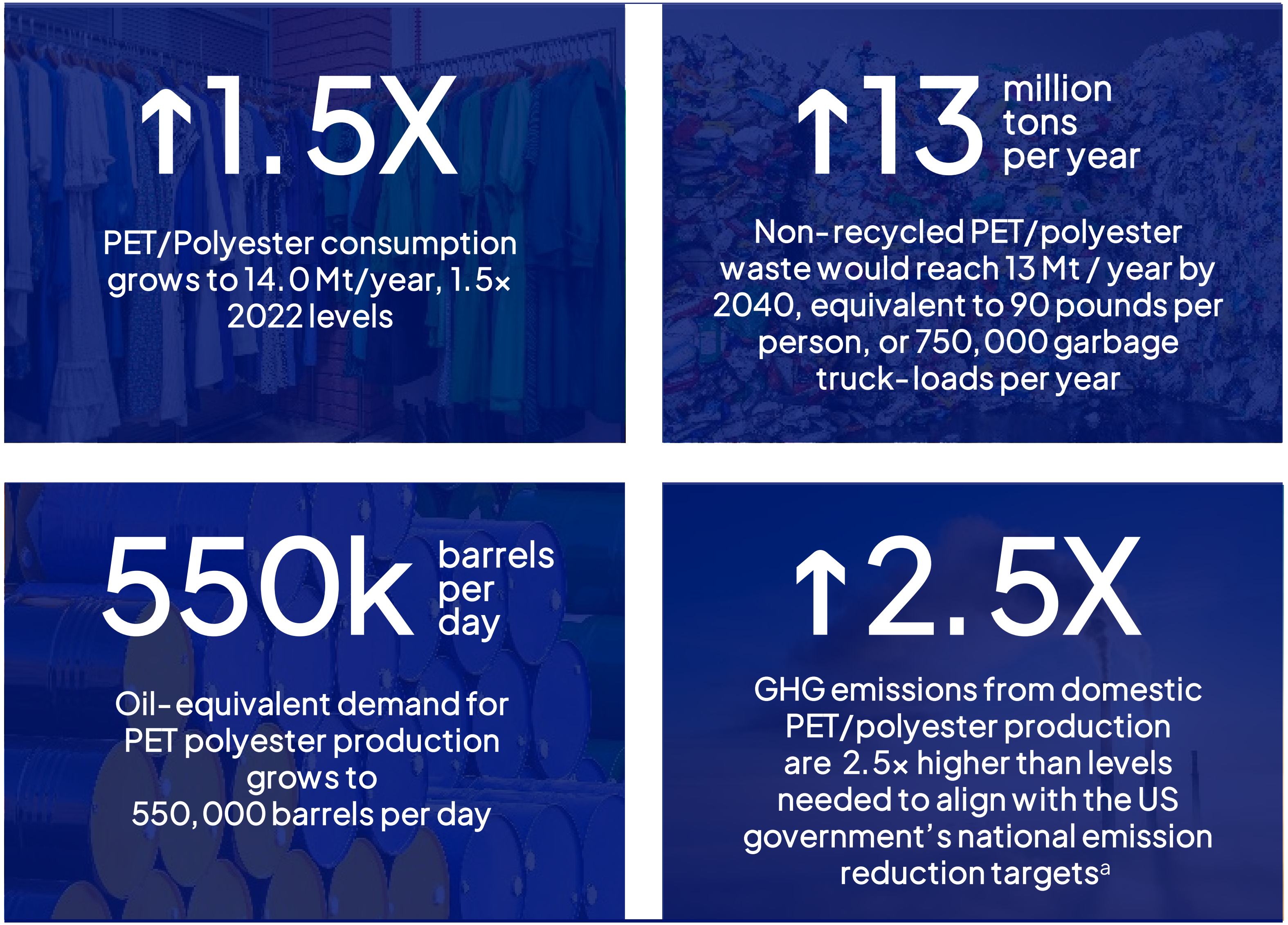
Sensitivity modeling has also been used to understand the impact of deviations from the Ambitious Circularity Scenario and the factors that have the highest impact on the overall system outcomes by 2040.

Scenarios, sensitivities and modeling methodology are outlined in detail in the technical appendix.

The 2040 Current Trends Scenario

Continuation of recent PET/polyester consumption trends and end-of-life disposal/recycling pathways between now and 2040 lead to substantial growth in material consumption, GHG emissions and waste generation *(Exhibit 9)*.

EXHIBIT 9 **Key insights from a 2040 Current Trends Scenario for the US PET/polyester system**



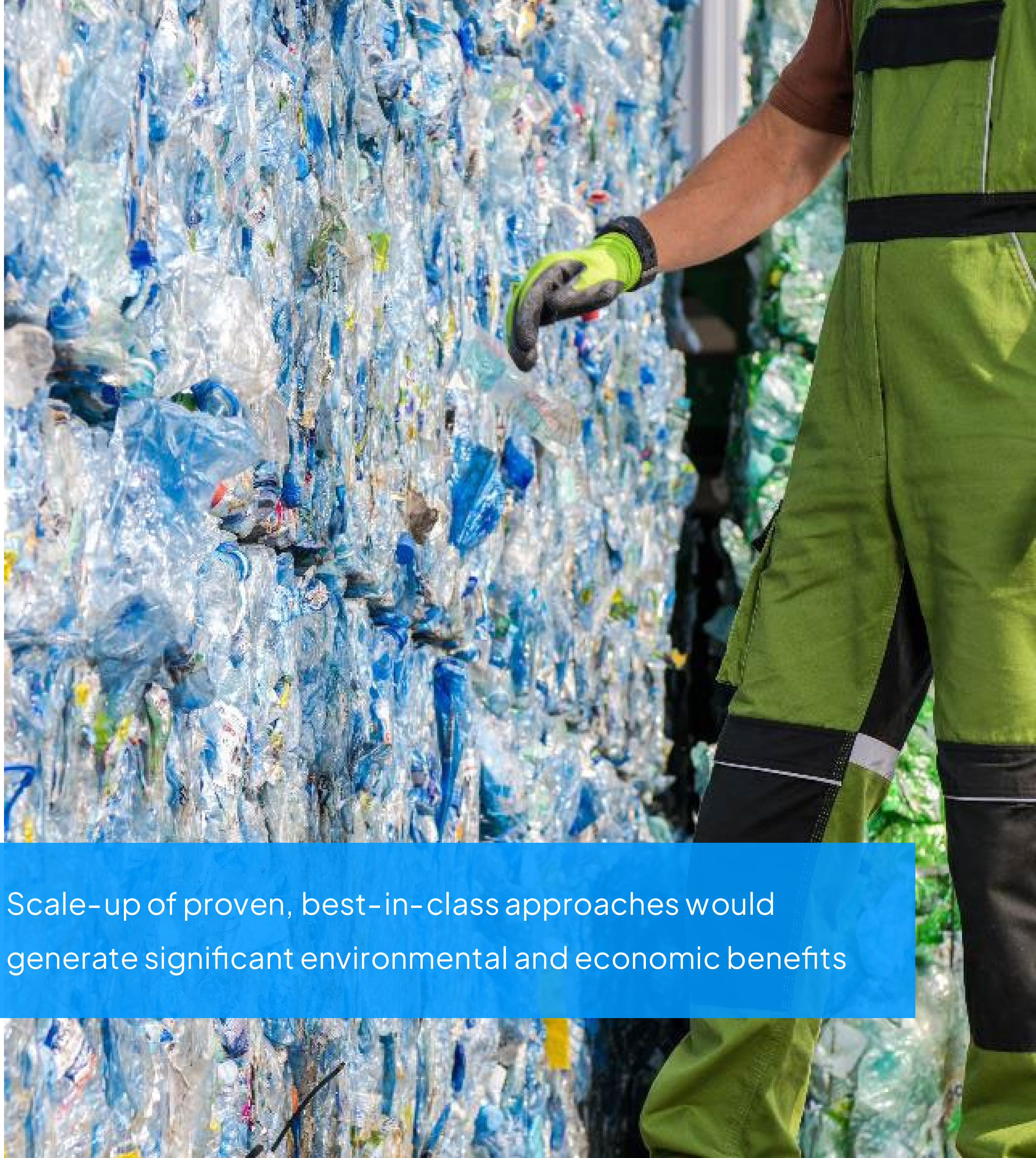
Note a. The U.S. has a goal of net-zero emissions no later than 2050 (The Long-Term Strategy of the United States: Pathways to Net-Zero Greenhouse Gas Emissions by 2050). This would require GHG emissions to reduce by approximately 70%, from 2022 to 2040 (Systemiq analysis). In the Current Trends Scenario, emissions reduce by only around 25% by 2040, as a result of electricity grid decarbonization (without further electrification).

The Ambitious Circularity Scenario is based on a principle that proven, best-in-class approaches already operating in the U.S. can be widespread by 2040. An overview of modeling principles and approaches is provided in *Exhibit 10* and detailed in the technical appendix.

Results

Scale-up of proven, best-in-class approaches across the U.S. by 2040 would lead to a transformation of the PET/polyester systems, particularly for PET packaging, and would generate significant environmental and economic *benefits (Exhibits 11–15).*

This scenario marks a point on the journey to an even more circular PET/polyester economy. Notably, polyester textiles would still have significant room for further reduction of consumption and increased recycling. However, in the context of consumption models and recycling rates today, the benefits of achieving the 2040 Ambitious Circularity Scenario are extensive.



Scale-up of proven, best-in-class approaches would generate significant environmental and economic benefits

EXHIBIT 10 Modeling principles and key assumptions for the 2040 Ambitious Circularity Scenario

Modeling principles

- Proven, best-in-class, circularity approaches are widespread by 2040
- Best-in-class principles can be applied at a state level (e.g. U.S. average beverage bottle collection rate in 2040 achieves Oregon's beverage bottle collection rate today) or technology level (e.g. weight reduction of PET beverage bottles based on best-in-class technology today, applied with 50% market penetration to account for technology readiness level)
- Bottom-up approach used for less established systems where best-in-class data is not directly available

Assumptions overview

Upstream Reduce, reuse & re-design	Downstream Collect, sort & recycle
Packaging • 38% consumption reduction due to lightweighting, refill and return models (e.g., dispensers), as well as new models (e.g., concentrates) adopted at scale • Shift from opaque/colored to clear PET packaging where technically feasible (80% shift for bottles and 90% for thermoforms)	**Packaging collection** • 70% of all packaging gets collected and sorted based on improved curbside collection, sorting, and Deposit Return Systems for beverage bottles **Textiles collection** • 23% of all textiles collected through high proximity drop-off points (incl. charity) and innovative collection models
Textiles • 15% consumption reduction due to avoided destruction of unsold polyester apparel, textile manufacturing waste reduction, slowdown of fast-fashion trends, and growth of resale and rental • 10% shift from polyester-poor to polyester-rich apparel, based on action by market leaders	**Sortation and recycling infrastructure** • Sortation, mechanical recycling, and depolymerization recycling infrastructure scale up to meet supply from collection and sorting • rPET imports do not undermine growth of domestic recycling sector

Scale-up of proven circular economy approaches by could cut waste, create U.S. jobs and mitigate climate change.

EXHIBIT 11 Key insights from a 2040 Ambitious Circularity Scenario for the US PET/polyester system

↓ ½

Virgin PET/polyester consumed
reduces by half
(by 5.9 Mt/year by 2040) [a]

↓ ½

PET/polyester waste to landfill and incineration
reduces by half
(by 5.5 Mt/year by 2040) [a]

70%

Recycling rate for PET packaging increases to 70% (up from 23%) and to 19% (up from >1%) for polyester textiles [a]

↓ 58%

GHG emissions for PET/ polyester consumed in the U.S. reduces by 58% for PET packaging and by 16% for polyester textiles [a]

↑ 46k

Generates
46k net additional direct jobs
in the U.S. [b]

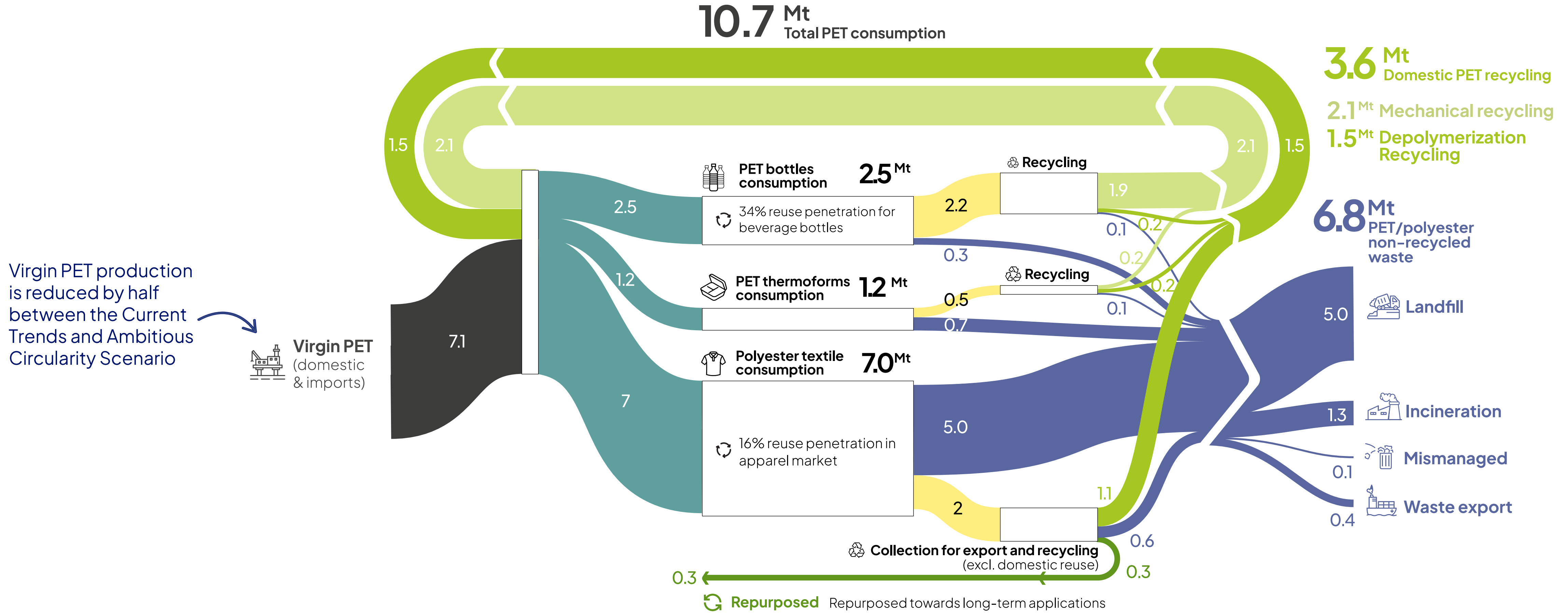
$4.9 bn

Generates $4.9 billion in revenues for U.S. recycling industries, a 4.5x increase [b]

Note a. Relative to a continuation of current trends by 2040; b. Relative to 2022.

Applying proven circular approaches could transform the PET packaging and polyester textiles system. For non-bottle packaging and textiles to unlock high recycling rates in line with PET bottles, further innovation in collection is required.

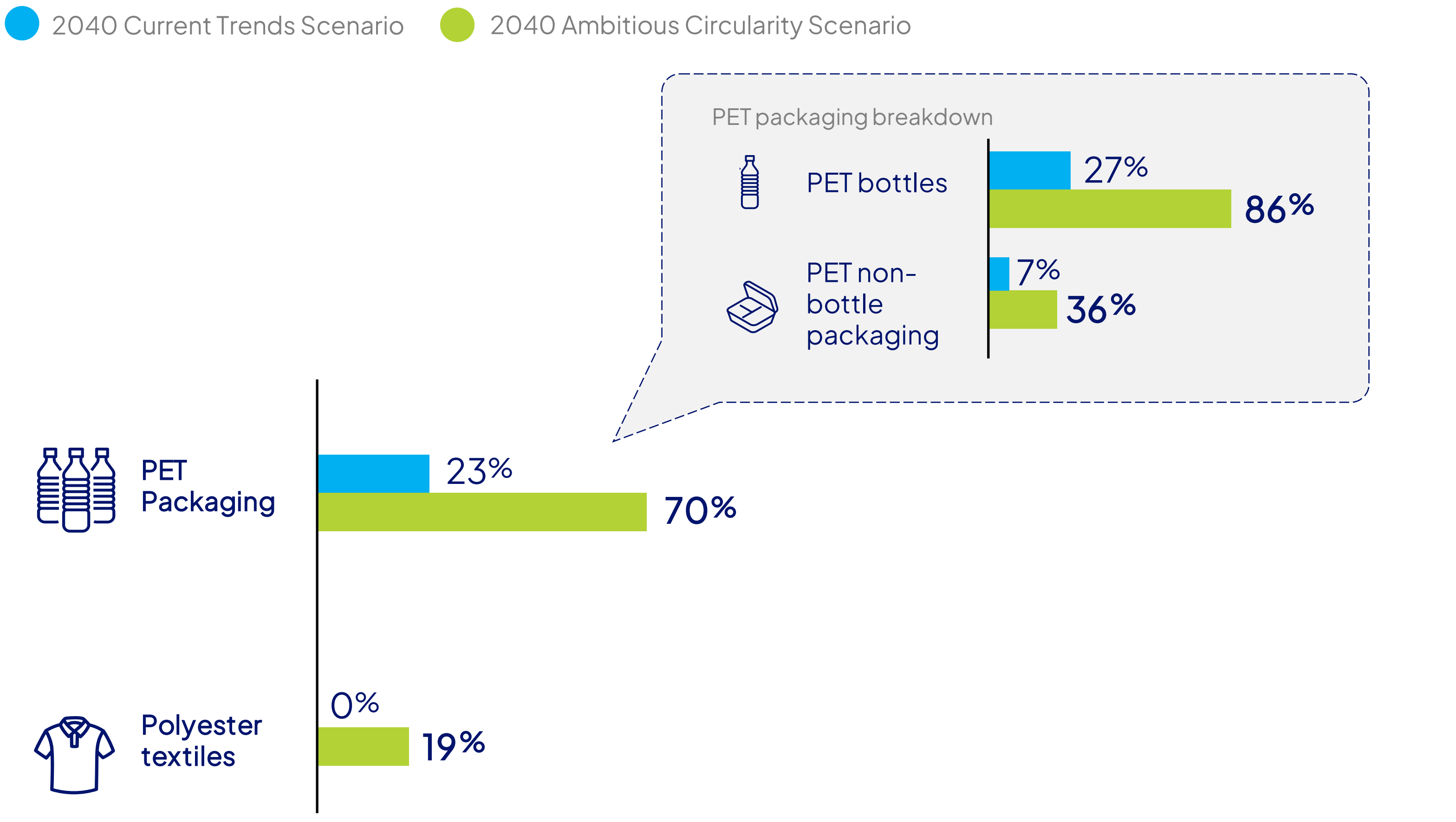
EXHIBIT 12 **U.S. PET packaging and polyester textiles flows,** Ambitious Circularity Scenario, 2040



Notes **a.** All "Waste export" comes from textiles since we assume an efficient system by 2040 that does not rely on exports of packaging waste; **b.** Bio-PET is excluded; **c.** Bottle reuse (e.g., through dispensers, bottle refill and return, home filtration, home carbonators, public water fountains) and textile resale (e.g., through charity, peer-to-peer marketplaces, or branded recommerce) are captured in upstream consumption reduction; **d.** The depolymerisation mass flow includes losses from mechanical recycling that are used as input to depolymerisation as they cannot be recycled otherwise. Note that this makes the vast majority of the flow from PET bottle recycling to depolymerisation; **e.** The Polyester textile consumption box does not equal the sum of flows going out of it since we model lifetimes, and consumption is increasing in the years before 2040; **f.** Sources are provided in the technical appendix. **f.** PET thermoforms consumption includes a small share of other PET applications such as strapping and films (see Exhibit 1)

The Ambitious Circularity Scenario demonstrates strong progress towards high recycling rates across all product categories, with 2040 progress reflecting different starting points.

EXHIBIT 13 **Recycling rates by product categories,** Ambitious Circularity Scenario, 2040



Key Insights

PET beverage bottles could achieve high recycling rates of 86% in the Ambitious Circularity Scenario (vs. 27% in the Current Trends Scenario), reflecting the performance of proven, best-in-class approaches to collection, sortation and recycling today (e.g. Oregon achieves bottle collection rates of 90% today through its Deposit Return System[a]).

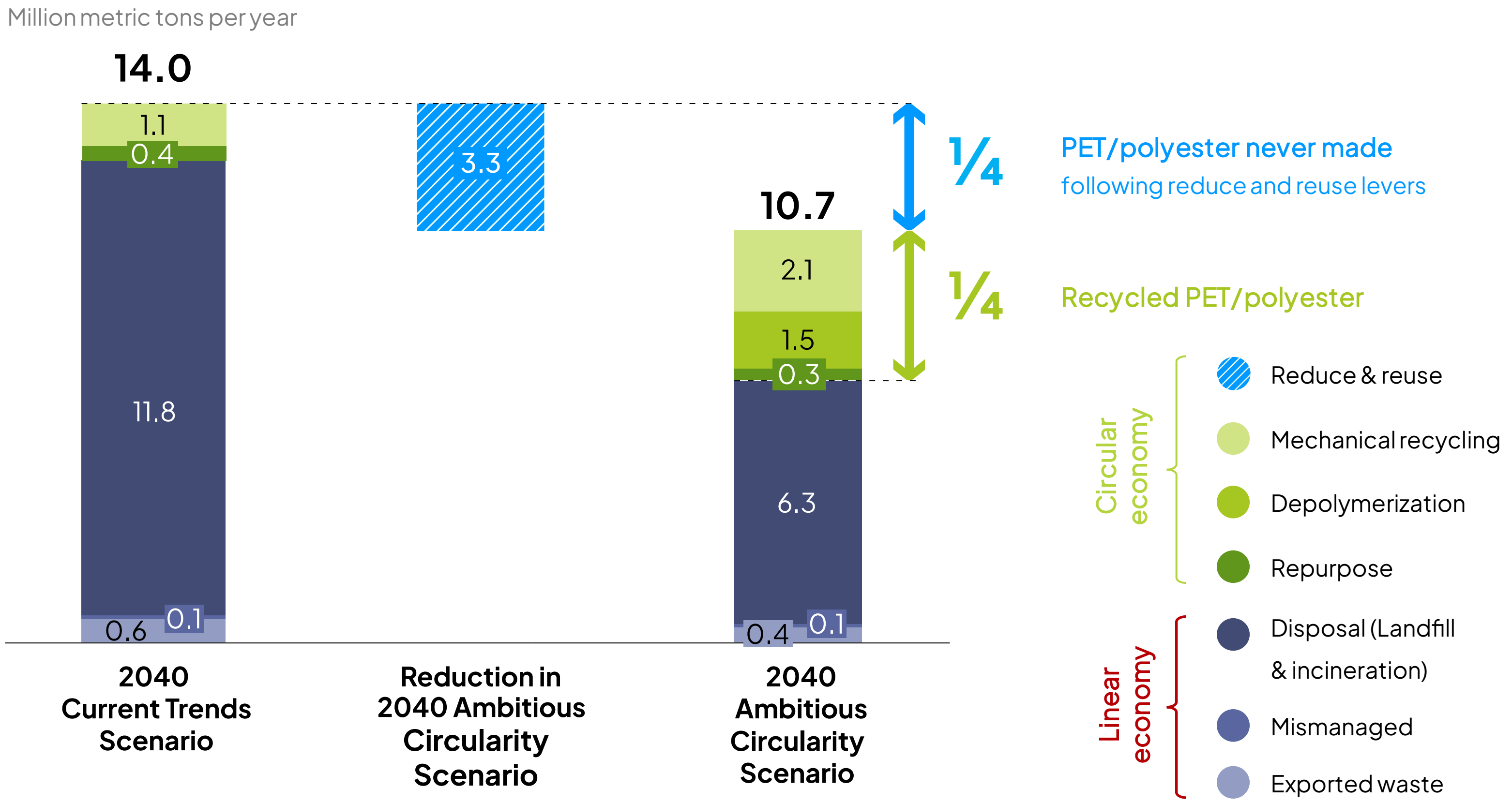
PET non-bottle packaging (mainly thermoforms) and **polyester textiles** could become recycled at meaningful scale in the Ambitious Circularity Scenario, with recycling rates of 36% and 19% respectively. This would mark a significant step up compared to a continuation of current trends, where 7% of other PET packaging and less than 1% of polyester textiles are recycled.

PET non-bottle packaging and textiles will require further innovation, beyond current best-in-class approaches, to achieve higher recycling rates. This includes collection systems as well as sortation and separation of complex multi-material products, such as those found in homeware and automotive applications.

Note a. Based on unpublished data from The Recycling Partnership and Eunomia

In the Ambitious Circularity Scenario, approximately a quarter of PET and polyester waste could be avoided through reduce and reuse approaches and an additional quarter through recycling.

EXHIBIT 14 **Fate of PET packaging and polyester textiles in the Ambitious Circularity Scenario**



Key Insights

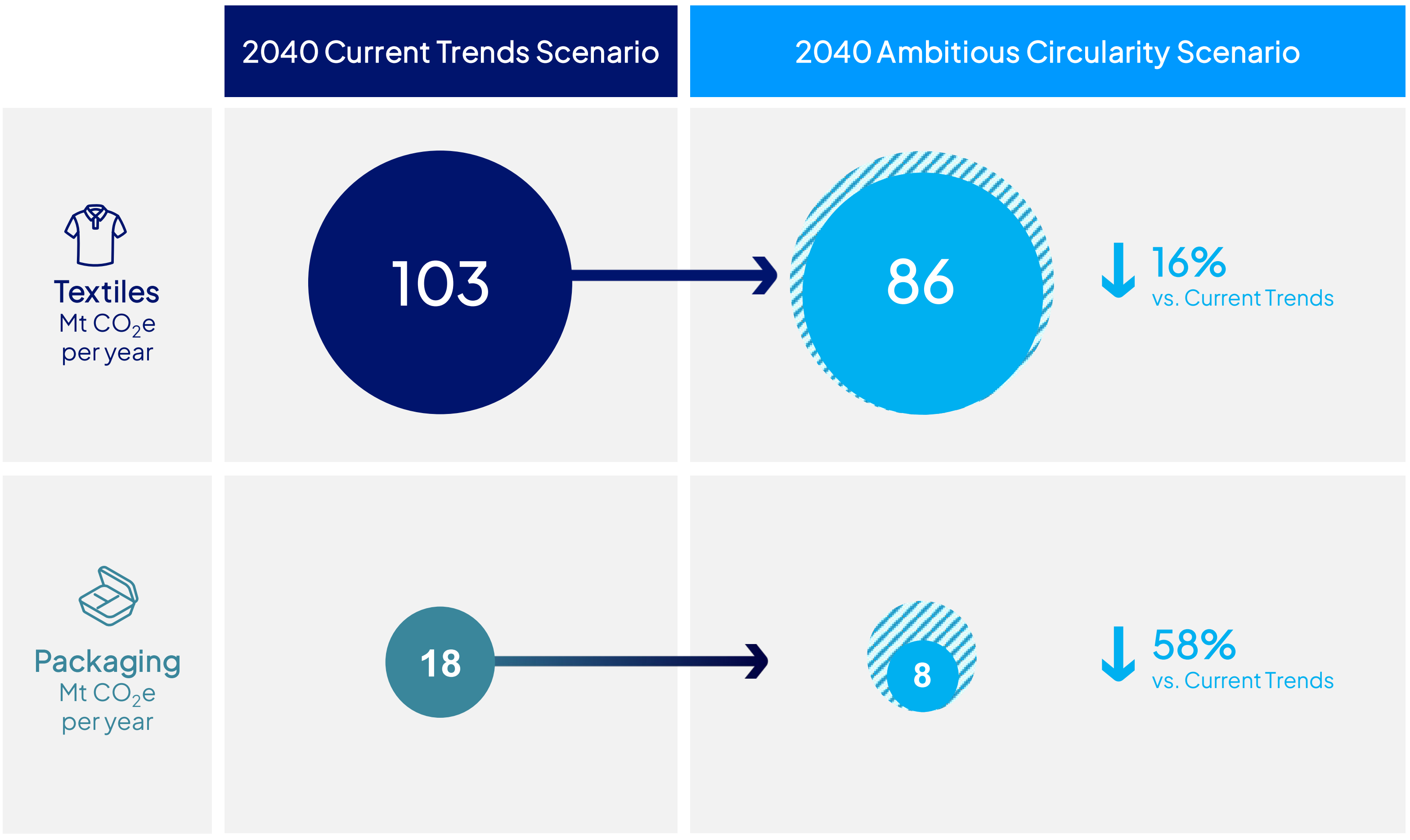
Proven reduction and reuse approaches could avoid one-quarter of PET/polyester consumption, relative to a continuation of current trends. An additional quarter could be recycled, meaning that in total around half of all PET/polyester consumption in the 2040 Current Trends Scenario could be either reduced, reused or recycled (see Technical Appendix).

The complementary application of mechanical recycling and depolymerization recycling can significantly expand the recycling of PET and polyester. Recycled PET generated by mechanical recycling triples to 2.1 Mt, from 0.7Mt in 2022, and almost doubles relative to a continuation of current trends. Meanwhile complementary depolymerization recycling generates a further 1.5 Mt of recycled PET from hard-to-recycle materials. Together, this enables domestic recycled content supply to reach 3.6 Mt: five times the amount generated in 2022 and over three times that projected under a continuation of current trends.

Notes a. This slide is based on waste generation rather than consumption. Hence the total shown here differs from the total shown on slides that are based on consumption (as we model lifetimes there is a "time gap" between consumption (i.e., system inflow) and waste generation (i.e., system outflow); **b.** We refer to elimination as efforts to reduce packaging through lightweighting, and headspace reduction. For textiles, elimination is framed as wastage reduction along the manufacturing value chain, reduction of overproduction, and decreased speed of consumption. Reuse of packaging includes both refill (including a shift to concentrates) and return models. For textiles, reuse considers rental and re-commerce models. Substitution of packaging considers shifts to coated beverage cartons and a switch to fibre-based packaging; **c.** Current trends in elimination, reuse, and substitution are implicit in the consumption growth projection and not modelled separately.

GHG emissions of PET packaging could be reduced by almost 60% through proven "reduce, reuse, recycle" approaches, while the textiles system require further innovation to unlock emissions reductions.

EXHIBIT 15 **GHG emissions scenario comparison for packaging and textiles**



Key Insights

GHG emissions from **PET packaging** are reduced substantially, by 58%, in the 2040 Ambitious Circularity Scenario, compared to a continuation of current trends. This is driven by a 38% reduction in consumption, through reduced material use, refill and return models (e.g. refillable dispensers), and new product models (e.g. concentrates), as well as a tripling of the recycling rate from 23% to 70%.

GHG emissions from **polyester textiles**, which account for a larger share of combined PET/polyester emissions, are reduced by 16%. The process of spinning polyester into fibers generates the majority of polyester emissions, making efforts to reduce consumption particularly important. Cutting emissions further will require innovation, beyond currently proven approaches, as well as accelerated decarbonization of textiles supply chains (see *Technical Appendix*).

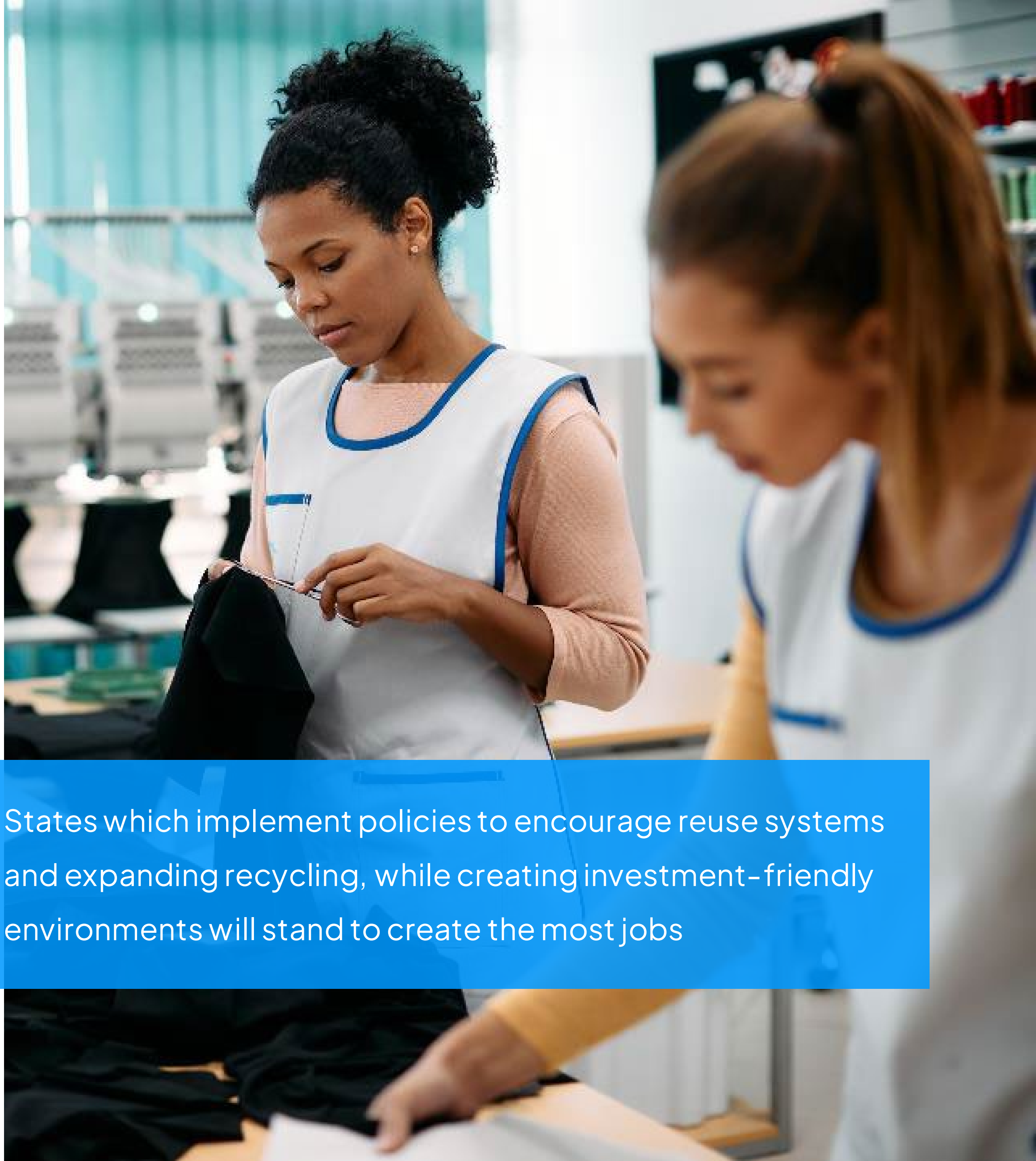
While these emissions are tied to U.S. PET/polyester consumption, a significant portion of these emissions are generated abroad, particularly during the production and conversion of textiles.

In the Ambitious Circularity Scenario, approximately 46,000 additional direct U.S. jobs could be created by 2040.[a]

There is a significant U.S. job creation opportunity in both the reuse/resale and collection/sortation/recycling sectors, in approximately equal proportions. States which implement policies to encourage reuse systems and expand recycling, while creating investment-friendly environments for infrastructure that can serve multiple states (such as large recycling plants), will stand to create the most jobs.

Indirect and induced job creation effects will create a substantial number of additional jobs, with studies estimating indirect and induced jobs to be up to two to four times higher than direct jobs[31,32]. This suggests a total opportunity to create in the range of 100,000 to 200,000 direct and indirect jobs.

Implementing the Ambitious Circularity Scenario also brings social benefits, such as reducing environmental justice issues. This includes mitigating the social and health challenges faced by communities near industrial facilities across the lifecycle of PET/polyester products, including manufacturing, landfill and incineration, as well as addressing the impacts of waste transport and pollution, including air pollution.



States which implement policies to encourage reuse systems and expanding recycling, while creating investment-friendly environments will stand to create the most jobs

Note a. U.S. job creation considers direct jobs only. Job creation is measured relative to 2022 and accounts for a 2% workforce reduction in the production and conversion as well as landfill and incineration industries. It does not account for impacts on retail jobs (e.g., losses in fast fashion retail).

BOX 1

Projected Role of Mechanical and Depolymerization Recycling in the Ambitious Circularity Scenario

Mechanical recycling and depolymerization recycling are complementary technologies, enabling higher overall recycling rates when deployed together. A system that provides both mechanical and depolymerization recycling pathways significantly expands the range of PET/polyester applications that can be recycled (*Exhibit 16*).

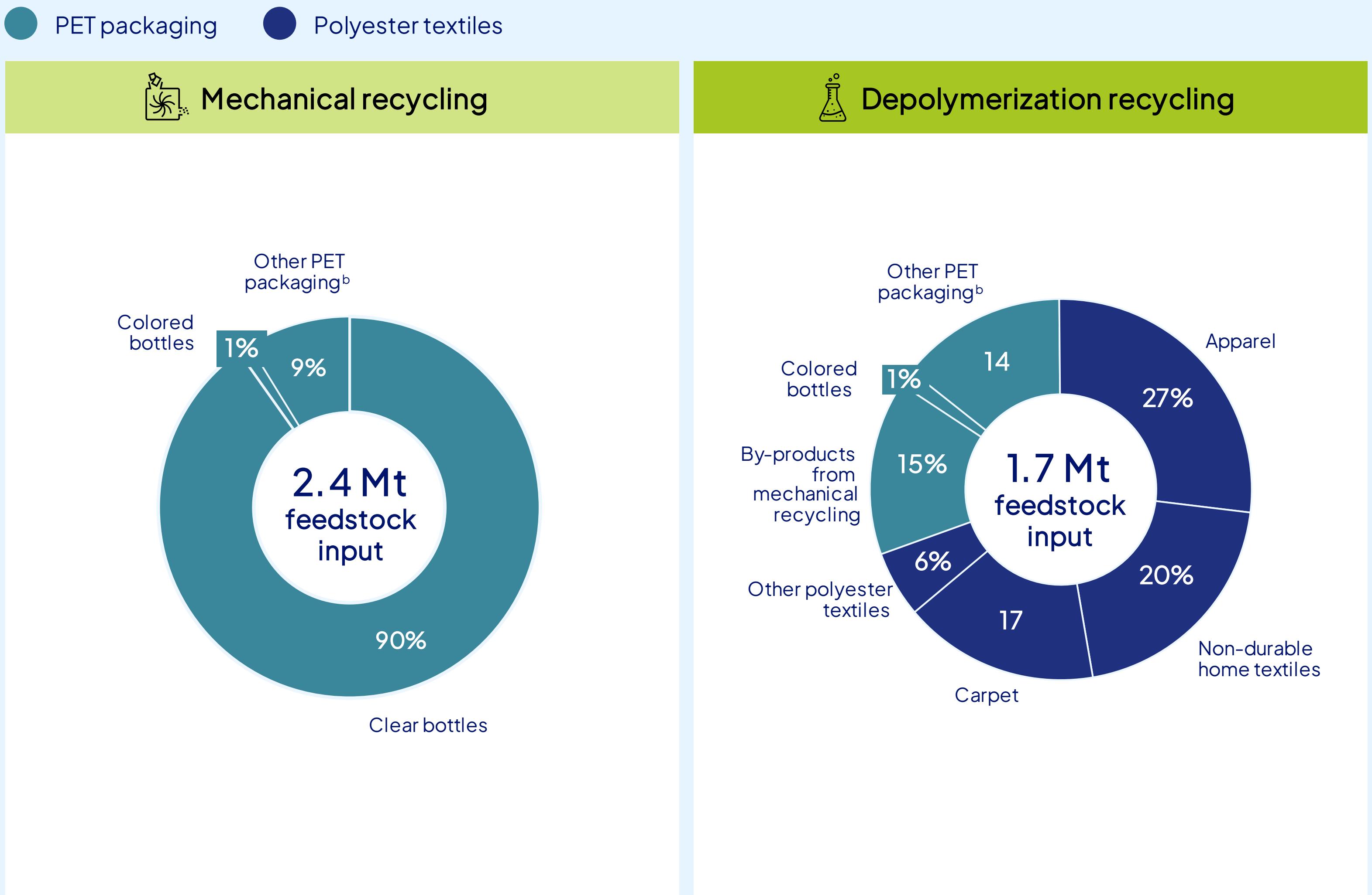
Depolymerization provides a material-to-material solution for recycling of harder-to-recycle packaging formats and textiles with high polyester content into virgin-equivalent rPET that meets market demands for performance, food safety and color.[a] It does this by converting PET/polyester back into monomers (the building blocks of new plastics) and then combining them again to make virgin-quality recycled PET/polyester.

Depolymerization recycling also future-proofs the system by ensuring a source of virgin-quality PET/polyester to blend with mechanically recycled PET once high recycling rates are achieved. Multiple mechanical recycling loops have been shown to negatively affect the functional properties, yield, and

Note a. Mechanical recycling for thermoforms is possible but would require additional dedicated sorting to produce thermoform-only bales. Mechanical recycling of colored bottles would also require dedicated sorting as well as a profitable end-market for grey rPET.

EXHIBIT 16 **Distribution of feedstock processed by mechanical and depolymerization recycling**

2040 Ambitious Circularity Scenario



b Other PET packaging includes thermoforms as well as other non-bottle PET packaging (e.g., strapping).

BOX 1

the quality of rPET output; however, the extent to which this will become an issue with high recycling rates remains uncertain[33,34].

A significant build-out of collection, sortation and recycling infrastructure is needed for both mechanical and depolymerization recycling. To secure the benefits of the Ambitious Circularity Scenario, PET processed by mechanical recycling would need to triple, to ~2.4 Mt[a] per year. In addition, to recycle materials that are hard to recycle mechanically, new depolymerization recycling infrastructure would be needed, expanding from the existing 0.1Mt, which came online in 2024, to process 1.7 Mt by 2040.

Other commonly-used plastics (e.g., polypropylene and polyethylene) are made from strong-linked molecules that are not suitable for depolymerization recycling and require energy-intensive thermal processes (e.g., pyrolysis) to break down the plastics into oils and gases, which then need further steps to be converted into new plastics.

The differences between depolymerization, pyrolysis-based and mechanical recycling technologies, are summarized in *Exhibit 17*, and further addressed in Annex A3.

Note a. Enabled by increased collection for recycling and a shift from colored/pigmented PET packaging to clear packaging, where possible; b. GHG emissions comparison is not relevant for product applications where mechanical recycling is not possible

EXHIBIT 17 **Comparison of recycling technologies**

	Mechanical recycling	Depolymerization recycling	Pyrolysis-based recycling
Description	Remolds PET/polyester at lower temperature into new applications without changing their chemical composition	Breaks bonds in polymers down into smaller molecules, called monomers, that are the building blocks for new plastics	Breaks down the polymer chain into pyrolysis oil by heating at high temperature within inert atmosphere. Pyrolysis oil can be used to make a range of hydrocarbon products
Feedstock	Rigid PET packaging, mostly clear PET bottles today	PET packaging that is more difficult to mechanically recycle and polyester textiles	PE / PP and mixed polyolefins Not suitable for PET/polyester recycling. PET is considered a contaminant to the pyrolysis process
Output	Flakes into pellets	Monomers into pellets	Pyrolysis oil into fuel, chemicals, or materials (into pellets)
Output quality (when converted back into plastic)	Varying grades (from food-grade to non-food grade) possible depending on input quality, processing technology and target end-market	Equivalent to virgin plastic	Equivalent to virgin plastic
Energy requirements	On average lower than depolymerization per ton of plastic processed	On average lower than pyrolysis per ton of plastic processed	On average higher than depolymerization per ton of plastic processed
GHG emissions of recycled PET vs. virgin PET	Lower GHG emissions than virgin PET	Most types of depolymerization generate lower GHG emissions than virgin PET[b]	Not applicable to PET

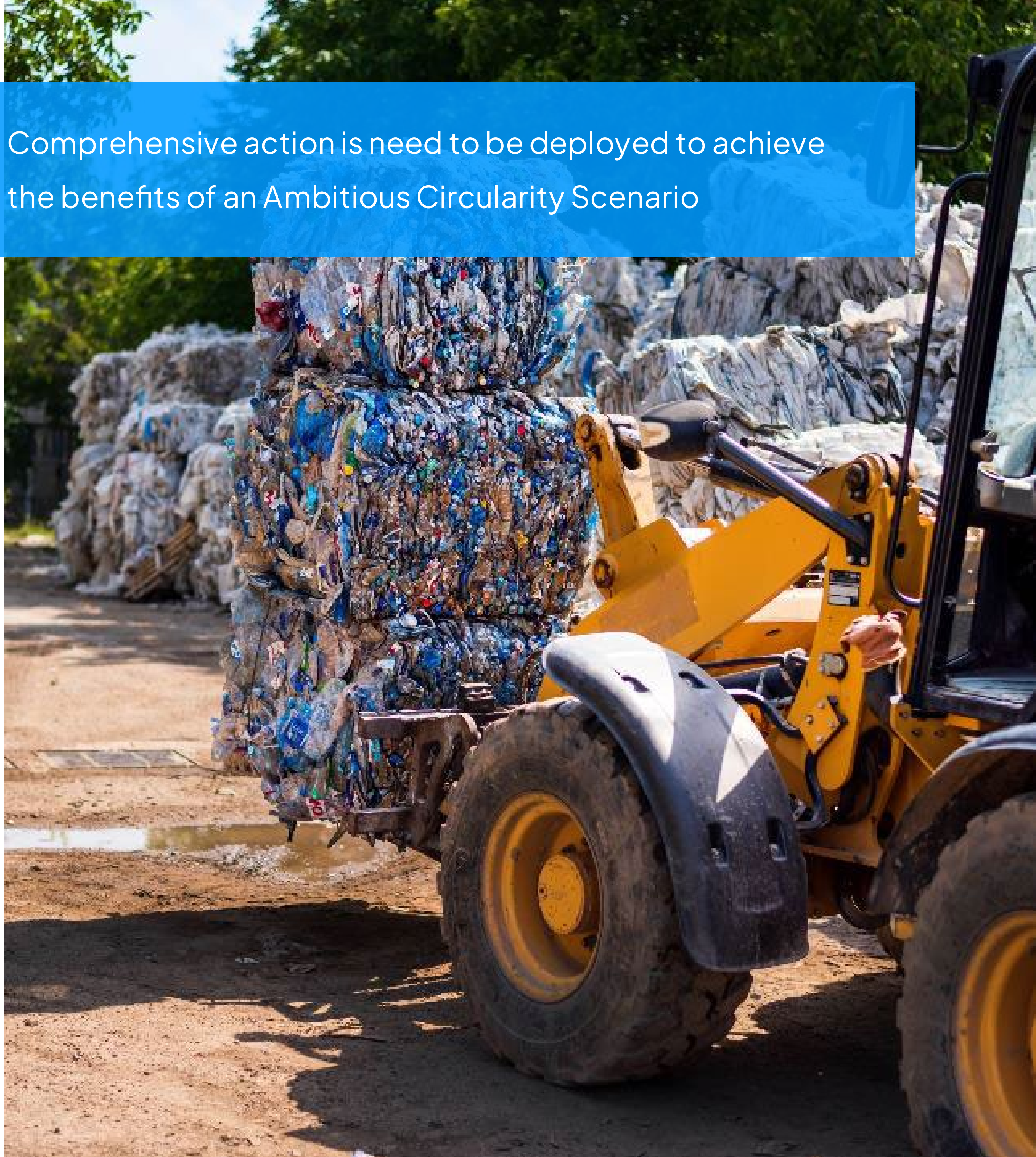
Sensitivity Modeling

Sensitivity modeling has also been used to understand the impact of deviations from the Ambitious Circularity Scenario and the factors that have the highest impact on the overall system outcomes by 2040. Sensitivity modeling highlights that comprehensive action is needed to achieve the benefits of an Ambitious Circularity Scenario.

Sensitivity model 1: Impact of no depolymerization recycling in the Ambitious Circularity Scenario

Sensitivity model 2: Impact of recycled PET import undermining domestic recycling in the Ambitious Circularity Scenario

Sensitivity model 3: Impact of the Ambitious Circularity Scenario only being achieved in first-mover states



Comprehensive action is need to be deployed to achieve the benefits of an Ambitious Circularity Scenario

EXHIBIT 18 **SENSITIVITY MODEL 1: Impact of no depolymerization recycling in the Ambitious Circularity Scenario**

	PET/polyester recycled (Mt)[a]	rPET Revenue (US$ bn)
Ambitious Circularity Scenario *As described previously*	3.6	4.9
Ambitious Circularity Scenario with no depolymerization recycling *If mechanical recycling develops but without any depolymerization*	2.1	3.0

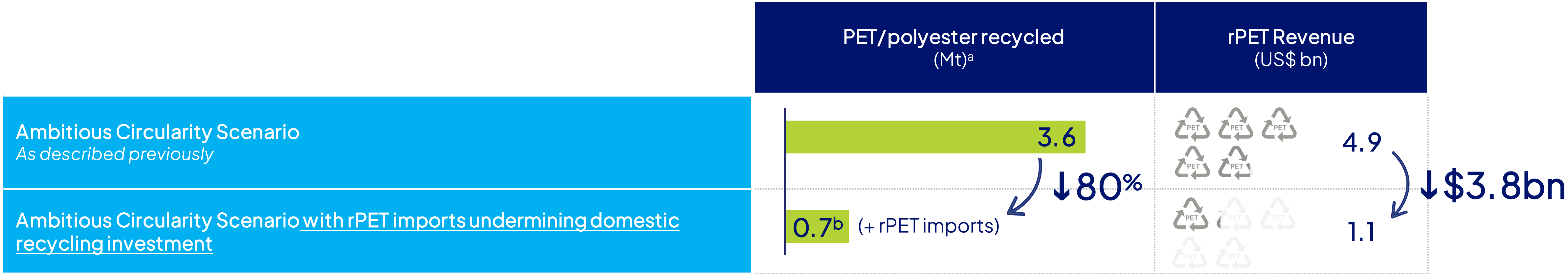
No depolymerization recycling is deployed

Mechanical recycling on its own will not achieve the results of the Ambitious Circularity Scenario.

- If depolymerization is not included in the Ambitious Circularity Scenario, around 40% less packaging and textiles are recycled and 40% less recycled PET is generated, reducing U.S. recycling revenues by $1.9bn per year.
- This is because without depolymerization, polyester textiles would not be recycled, some packaging categories which are harder to mechanically recycle could see lower recycling rates (e.g., colored and opaque packaging, and degraded or contaminated clear bottles), and PET waste that is lost from the mechanical recycling process would not be recycled.
- While not quantified in the sensitivity analysis, depolymerization recycling could also help to "future-proof" the circular economy transition for PET/polyester by:
  - Enabling higher recycling rates even if design for recycling approaches, such as moving from colored/opaque to clear PET where possible, are not full realized;
  - Enabling higher recycling rates if tray-to-tray mechanical recycling does not scale up;
  - Creating virgin-quality rPET output, to overcome degradation challenges resulting from multiple mechanical recycling loops;
  - Increasing supply of rPET suitable for food and beverage contact ("food-contact")[b], to help overcome challenges related to contamination of food-contact feedstock, and process and technology investments required to increase food-contact rPET from mechanical recycling.

Note **a.** Equivalent to domestic rPET generated; **b.** 34% rPET was used in contact-sensitive food and beverage bottles in 2020 based on NAPCOR 2020.

EXHIBIT 19 **SENSITIVITY MODEL 2: Impact of rPET imports undermining domestic recycling in the Ambitious Circularity Scenario**



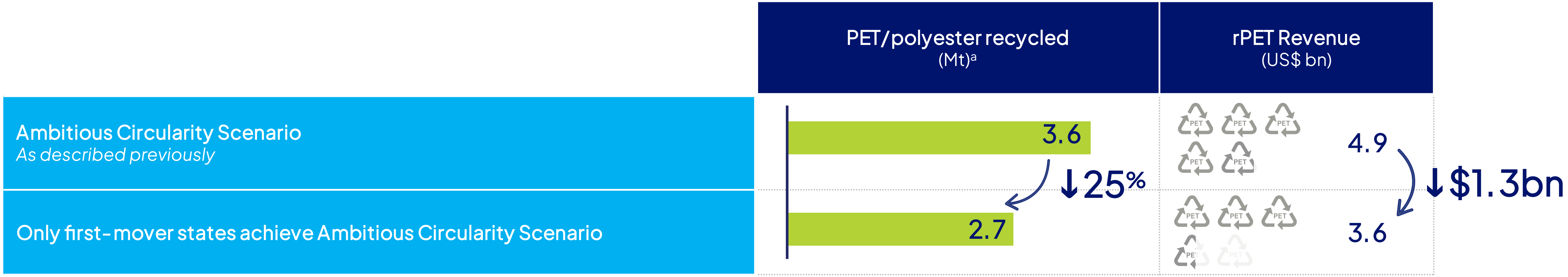
Recycled PET imports undermine domestic recycling investment

rPET imports have grown in recent years, to supply 20% of rPET demand in the U.S. in 2022[b]. As a result, stakeholders have raised concerns about the potential impact of rPET imports on domestic recycling investments and job creation, as well as the indirect social implications both in the U.S. and in the Global South.

If investment in new U.S. sorting and recycling infrastructure were to stop between now and 2040 due to high rPET imports[c], the amount of PET/polyester recycled could fall by 80% (PET packaging recycling rate could fall from 70% to 24%, while polyester textiles would not be recycled). This could increase landfill/incineration by 2.9 Mt and reduce revenues for recyclers by around $3.8bn per year.

Note **a.** Equivalent to domestic rPET generated; **b.** Systemiq analysis based on modeling outputs as well as unpublished data from NAPCOR; **b.** This sensitivity analysis assumes that demand for recycled PET above the amount generated in 2022 is fully met through rPET imports.

EXHIBIT 20 **SENSITIVITY MODEL 3: Impact of the Ambitious Circularity Scenario only being achieved in first-mover states**



Only first-mover states achieve Ambitious Circularity level

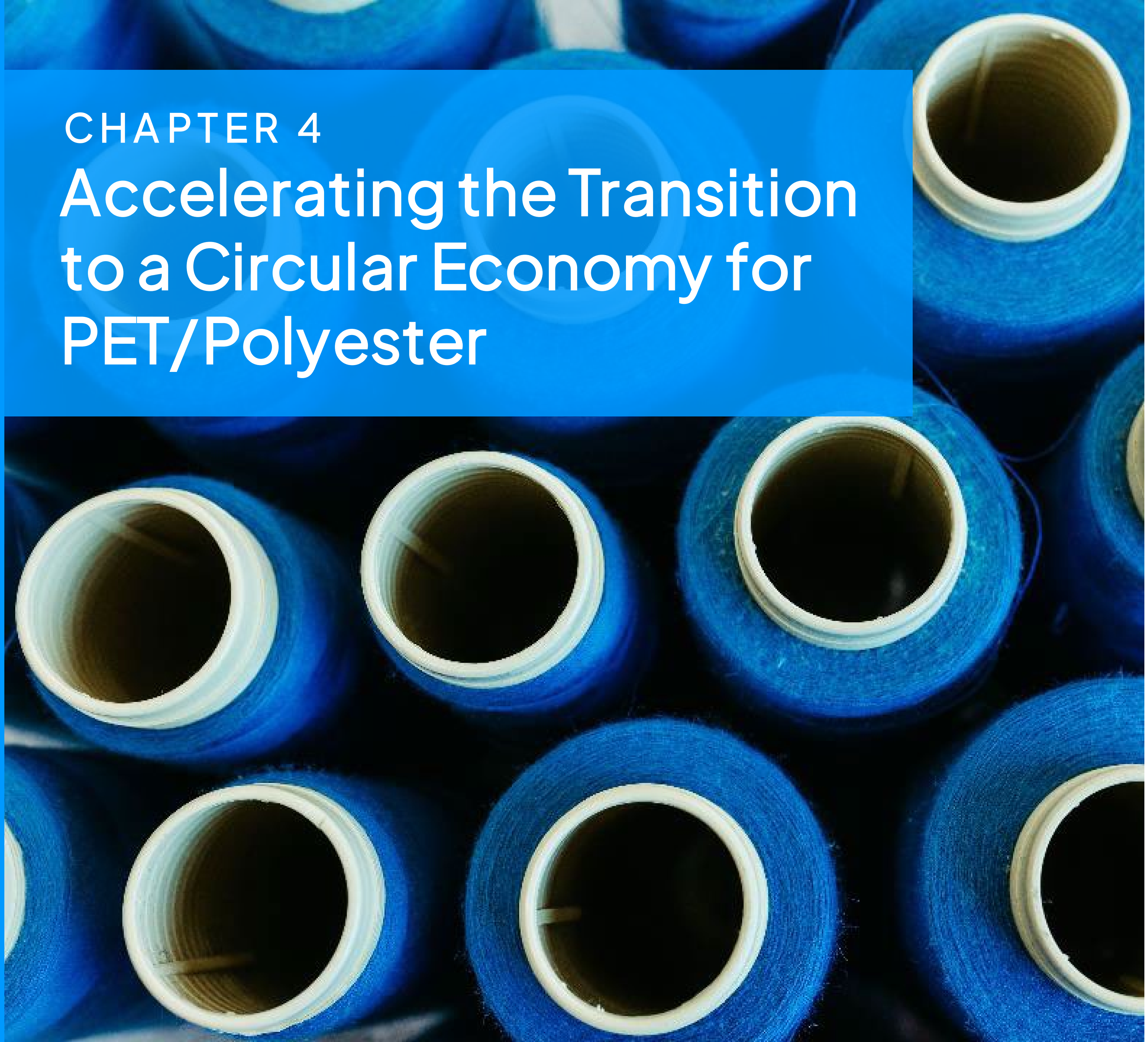
The Ambitious Circularity Scenario 2040 assesses the impact of adopting proven circular economy strategies across all 50 states of the U.S. In recognition of the divergent starting points and political realities of the different states, a sensitivity analysis is applied to assess the impact of a "two-speed" adoption. Under this sensitivity analysis, adoption of circular economy strategies is concentrated in the 15 first-mover states that are already taking steps towards circular economy legislation, while the remaining states do not progress beyond 2022 levels.

The sensitivity analysis shows that if proven[b] solutions are implemented in these 15 first-mover states[c] (those that have already passed packaging EPR legislation or have introduced packaging EPR bills at the time of this report) the total volume of PET/polyester recycled would still reach 2.7 Mt by 2040. This is only 25% below the recycling volume in the Ambitious Circularity Scenario, because the 15 first-mover states represent a disproportionate share of the U.S. population. This finding provides a positive reinforcement for the leadership that is already being shown by first-mover states, while still encouraging the other 35 states to follow suit.

Note a. Equivalent to domestic rPET generated; b. Refers to the same proven solutions that are implement across all states in the Ambitious Circularity Scenario; c. California, Maine, Oregon, Minnesota, and Colorado have passed EPR legislation, while Hawai'i, Illinois, Maryland, Massachusetts, Michigan, New Hampshire, New York, New Jersey, Rhode Island, Tennessee, and Washington have introduced EPR legislation at the time of publication

CHAPTER 4

Accelerating the Transition to a Circular Economy for PET/Polyester



Recommendations are outlined in the Executive Summary covering the following areas:

- **Ambitious policies;**
- **Ambitious industry action;** and
- **Ambitious collaboration towards new technology scale-up**

In this section (*Exhibits 21–23*), further information is provided to support the recommendations.

EXHIBIT 21 **Supporting information for government policy makers and government agencies**

1

Adopt best practice policies and implementation approaches to reduce unnecessary consumption of textiles and single-use packaging. Examples include:

- **Restrictions and disclosure requirements** on the destruction of unsold apparel, alongside **policies to disincentivize "fast and ultra-fast fashion"** and **reduce the use of unnecessary packaging.**
- **Reuse/refill mandates or incentives** to support the transition from single-use to reusable packaging.
- **Collaborating with industry** to develop new circular systems for practical applications, for example closed loop reuse systems for beverage containers at venues (e.g. malls, universities), events (e.g. sport stadiums), or city-level reuse/refill initiatives, including public water fountains.

EXAMPLES AND SUPPORTING INFORMATION

In California, the Plastic Pollution Prevention and Packaging Producer Responsibility Act (SB 54, 2022) requires that the state achieve a 25% reduction of plastics in single-use products by 2032[35].	Arizona State University reusable container program provides a replicable example of a university developing new circular systems to reduce single-use packaging consumption[36].	A San Francisco public water fountain initiative is developing a collaboration between the city, the state, community groups and UC San Francisco[37].	French "Anti-Waste Laws" ban the destruction of unsold apparel[38] and legislators are discussing measures to limit excesses of ultra-fast fashion (e.g., ban on advertising, environmental charge on low-cost items)[39].	European Ecodesign for Sustainable Products (ESPR) legislation promotes sustainability, circularity, and reduces waste in textiles[40].

2

Introduce well-designed EPR legislation for both packaging and textiles, seeking harmonization and convergence where possible within the U.S., building on lessons learned domestically and globally, and ensuring that EPR legislation is designed to support the key pillars of the PET/polyester circularity approach outlined in this study. For example, EPR legislation should:

- **Encourage and reward product design for circularity through eco-modulation**[a] (including durability, reuse, recycling, and low microplastic release);
- **Incentivize U.S. domestic infrastructure,** leveraging existing sorting and recycling systems and scaling up new ones, rather than large-scale imports of recycled materials; this will help increase U.S. recycling rates and reduce landfill volumes over time;
- **Consider high-yield material-to-material recycling technologies** as a responsible end-market to widen the scope of products that can be recycled into high-value outputs. Ensure that EPR system design allows for innovation of high-yield material-to-material recycling technologies and has the flexibility to adapt as technology, infrastructure and product design evolve;
- **Adopt differentiated strategy for textiles EPR compared to packaging,** taking into account different global supply chain configurations; supporting circular and durable design, apparel resale/recommerce and not only recycling; and considering the impact of EPR fees on export markets for apparel resale. Clarity on how markets for collected recyclables are defined and considered is particularly important for establishing textiles EPR, while accounting for full coverage of "net costs"[b] is required to incentivize investments in sorting and recycling infrastructure;
- **Be clear on which packaging and textiles products will be covered**, the recycling targets or KPIs that will be applied, and who is obligated to meet them, and ensure that EPR systems are interoperable across states;
- **Provide support for a broad range of interventions** to enable circularity including end-market development and research and development (R&D) funding via the Producer Responsibly Organization (PRO);
- **Encourage flows of recycled materials into high-value end products** with potential for multiple recycling loops rather than low-value non-recyclable products; this supports the economics of recycling, and thus encourages investment in infrastructure;
- **Evaluate the benefits of integrating well-designed Deposit Return Systems (DRS)** for beverage containers (commonly referred to as Bottle Bills) on top of a curbside collection model for all other packaging and textiles; this analysis should take into account the proven potential for significantly higher recycling rates within DRS systems and the opportunity to prevent contamination versus the potential downside impacts of lower value of curbside packaging recycling streams when beverage containers are removed;

EXAMPLES AND SUPPORTING INFORMATION

EPR legislation for packaging is now enacted in five states and under active discussion in ten other states[c]. EPR legislation for textiles has been passed in California under the Responsible Textile Recovery Act (2024) also known as Senate Bill 707[41] and is currently proposed in New York under Senate Bill S6654[42].

Overarching principles for well-designed EPR and DRS systems have been developed through various initiatives and supported by leading companies including the Consumer Goods Forum[43], the Ellen MacArthur Foundation Global Commitments[44] and Circular Fashion initiative, and by the American Beverage Association and WWF[45,46].

Variable fee-setting in EPR systems can encourage design for circularity (known as eco-modulation). Principles for effective eco-modulation were published by the CGF in 2022[47].

Close coordination between EPR and DRS is essential if both are developed[48].

Notes **a.** Variable fee-setting in EPR systems to encourage circularity; **b.** Legislation introduced: Washington, Michigan, Illinois, Tennessee, New York, New Hampshire, Massachusetts, Connecticut, New Jersey, Rhode Island.; **c.** Net of recycling revenues

3 Enact policies to increase demand for post-consumer recycled content (rPET) to reduce market volatility. Examples include:

- **Recycled content mandates** in legislation;
- **Variable EPR fees** (known as eco-modulation);
- **Incentives and public procurement rules** promoting use of recycled materials from U.S. recyclers;
- **Supporting the development of end-markets for recycled materials**; and
- **Implementation of credible mechanisms** to account, trace, and ensure safe recycled content from plastic waste inputs to recycled plastic.

EXAMPLES AND SUPPORTING INFORMATION

Executive Order 14057 (2021) directs federal agencies to prioritize the purchase of sustainable products, including those made from recycled materials[49].

The Comprehensive Procurement Guidelines (CPG) Program encourages the federal government to use recycled materials in products purchased by government agencies[50]. Similar initiatives exist at the state level (e.g. California's Buy Recycled Campaign[51]).

Recycled content mandate in Washington State requires at least 50% post-consumer recycled content in beverage bottles by 2031, including incremental targets and targets on other products[a, 52].

European legislation, particularly the Single Use Plastics Directive (2019)[53] and Packaging and Packaging Waste Regulation (2024), mandates required levels of recycled content in packaging[54].

UK Plastic Packaging Tax Regulations (2022) place a U.S. $280/metric ton tax on plastic packaging unless it contains more than 30% recycled content[55].

Consumer Goods Forum (CGF) has provided some guidance on traceability mechanisms[56].

4 Set recycling targets by product type for both packaging and textiles, expand coverage of curbside recycling collection for all packaging types, and establish highly-localized drop-off points for textiles, combined with extensive public education campaigns.

EXAMPLES AND SUPPORTING INFORMATION

In California, SB54 requires a 30% recycling, reuse or composting rate for single-use plastics used in the state by 2028, followed by targets of 40% by 2030 and 65% by 2032[57].

RefashionNYC is a partnership between the New York City Department of Sanitation (DSNY) and the nonprofit organization Housing Works that provides textile recycling drop-off bins[58].

Note a. Packaging recycled content mandates also set in California, New Jersey, Oregon, Connecticut and Maine.

5

Increase the price of sending waste to disposal through higher landfill and incineration fees to further boost reuse and recycling and disincentivize linear models.

EXAMPLES AND SUPPORTING INFORMATION

Regional average landfill fees range from $43 per metric ton in the Southeast to $83 in the Northeast[59].

Northern European countries (e.g. Denmark, Finland) charge landfill fees of $80–110 per metric ton[60].

Massachusetts has implemented a law banning disposal of textiles in landfills and incinerators, active from November 2022.

6

"De-risk" private sector investments by increasing public investment into circularity infrastructure, technology, and research. Public investment can be made as grants or loans from the federal through municipal level or incorporated into blended financing opportunities. Public sector investment can support a systems-change "tipping point" by catalyzing investment from the private sector into reuse and recycling infrastructure, including collection, sortation and high yield material-to-material recycling. In addition, many of these infrastructure investments are capital intensive, with longer payback periods, and so could benefit from "de-risking" from the public sector.

EXAMPLES AND SUPPORTING INFORMATION

Funding for chemical recycling technologies has expanded through the Bipartisan Infrastructure Bill[61] and the ReCOVER Act[62]. Government grants by the EPA such as the Solid Waste Infrastructure for Recycling (SWIFR) and the Sustainable Materials Management (SMM) allow waste authorities to integrate new technologies to modernize recycling infrastructure and improve data collection and tracking systems[63].

PET/polyester recycler Eastman will be awarded up to $375 million in Bipartisan Infrastructure Law and Inflation Reduction Act funding from the U.S. Department of Energy and $70 million from state and local tax incentives to accelerate the development of a second large-scale low-carbon depolymerization facility.[64]

The federal government's CHIPS and Science Act invested $453 billion in U.S. semiconductor manufacturing[65] and could provide a useful parallel for recycling infrastructure investments.

Tax credits are available to companies investing in recycling technologies at a federal and state level.[66]. At a federal level, companies can apply for an investment tax credit (ITC) for equipment and machinery used in recycling processes and R&D tax credit for R&D expenditure. Many states also offer additional tax credits.[67]

EXHIBIT 22 Supporting information for companies in the packaging and textiles value chain

7

Reduce unnecessary consumption (and waste) of textiles and single-use packaging through reduction of material use, collaborating on deploying reuse/resale systems, reselling or donating unsold textiles, and moving away from "fast and ultra-fast fashion" business models.

EXAMPLES AND SUPPORTING INFORMATION

The global Fashion ReModel initiative from the Ellen Macarthur Foundation aims to identify solutions and unlock barriers in order to scale circular business models. Companies are making revenue-based commitments with concrete plans to shift towards reuse, repair, rental models[68].

The Petaluma Reusable Cup Project (part of the NextGen Cup Challenge) provides a replicable example for collaboration between corporations and government agencies to encourage reuse/refill, focused on coffee cups[69].

8

Implement best practice design for circularity through industry collaboration and alignment, to enable durability and multiple reuse cycles, maximize recycling and the production of high-value rPET, and minimize microplastic release. Accelerating design for circularity while maintaining fitness for use is particularly necessary for polyester textiles, including shifting from blends to high-purity textiles, and will require value chain collaboration to align on best practices.

EXAMPLES AND SUPPORTING INFORMATION

For packaging, best practice design for recycling guidelines are provided by organizations such as the Association of Plastic Recyclers.[70]

Design for circularity guidelines for textiles are not established to the same extent as for packaging and will require further alignment in the industry, as textile resale and recycling develops. Guidelines have been developed by NGOs including ECOS[71] and the Ellen Macarthur Foundation.[72]

Signatories to the Microfibre Consortium commit to sharing outputs of materials testing to better understand microfibre release and prevention.[73]

9

Maximize textile collection for reuse and recycling by offering and incentivizing take-back programs and accessible collection points in apparel, homeware, and carpet stores and collaborating with existing collection programs. Collaboration on collection will lay the groundwork and gather brand/retailer momentum behind EPR policy for textiles.

EXAMPLES AND SUPPORTING INFORMATION

In 2024, Accelerating Circularity launched the next phase of Building Circular Systems (BCS), aiming to scale textile-to-textile (T2T) recycling systems in the U.S. and EU through expanded market-building trials, a Textile Hierarchy Tool that outlines pathways for used textiles and education on circular T2T systems[74].

Also in 2024, Goodwill Industries International launched a two-year pilot study, backed by the Walmart Foundation, to explore textile recovery at scale through 25 Goodwill organizations in Canada, Michigan, and the Northeastern and Southeastern U.S.[75].

A textile recovery pilot launched in 2020 by the Los Angeles Sanitation and Environment Department and the California Product Stewardship Council will collect fabric waste from businesses for recycling.[76]

10

Increase procurement of domestically-generated post-consumer recycled content from both packaging and textiles through long-term contracts to reduce market volatility and boost domestic infrastructure investment. Reducing the textile industry's reliance on rPET from bottles is necessary in order to strengthen the circularity of both value chains.

EXAMPLES AND SUPPORTING INFORMATION

Beverage companies including Coca-Cola, PepsiCo, Danone, Nestle, Suntory, Keurig Dr Pepper are purchasing recycled PET at scale to achieve ambitious commitments for post-consumer recycled plastic content in bottles.

Fashion retailers and brands including H&M Group, VF Corporation, Nike, Patagonia, Ralph Lauren and EILEEN FISHER all have commitments to source sustainable materials, including recycled polyester.

Over 150 companies are signatories to the Textile Exchange's Recycled Polyester Challenge, an initiative aimed at raising the market share of polyester that comes from recycled sources from 14% in 2019 to 45% in 2025.

11

Implement best industrial practices to control microplastics generation, capture microplastics during use phase (e.g. washing machine filters) and during the recycling and handling process (e.g. dust and water controls).

EXAMPLES AND SUPPORTING INFORMATION

Operation Clean Sweep is a collaborative voluntary initiative from the European plastics industry to eliminate pellet loss from plastic production and recycling facilities.[77]

EXHIBIT 23 **Supporting information for government, industry and investors to enable technology scale-up**

12

Work together to create the enabling environment, investment flows and industry adoption required to deploy new and proven technologies at scale. Examples include digital technologies to forecast demand and reduce unsold stocks in textiles, advanced sensor-based and AI-enabled sorting of packaging and textiles for resale, reuse or recycling, and deployment of advancements in both mechanical recycling and depolymerization recycling *(see example of technologies in Exhibit 8).*

EXAMPLES AND SUPPORTING INFORMATION

- The National Science Foundation (NSF) provides grants for circular economy research, including PET recycling, to support collaborations between academia and industry.[78]
- Large corporations are forming joint ventures to share the financial burden of scaling new technologies, e.g. H&M and Vargas Holding investing in Syre textile recycling technology[79], Shinkong investing in Ambercycle facility.[80]
- Some states are collaborating to create regional recycling hubs to scale up infrastructure and technologies (e.g., South and North Carolina [81,82]).
- Holygrail 2.0 is a collaboration of AIM (European Brands Association) and The Alliance to End Plastic Waste to develop and implement digital watermarks for packaging in the EU to improve sorting and recycling.[83]

Supporting information for researchers

Key outstanding system questions and knowledge gaps have been identified in this study and are recommended for further research. These are outlined in the executive summary.

ANNEX

The State of Circularity for PET/Polyester Packaging and Textiles in the U.S.

This annex provides a detailed assessment of state of circularity for PET/polyester packaging and textiles in the U.S. to complement Chapter 1.

It is structured into four sections:

State of “Reduce” for PET Polyester and Textiles

Minimizing material use is a key circular economy strategy that reduces waste and GHG emissions and often also reduces costs. Packaged goods brand owners and packaging suppliers have led voluntary reduction efforts over the last years such as the lightweighting of packaging (e.g. the weight of a 16.9 oz. uncarbonated water PET bottle more than halved between 2000 and 2014[89]) and reduction of unnecessary and problematic packaging. At-home soda dispensers are sold nationwide, allowing users to make carbonated water and add flavors. The at-home soda dispenser market has experienced a revival in recent years, with PepsiCo purchasing SodaStream for $3.2 billion in 2018.

Despite these efforts, bottle consumption has increased by 22% and thermoforms consumptions by 16% since 2016.[a] Polyester textiles have grown due to shifts toward synthetic fibers, coupled with increasing per capita consumption of apparel items.[90]

In addition, net substitution of PET as a preferred material choice for some packaging applications may play a role in the growth of PET consumption although industry data is not available to confirm this (see *Box 2*).

Packaged goods brand owners and packaging suppliers have led voluntary reduction efforts over the last years, but despite these efforts, consumption has increased.

Note a. Systemiq analysis based on Dow Jones data

BOX 2

Substitution needs to be assessed on a case-by-case basis to optimize environmental impact

While shifting away from plastic is typically viewed as the more sustainable option by U.S. consumers[91], this is sometimes not the case if all environmental impacts are taken into account.

Substituting between materials can be positive for the environment but it can also lead to unintended negative consequences. This complexity arises because environmental impact assessments are multifaceted and involve trade-offs across various impact metrics (e.g. circularity standards/frameworks[92, 93, 94], GHG emissions, biodiversity, land use, water use). Therefore, material substitutions must be carefully evaluated to ensure that gains in one area do not lead to significant setbacks in another.

Single-use PET has the benefit of being lighter weight and having preferable life cycle GHG emissions compared to single-use glass. Despite its high circularity potential, glass consistently ranks as generating the highest GHG emissions, with more than double the impact compared to PET, fiber-based and aluminum alternatives, largely due to its weight.[95]

Compared to other major PET/polyester alternatives, including aluminum packaging, fiber-based packaging and cotton textiles, the relative performance of PET/polyester will depend on the application and the context[96] and therefore it should be evaluated on a case-by-case basis. Environmental impact assessment can depend on study design parameters as well as a range of factors that vary with location and product design, such as the sourcing of materials, recycling rates and product weight.

While plastics may score lower on circularity metrics than paper-based packaging, especially given variations in product composition and local recycling capabilities, paper packaging can negatively impact land and water use. GHG results can vary based on the transport distances. In the case of beverage bottles, life cycle assessments have shown different results for whether aluminum cans, PET bottles or paper-based cartons result in the lowest global warming potential. These assessments can also change over time based on recycling improvement or the pace of decarbonization of different materials.

Brands and retailers have made shifts both toward and away from PET in packaging, while shifting away from polyester textiles is not common practice. Examples of substitution away from PET include water sold in aluminum cans and paper-based cartons[97, 98], paper-based solutions for cleaning products bottles[99] and paper-based clamshells and trays.[100] In other cases, packaging has moved toward use of PET; for instance, for polystyrene cookie trays[101] and yogurt tubs, expanded polystyrene meat trays[102], toy and personal care blister packaging, made previously from PVC.[103]

State of “ Reuse” for PET Polyester and Textiles

Small scale reuse/refill solutions, focused on reducing PET beverage bottle consumption, are available and in some cases growing. For example:

- The U.S. has a long-standing system of public water fountains, and drink dispensers are starting to appear at venues, airports and train stations, and retail stores.[104]

- An established reuse system exists for refillable 5-gallon PET water bottles, where customers can choose delivery and pickup services or refill/exchange jugs at retailers.[105,106] Reusable 5-gallon PET bottles currently represent 9% of bottled water consumption in the U.S[a].

- Companies provide reusable cups at sports stadiums, which can be refilled and returned after use, supporting up to 300 reuse cycles.[107]

- Other reuse models for returning bottles in stores, at collection points or via curbside pickup, are limited to pilots in the U.S.

Online commerce is driving the growth of apparel resale, reporting 23% revenue growth in 2023 and now representing half of the U.S. secondhand market[108]. The remainder of the secondhand market is covered by thrift and charity shops as well as consignment stores. Resale is very limited for non-apparel polyester textiles.

Charities and thrift stores are the most established system for textile collection and reuse. The Goodwill network is the largest actor in the U.S. retrieving more than 1.8 Mt[b] of used goods every year.[109,110] The collection and resale of apparel is an important source of secondhand clothing for markets in the Global South.[111] Approximately 70% of all apparel collected through charities and thrift stores[112] is exported to the Global South. However, a significant share of exported apparel ends up being disposed in the receiving country, either because it is not suitable or as a result of excess supply.[c,113] Given the limited waste management infrastructure of many export markets, these unwanted clothes are at risk of mismanaged disposal, such as in open dump sites.[114]

Notes **a.** Systemiq analysis (2024); **b.** 4 billion pounds; **c.** In Ghana, for example, this share accounts for 40% of all second-hand apparel imports.

ANNEX A3

State of " Recycle" for PET Polyester and Textiles

A comparative analysis of different PET/polyester recycling technologies.

Notes **a.** PET thermoforms are primarily recycled together with bottles as a small share (typically less than 15%). If there are too many thermoforms included with bottles it can negatively impact yields. Although PET thermoforms-only bale are sorted in California in ~10 material recovery facilities (MRF), dedicated thermoform-to-thermoform mechanical recycling is not yet operating in the U.S. **b.** Colored bottles are mechanically recyclable, although can be considered a contaminant for mechanical recyclers today given that they need to be separated from clear PET packaging to avoid discoloring rPET output. **c.** Some composite packaging, such as multi-material thermoforms, may not be suitable for depolymerization. **d.** Depolymerization technology is capable of recycling polyester textiles even though today in the U.S. textiles are not the primary feedstock of depolymerization plants. Estimates suggest polyester content of textiles will need to be above 80% to be accepted as feedstock, although this is yet to be verified at scale. **e.** Yield ranges are based on consolidated averages of diverse technologies and are dependent on feedstock quality.

EXHIBIT A3 **Comparison of PET/polyester recycling technologies**

	Mechanical recycling for PET/polyester	Depolymerization recycling for PET/polyester
Description	Remolds PET/polyester at lower temperature into new applications without changing their chemical composition	Breaks polymers down into smaller molecules, called monomers that are the building blocks for new plastic
Formats with commercial scale recycling available in the US	Clear bottles Thermoforms (e.g. trays/clamshells) in limited volumes/locations[a] Colored bottles in limited volumes / locations[b]	Most PET packaging[c] Polyester-rich textiles[d] (e.g. apparel, towels, carpet, curtains, automotive applications)
Material-to-Material yield reported in published studies[e, 115]	65% 95%	70% 90%
Output	Flakes into pellets	Monomers into pellets
Output quality	Varying grades (from food-grade to non-food grade) possible depending on input quality, processing technology and target end-market	Equivalent to virgin plastic
US capacity (Million metric tons per year)[116]	2.7	<0.4

Barriers to Circularity for PET Polyester and Textiles

A systematic analysis of economic and structural barriers to PET/polyester circularity was carried out for this study, drawing on insights from Steering Group members, expert interviews and prior research. The analysis identified six factors that have held back the growth of the circular PET/polyester economy in the U.S. each reinforcing the others.

EXHIBIT A4 Six factors have held back the growth of "reduce-reuse-recycle" circular economy for PET/polyester in the U.S.

<table>
<tr><th>Barriers</th><th>Reduce</th><th>Reuse</th><th>Recycle</th></tr>
<tr><td>The underlying economics of PET/polyester reuse and recycling are challenging</td><td colspan="3">Low cost of virgin PET/polyester manufacturing (from oil and natural gas), due to scale, long-term optimization and fossil-fuel subsidies
High cost of recycled PET due to fixed recycling cost and the management of PET/polyester waste not being accounted for in the virgin product price, leading to a cost gap of ~5–20% between virgin PET and recycled PET
Price coupling of rPET to virgin PET results in volatile rPET market and prevalence of short-term contracts
Low disposal costs (to landfill and incineration) compared to other countries disincentivize recycling</td></tr>
<tr><td rowspan="2">Government policy and industry commitments have not sufficiently supported circular systems</td><td rowspan="2">No regulation on the destruction of unsold apparel or packaging reduction
Insufficient industry commitments on packaging reduction</td><td colspan="2">Financial mechanisms (Extended Producer Responsibility) not in place to reflect the cost of collecting, sorting and responsibly disposing of waste, incentivizing use of less packaging</td></tr>
<tr><td>Limited states with reuse mandates and targets
Insufficient industry action and product availability on reuse
Insufficient industry action on product durability and design</td><td>Insufficient industry action on design for recycling
Low coverage of curbside collection of packaging in many states (e.g., 40% of the US population does not have curbside collection of PET bottles)
Low coverage of Deposit Return Systems ("bottle bills") for beverage bottles, where average collection rates are ~65% (and up to 90%), compared to ~25% for states without bottle bills
Limited states with recycling rate targets, recycled content mandates or recyclability mandates
Insufficient end-market demand on recycled content
Many EPR laws do not allow chemically-recycled plastics to count in recycled content calculation
Lack of uniform recycling policies across and within states can create some challenges for companies operating nationwide</td></tr>
</table>

<table>
<tr><th>Barriers</th><th>Reduce</th><th>Reuse</th><th>Recycle</th></tr>
<tr><td>Development and deployment of new product designs and reuse/recycling technologies has not kept pace with the scale of the challenge</td><td>▪ Proven solutions to reduce consumption have potential for greater scale-up, including lightweighting of beverage bottles and use of concentrates</td><td>▪ Insufficient development and deployment (including through collaborative action) of new product delivery approaches such as reuse, refill, and resale</td><td>▪ Product design not always suitable or optimal for recycling with existing technology (e.g. colored PET bottles which could technically be clear PET)
▪ Limited deployment of advanced sorting and recycling technologies, including for historically challenging materials such as thermoforms, colored bottles and polyester textiles</td></tr>
<tr><td>Consumer awareness and action is highly variable</td><td></td><td>▪ Lack of Deposit Return Systems and reuse models in most states means consumers are unfamiliar with return behaviours, limiting roll-out of some reuse models</td><td>▪ Variable participation in recycling, with ~40% of consumers not using a curbside recycling service when available</td></tr>
<tr><td>Knowledge gaps limit private and public sector conviction to take action</td><td>▪ Knowledge gaps remain on the extent and impacts of the release of microplastics and the presence of “chemicals of concern” in plastic and non-plastic materials
▪ Limited accessible and impartial information on environmental impact trade-offs between material alternatives for specific product applications</td><td>▪ Limited accessible and impartial information on environmental impact trade-offs between single-use and reuse for specific product applications</td><td>▪ Stakeholder concerns about the potential impact of rPET imports on the U.S. recycling industry</td></tr>
<tr><td>Public financing has not been sufficiently utilized to de-risk private sector investment that have been focused on short-term returns</td><td></td><td colspan="2">▪ Insufficient public investment in the form of grants or loans to help de-risk private sector investment into transformative technology and large-scale infrastructure, which can be challenging in the context of price volatility, risks such as recycled PET imports and uncertainty of future government policy and corporate commitments
▪ Traditional institutional investors often prioritize short-term returns, but many sustainable and circular solutions require long-term thinking</td></tr>
</table>

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CITATION

If referencing the content of this report, please use the following citation:
"Systemiq, 2024, Transforming PET Packaging and Textiles in the United States: Systems Change Scenarios and Recommendations to Cut Waste, Create Jobs, and Mitigate Climate Change"

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Transforming PET Packaging and Textiles in the United States

Systems Change Scenarios and Recommendations to Cut Waste, Create Jobs, and Mitigate Climate Change

This report assesses the current state of PET packaging and polyester textiles circularity in the U.S., uses detailed system modeling to quantify the impact of applying proven circular approaches (reduce, reuse, recycling) under different scenarios, and outlines recommendations for government and the private sector to achieve the benefits of an ambitious scenario.

For further information please see systemiq.earth/pet-polyester-us
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Advisory partners: Closed Loop Partners, eunomia, The Recycling Partnership