

An Overview of Recycled Plastics

October 2022

Fall AIChE Professional Development Event



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Agenda



01 Plastic and the circular economy

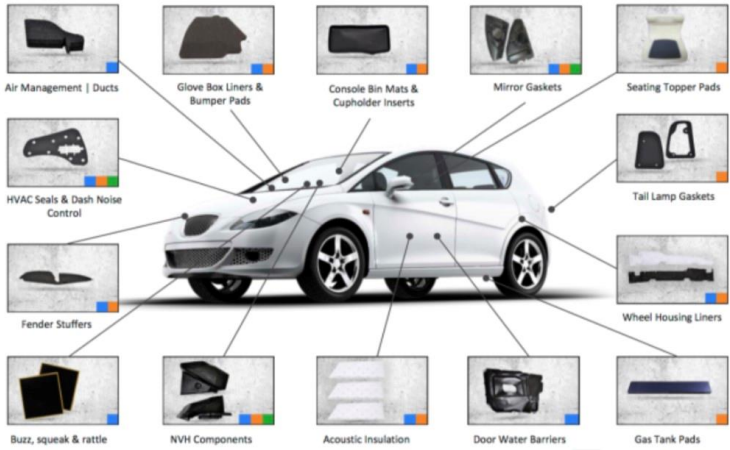
02 Mechanical recycling overview

03 Chemical recycling overview

04 Demand for recycled plastic

05 Bridging the supply/demand gap

What do you think of?



The 'Blue Planet' effect

- Tidal wave of mainstream consumer pressure/environmental activism
- Targeting climate change and plastic waste
- Focus on ESG, accountability expected and increasingly demanded



The switch away from plastics



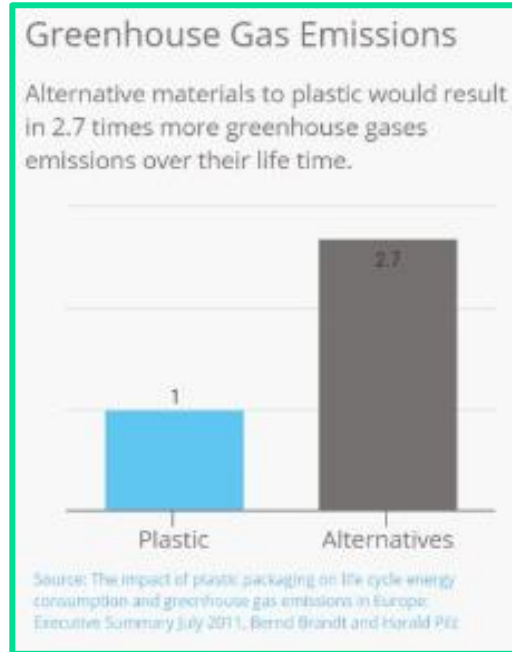
Energy

It would take around **twice** as much energy to use alternative materials to plastic packaging.



Plastic Alternatives

Source: The impact of plastic packaging on life cycle energy consumption and greenhouse gas emissions in Europe: Executive Summary July 2011, Bernd Brandt and Harald Pilz



For the same amount of bags, it takes 1 truck to deliver plastic bags and 7 to deliver paper bags.

Source: RAN Encourage Plastic Bag Recycling, Nevada News.

*"Worryingly, the brands report that decisions to switch away from plastic are often made without considering the environmental impact of the substitute materials chosen, or whether or not there is adequate collection and treatment infrastructure in place for them."
- Green Alliance, 'Plastic Promises' (2020)*

Source: Mark Victory (ICIS News), 'INSIGHT: Consumer and regulatory pressure risks encouraging less sustainable alternatives to plastic' (2020); Green Alliance, 'Plastic Promises - What the grocery sector is really doing about packaging' (2020); British Plastics Federation, 'Plastic Packaging - Frequently Asked Questions' (2020)



Mechanical Recycling

Process in Pictures



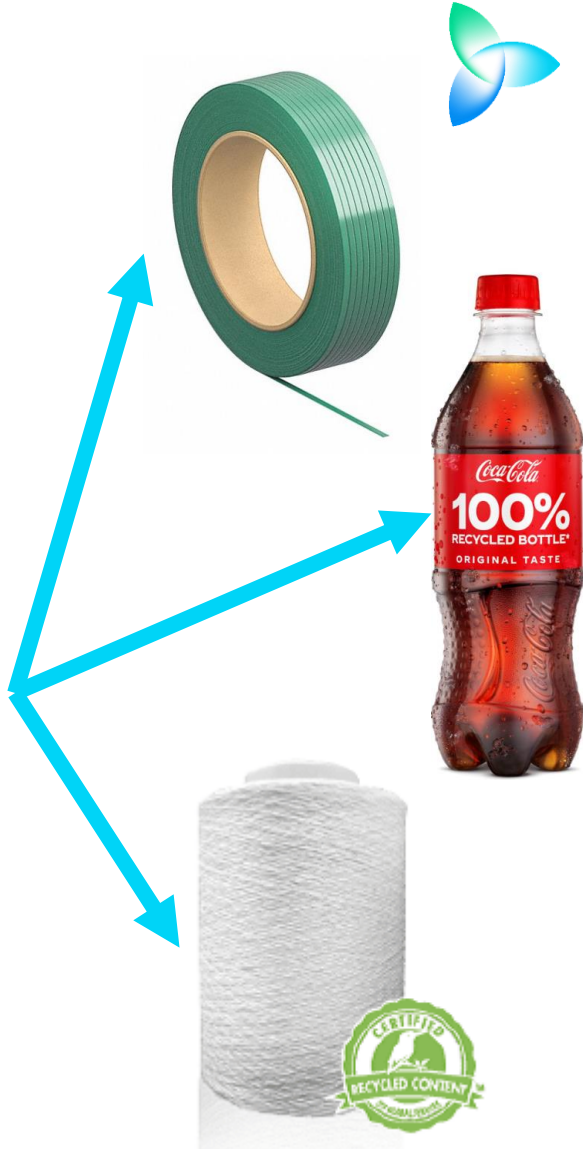
- Bale
 - Sort
 - Wash/remove label



- Flake
 - Grind
 - Wash/Sort

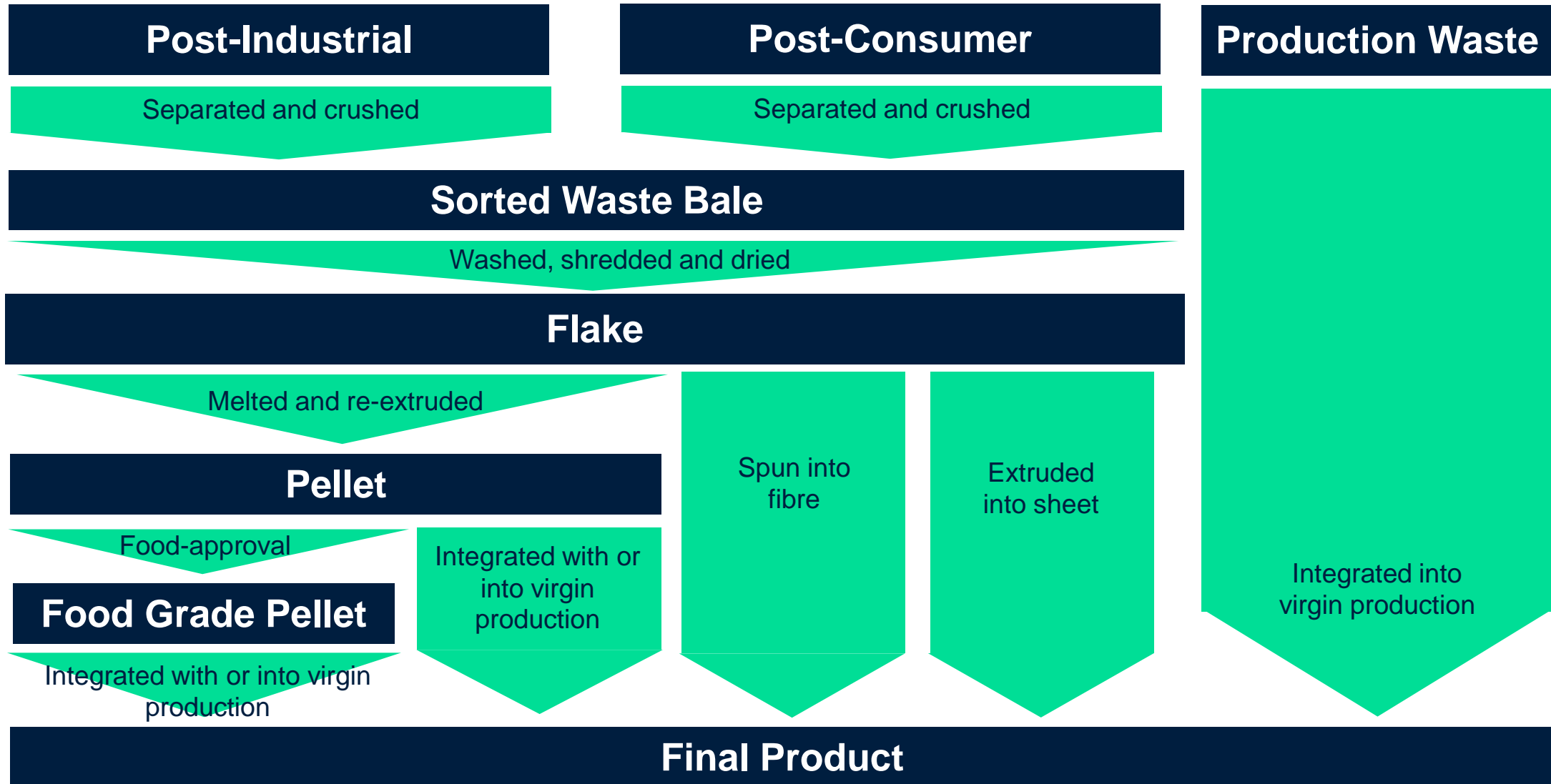


- Pellet
 - Extrude
 - Solid State Polycondensation

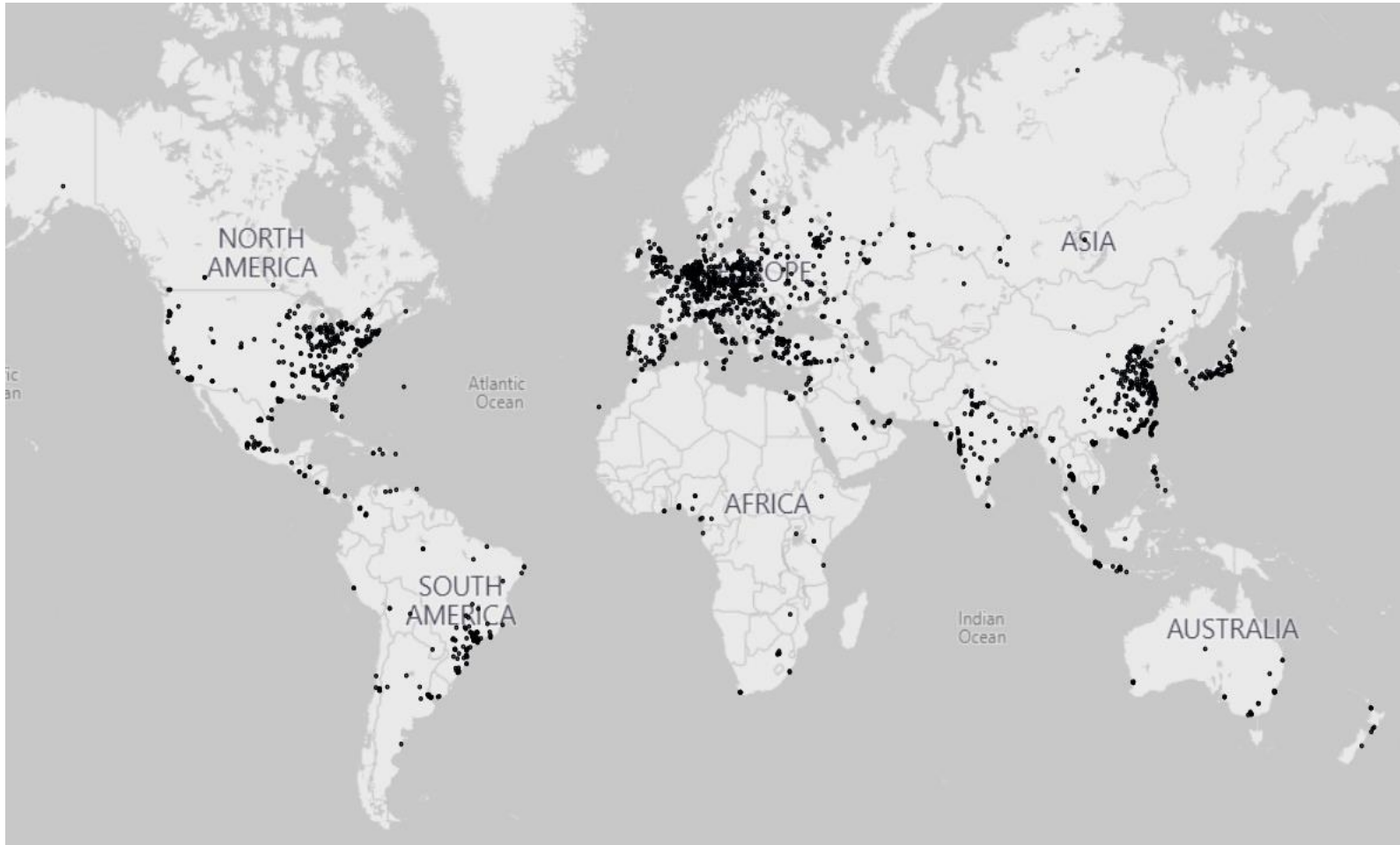




Mechanical Recycling of Plastic



Substantial mechanical recycling capacity



48
million tonnes

Recycled PET, PE, PP capacity in 2021

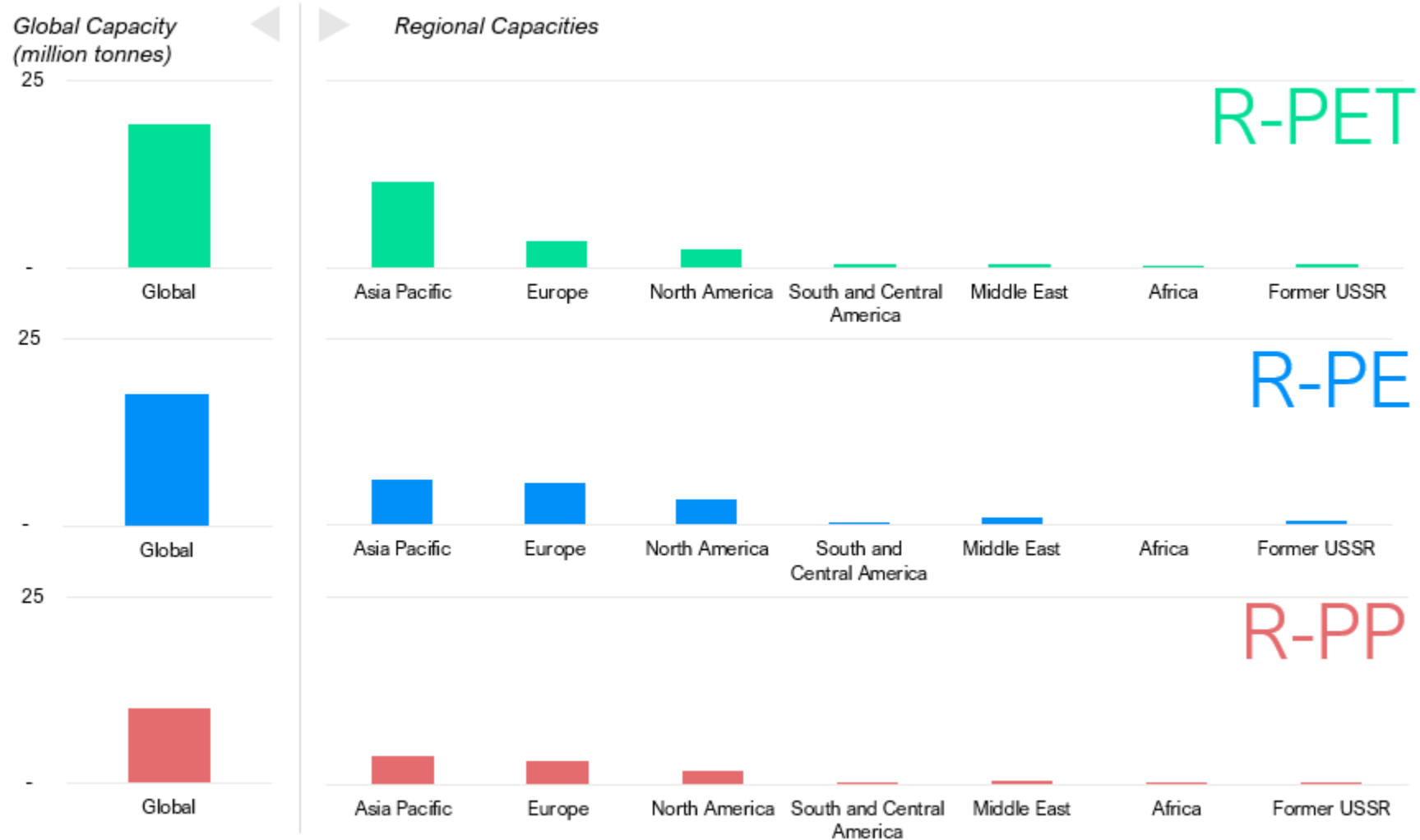
>2500

PET, PE, PP mechanical recycling plants

Source: ICIS, Recycling Supply Tracker – Mechanical, 2021 (Plants with 10kt+ annual capacity displayed)

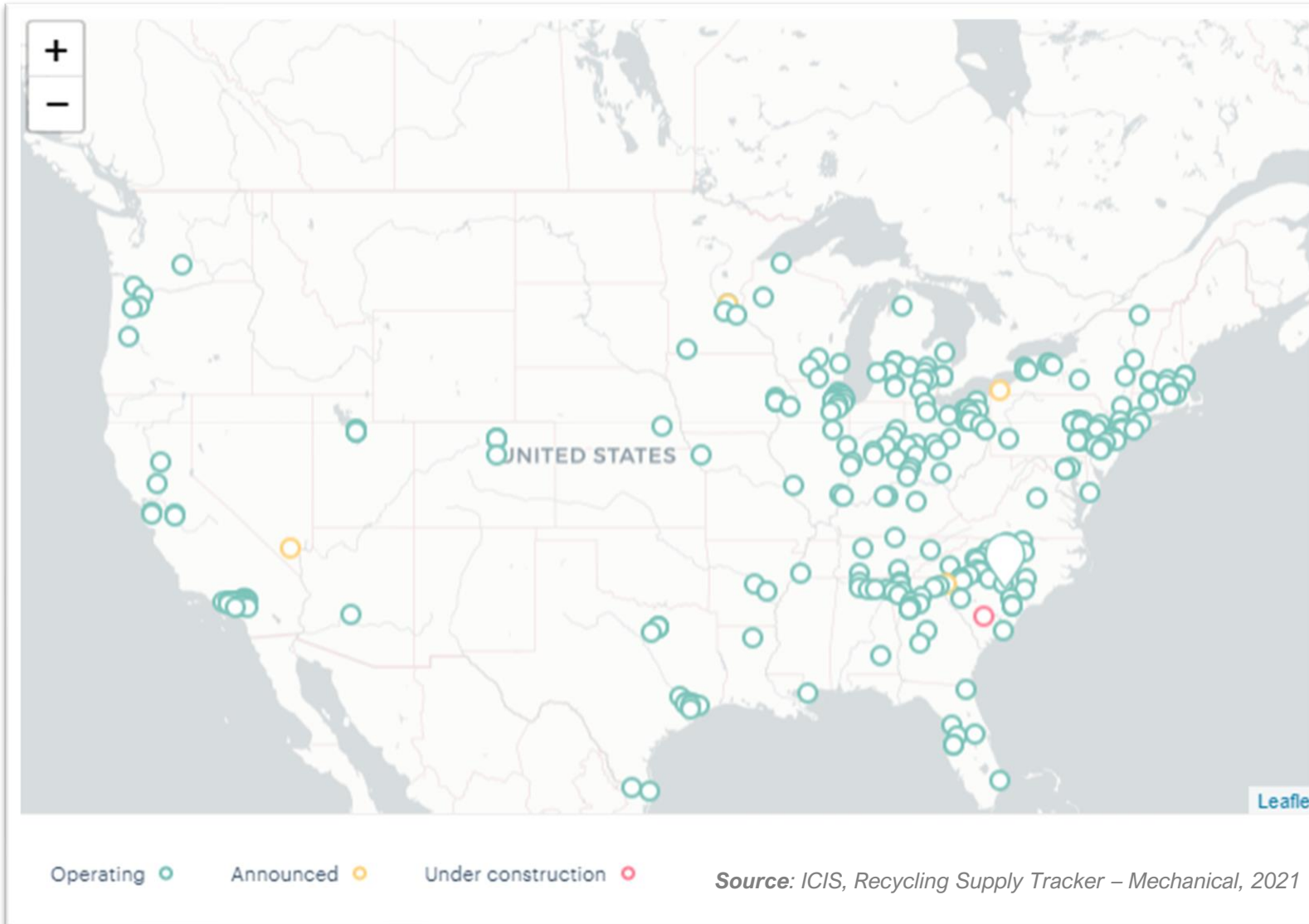


Mechanical recycling capacity focus on three key regions



Source: ICIS, Recycling Supply Tracker – Mechanical, 2021

Investment needed in the United States



6.6
million tonnes

Recycled PET, PE, PP capacity in 2021

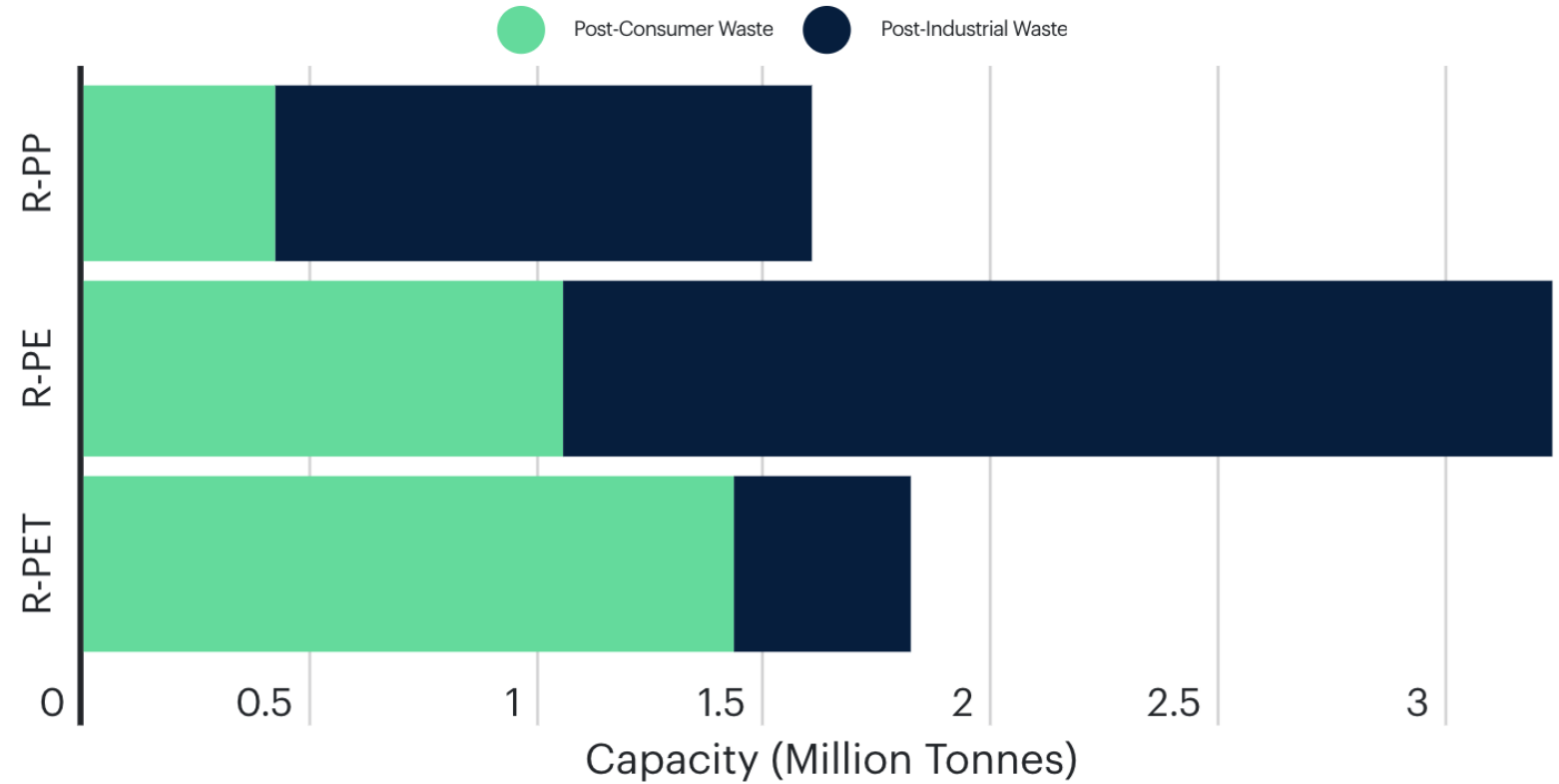
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PET, PE, PP mechanical recycling plants

US Capacity

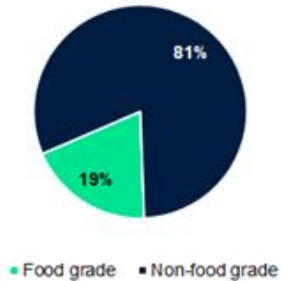


US Mechanical Plastic Recycling Capacities



Source: ICIS, Recycling Supply Tracker – Mechanical, 2021

North America recycling capacity by grade





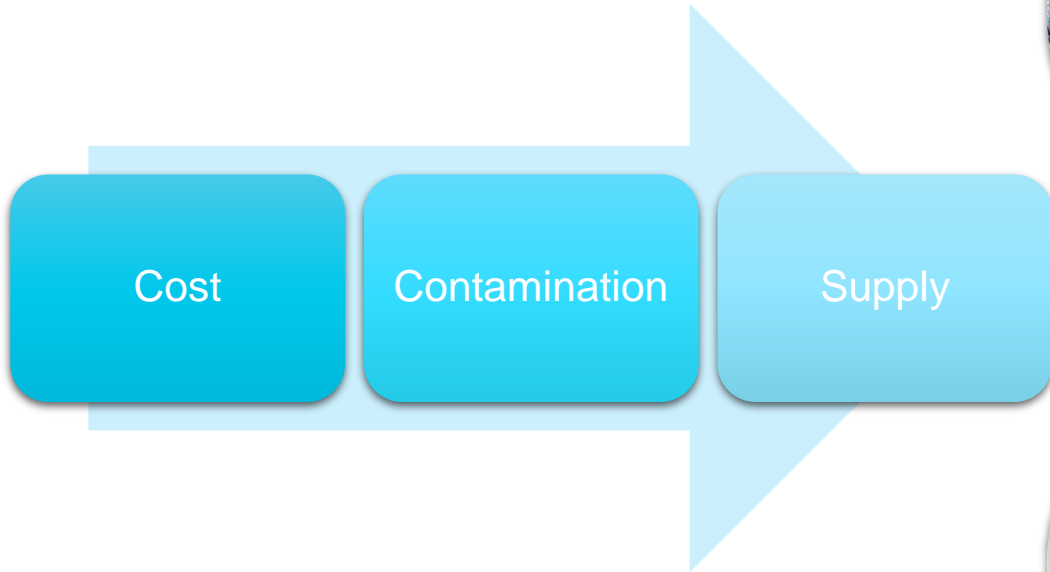
Chemical Recycling

Chemical Recycling

- Reverting plastic back to monomer or feedstock components
- Also called “advanced” or “molecular” recycling

Method	Output
Methanolysis	<ul style="list-style-type: none">• Feedstock• PET -> BHET
Glycolysis	<ul style="list-style-type: none">• Feedstock• PET -> DMT
Hydrolysis	<ul style="list-style-type: none">• PET -> PTA• Polyolefins -> mixed hydrocarbons
Pyrolysis	<ul style="list-style-type: none">• Pyrolysis oil
Gasification	<ul style="list-style-type: none">• Syngas
Purification	<ul style="list-style-type: none">• Polymer

Feedstock Sources



Post-Consumer

- Mechanical Recycling Process Waste
- Mixed Plastic Waste Bales



Post-Industrial

- Mechanical Recycling Process waste
- Production scrap material, production purge, obsolete warehouse material, post-commercial waste

End-Markets

Hydrocarbons: Pyrolysis oil and syngas

- Methane, propane and butane: heating
- Ethane: feedstock for ethylene
- Naphtha: petrochemical feedstock and gasoline blend
- Gasoline, jet fuel, diesel fuel, gas oil, base oils, and waxes: fuel and lubricant
- Bitumen: asphalt
- Hydrogen, methanol, and natural gas

Monomers

- Feedstock for polymers
- Other chemicals

Amcor increases use of advanced recycling materials leveraging ExxonMobil's Exxtend™ technology

GENERAL ANNOUNCEMENTS

April 12, 2022



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Advanced Recycling Project Yields Clear, Recyclable Cup for Wendy's



PlasticsToday

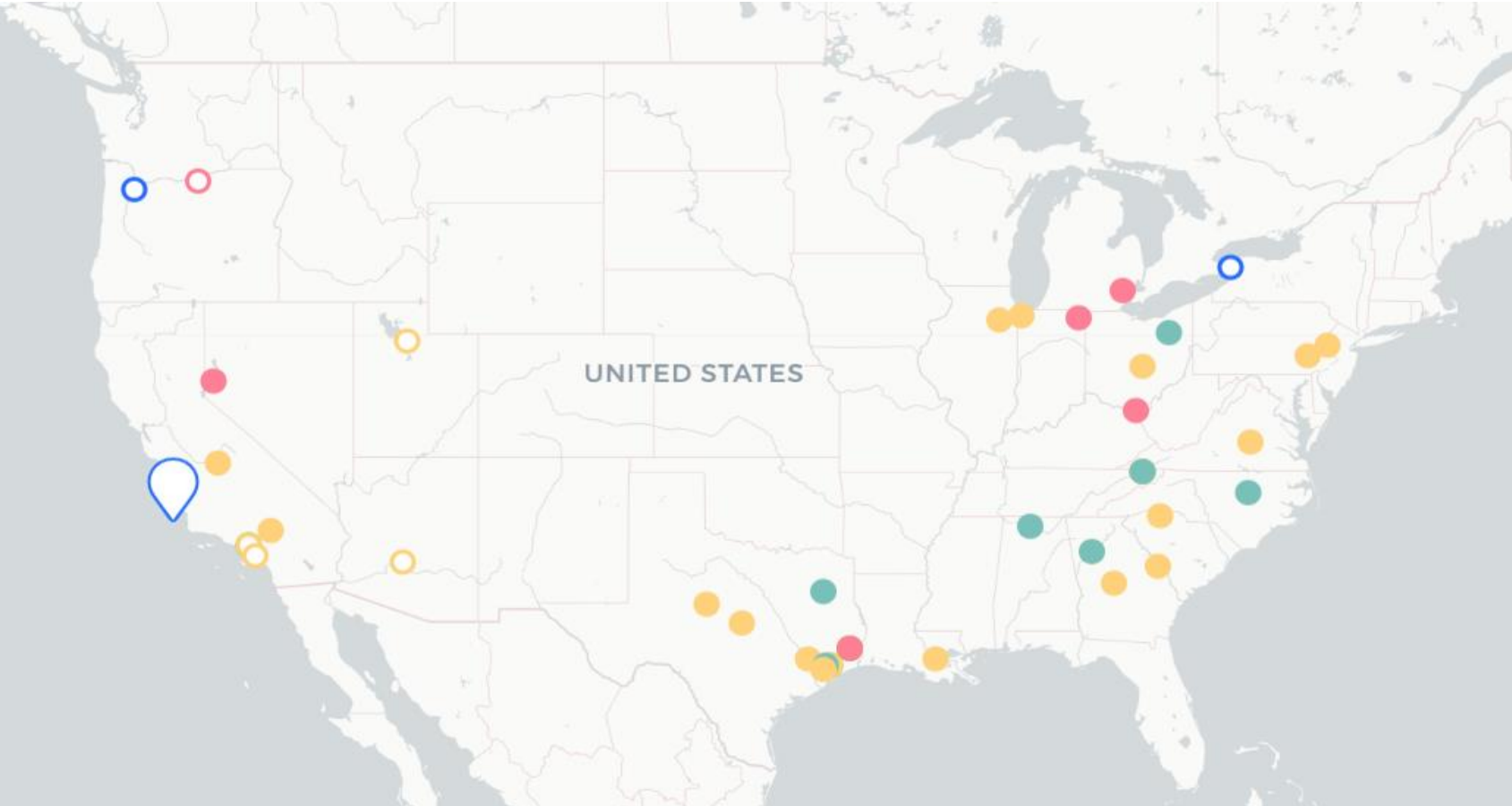


Wendy's

Berry

lyondellbasell

US chemical recycling footprint



45

Chemical recycling
announced plants identified
in the United States

15%

Plants currently operating at
commercial scale

Operating ● Under construction ● Announced ●

Solid circle: Commercial scale
Open circle: Pilot and Demonstration scale

Source: ICIS, Recycling Supply Tracker – Chemical, 2021

10/11/2022

LCA Debate, Open vs closed loop



Chemical

Mechanical

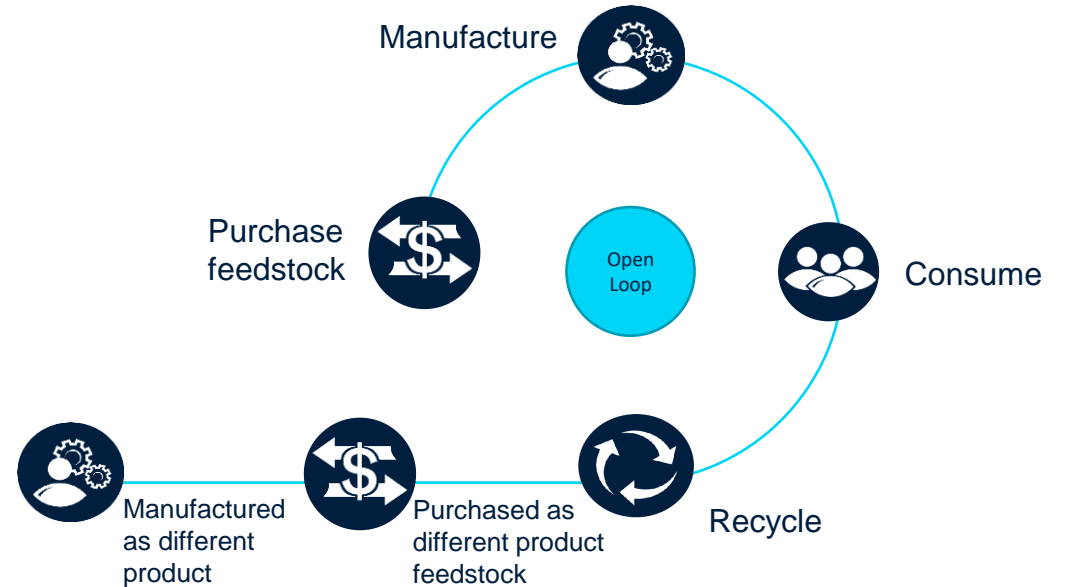
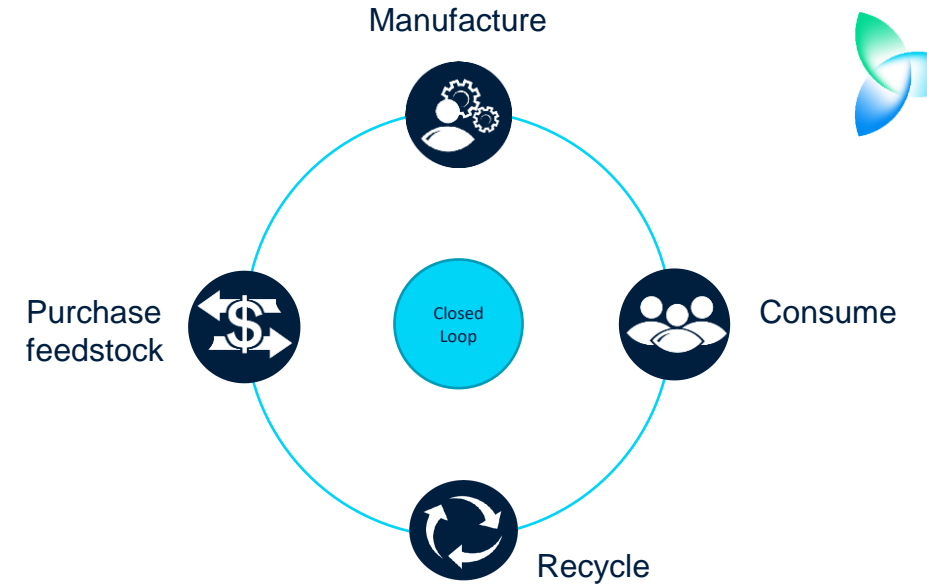
Open loop beyond plastic

Better than virgin

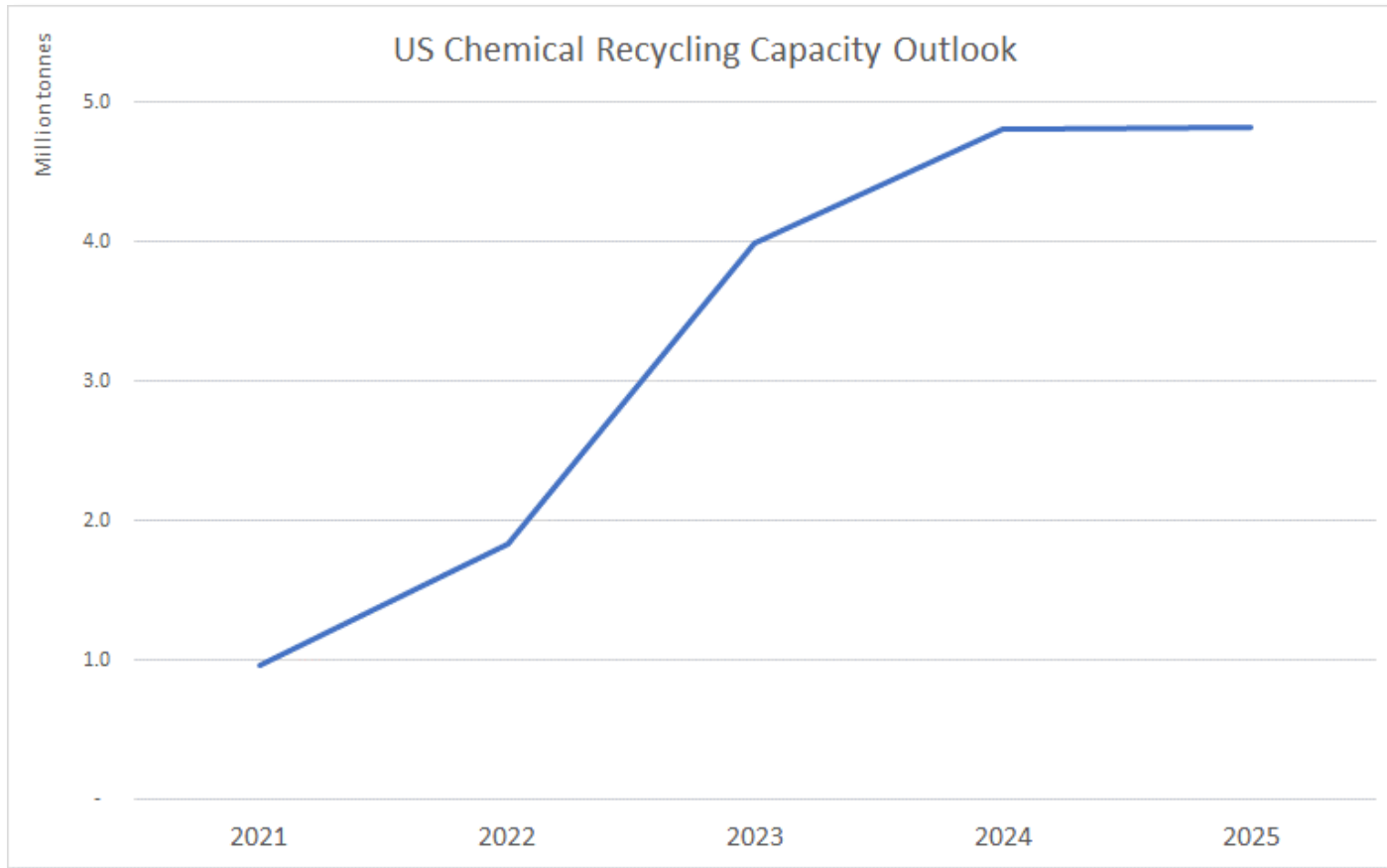
More energy intense

Washing step

Collection/transportation emissions



US announced chemical recycling facilities



5
million tonnes

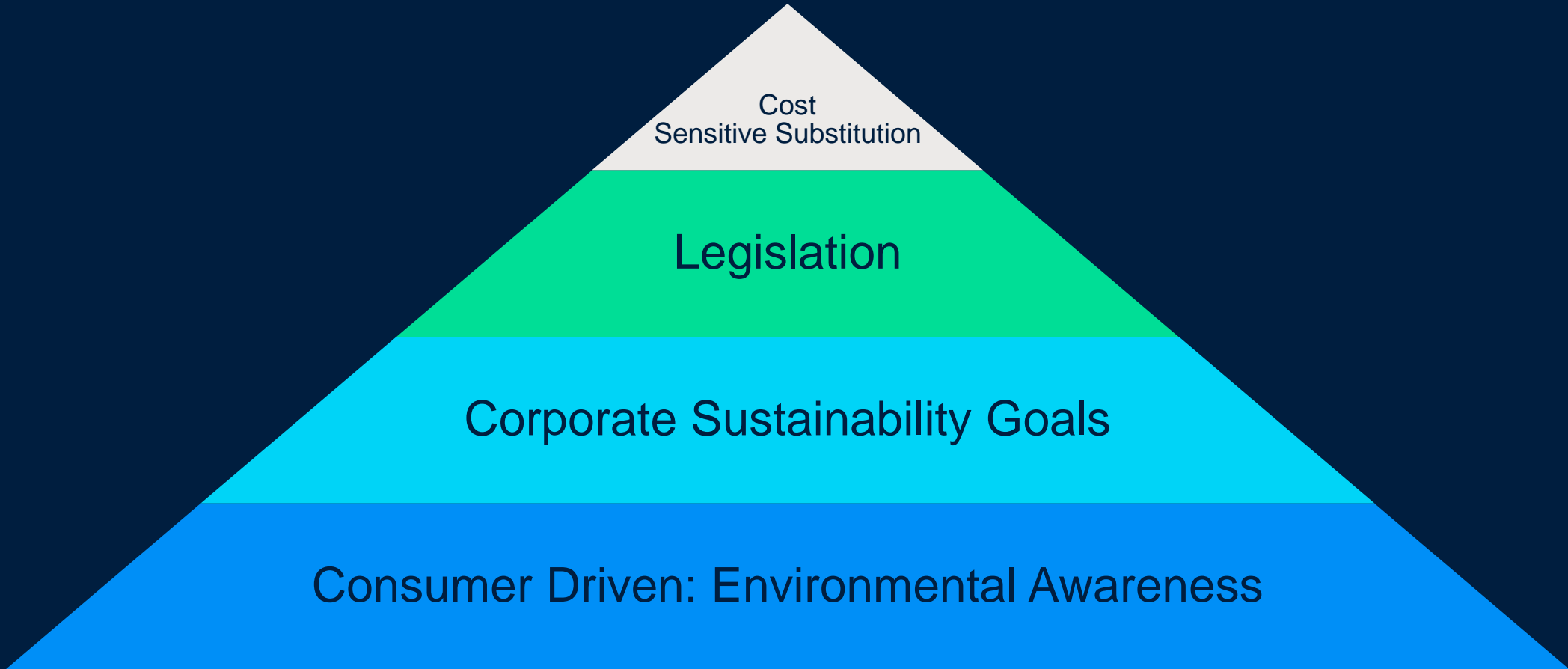
Chemical recycling capacity announced
in the United States by 2025

Uncertainties

- Delay or cancellation
- Feedstock sources
 - End-markets
 - Legal status

Source: ICIS, Recycling Supply Tracker – Chemical, 2021

Demand Drivers



Global Regulation



GLOBAL
Basel convention
Single use plastic bans
Extended Producer Responsibility

AMERICAS

- Save Our Seas Act (US 2020)
- Break Free From Plastic Pollution Act (US)
- US Plastics Pact

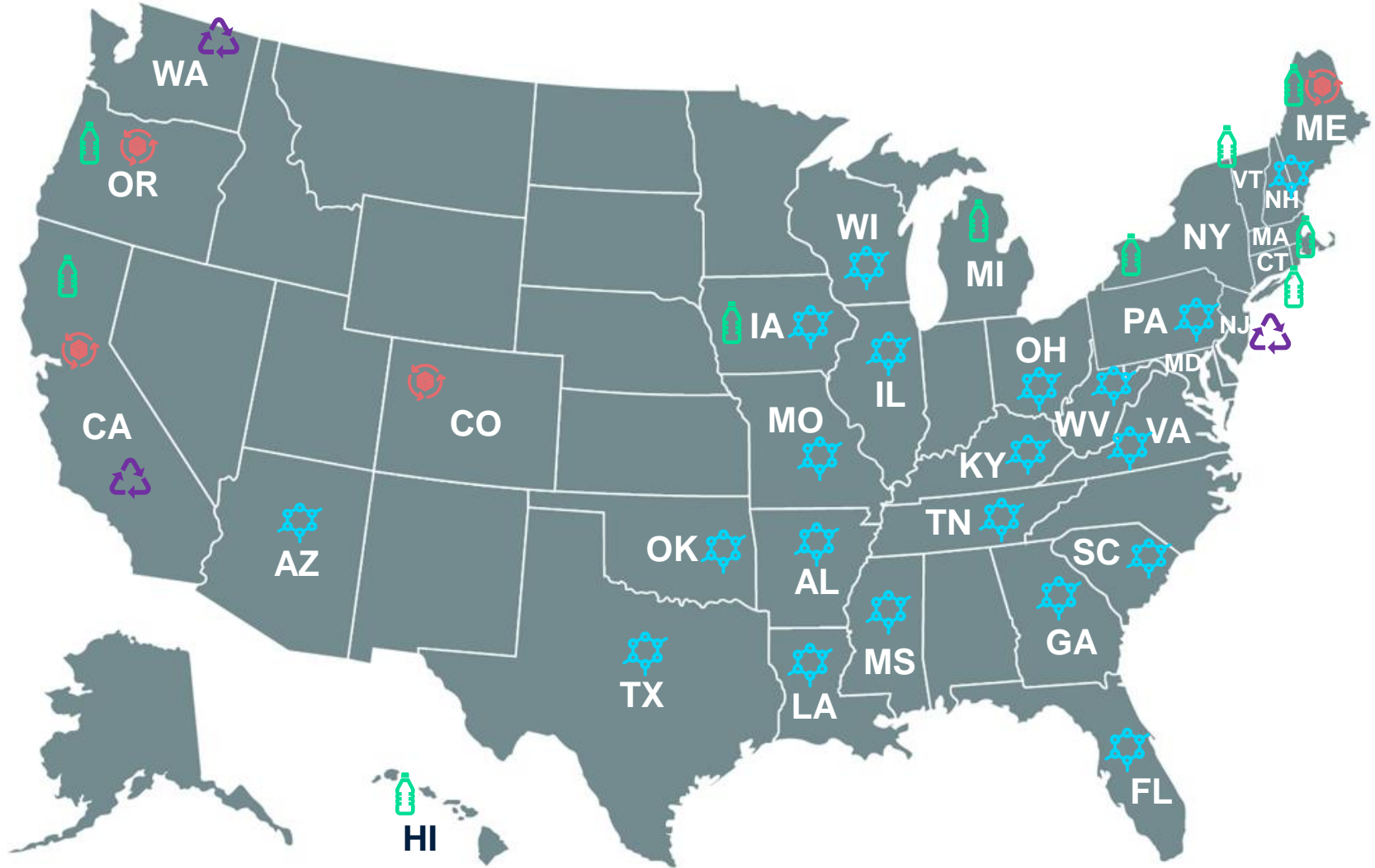
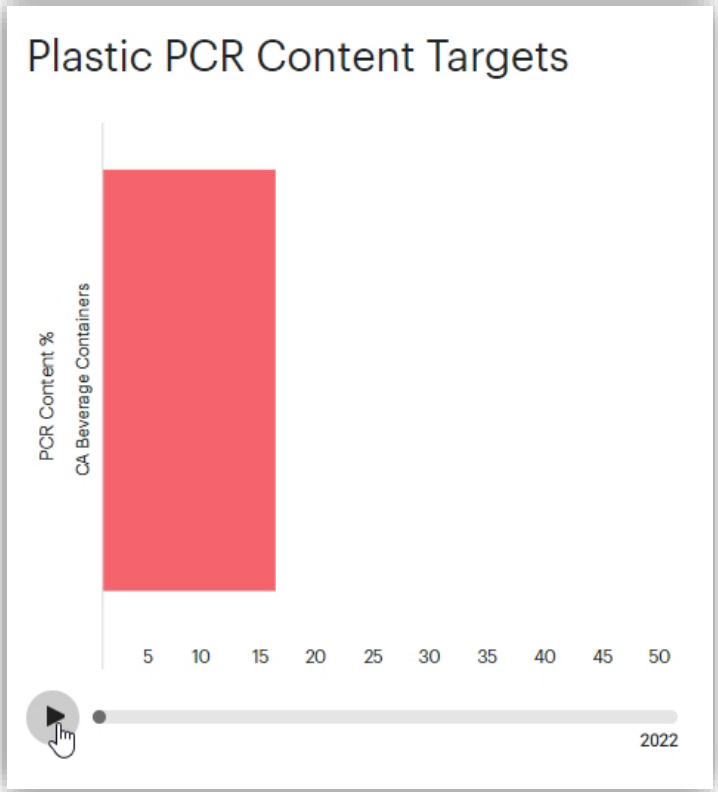
EUROPE





- Packaging and Packaging Waste Directive
- Circular Economy Package
- Single Use Plastics Directive
- EU Plastics waste charge
- Country specific plastic packaging taxes

ASIA PACIFIC

- National Sword / Plastic waste import ban (China)
- Waste export ban and Recycling Modernisation Fund (Australia)
- Deposit return schemes

US Legislation



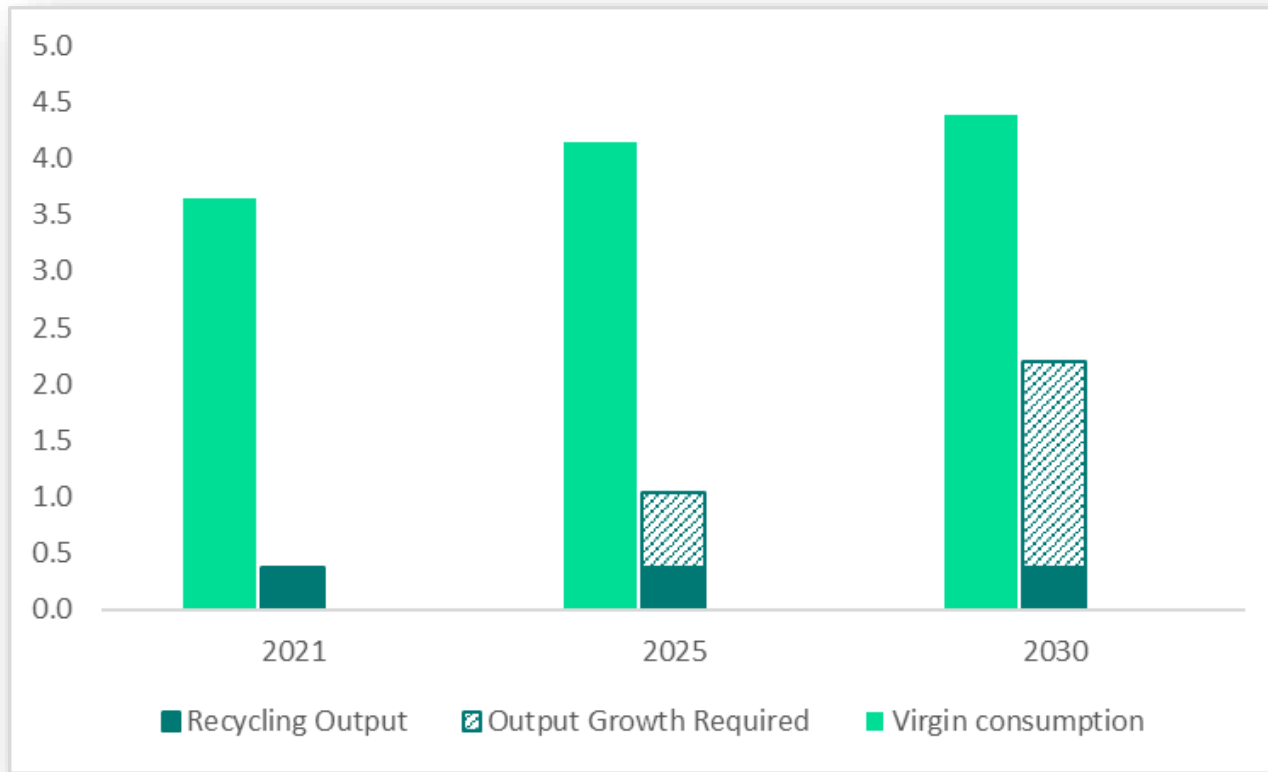
-  Bottle bill program
-  Minimum PCR content
-  EPR legislation
-  Chemical recycling adoption

10/11/2022



Required PCR for bottles to achieve 25% by 2025, 50% by 2030

PET



29%

CAGR required to meet 2025 target

101

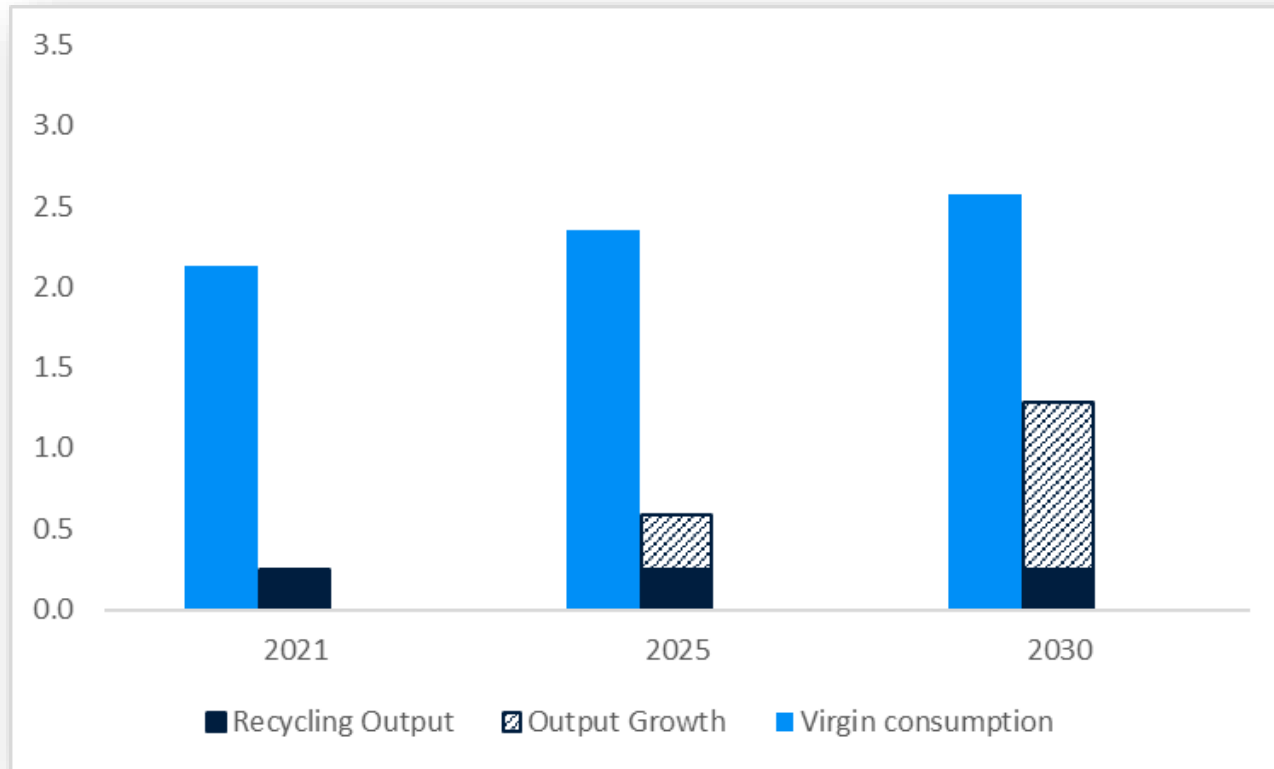
New PCR PET facilities with output of 18k tonnes/year required to meet 2030 target

Source: ICIS Supply and Demand Tracker, ICIS Mechanical Recycling Supply Tracker- 2021, ACC, NAPCOR, APR



Required PCR for bottles to achieve 25% by 2025, 50% by 2030

HDPE



87%

of total 2021 PCR HDPE output would satisfy 2025 target

58

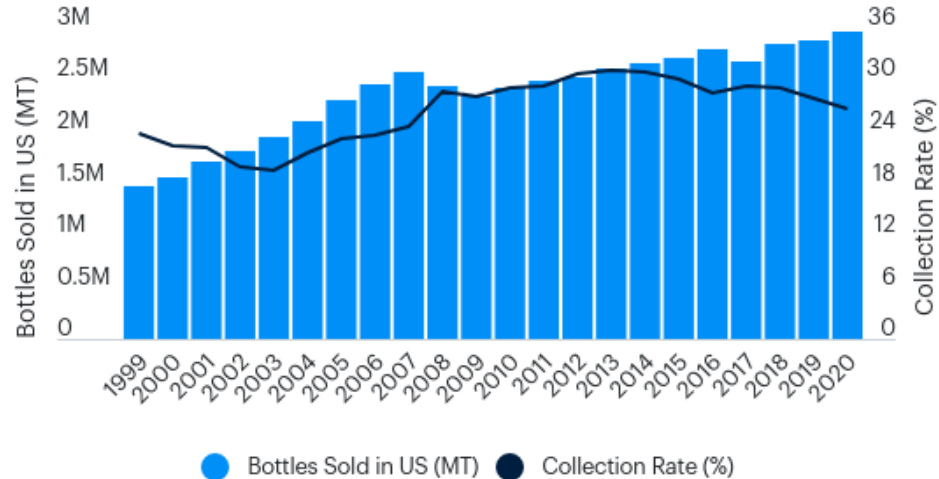
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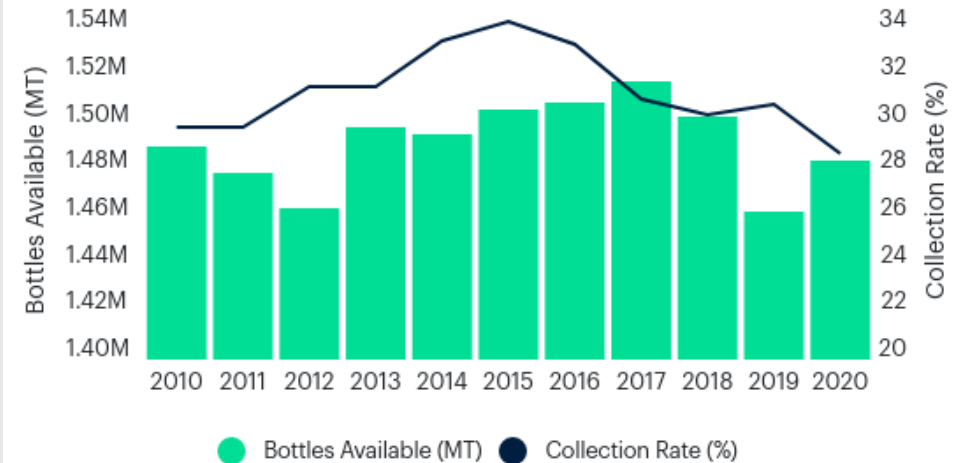
Bridging the Gap: US Collection Rates

US PET Bottle Collection Rate



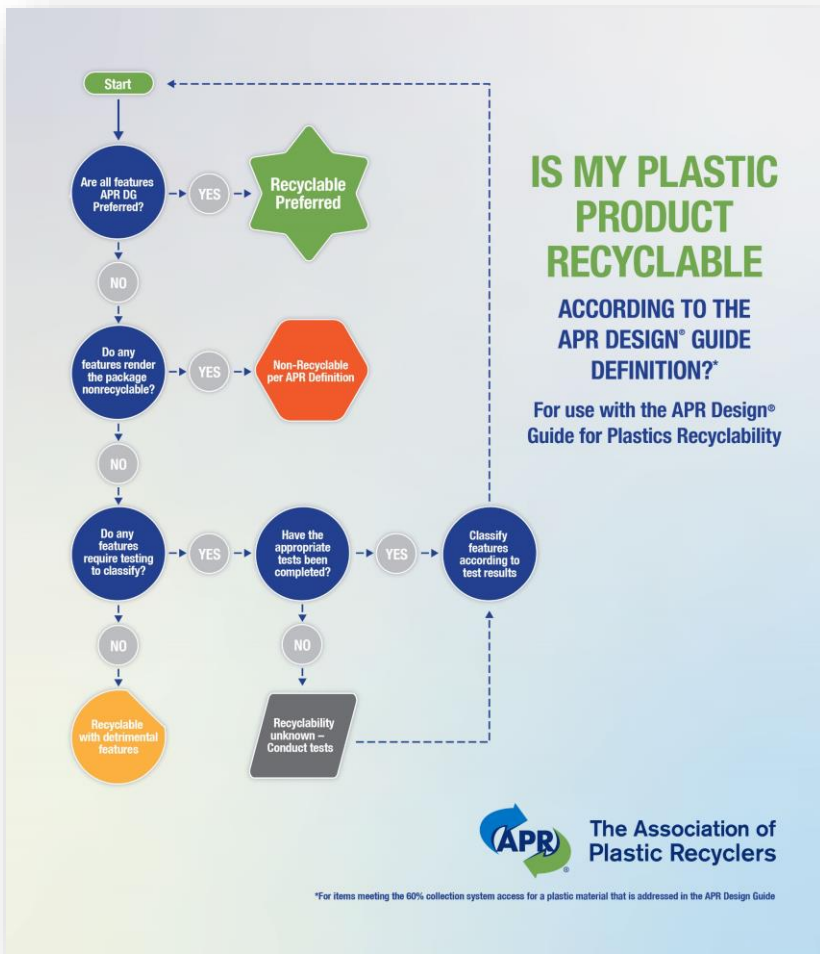
Source: NAPCOR 2020 PET Recycling Report

US HDPE Bottle Collection Rate



Source: ACC and APR

Bridging the Gap: Design for Recyclability



The U.S. Pact's Problematic and Unnecessary Materials List

U.S. Pact Activators will take measures to eliminate these items by 2025:

- Cutlery*
- Intentionally added¹ Per- and Polyfluoroalkyl Substances (PFAS)²
- Non-Detectable Pigments such as Carbon Black
- Opaque or Pigmented PET – Polyethylene Terephthalate bottles (any color other than transparent blue or green)
- Oxo-Degradable Additives, including oxo-biodegradable additives
- PETG – Polyethylene Terephthalate Glycol in rigid packaging
- Problematic Label Constructions – This includes adhesives, inks, materials (e.g., PETG, PVC, PLA, paper). Avoid formats/materials/features that render a package detrimental or non-recyclable per the APR Design® Guide. Labels should meet APR Preferred Guidance for coverage and compatibility and be tested in any areas where this is unclear.
- PS – Polystyrene, including EPS (Expanded Polystyrene)
- PVC – Polyvinyl Chloride, including PVDC (Polyvinylidene Chloride)
- Stirrers*
- Straws*

The How2Recycle Guide to Recyclability

The purpose of the How2Recycle Guide for Recyclability is to transparently provide the general public and How2Recycle member companies with guidance about what recyclability means, and insight about how the How2Recycle program assesses recyclability on a package-by-package basis.



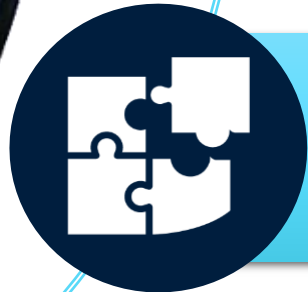
Looking towards the future



Time to transform



Significant collection and capacity improvements needed



Recycled plastic is only **part** of environmental solution



Thank You!

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