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The Disruptive Path to Circular Plastics

Alan Wei

Executive Director, China Plastics, Chemical Market Analytics by OPIS

Transformation from Linear to Circular Model for Plastics: Plastic Circularity

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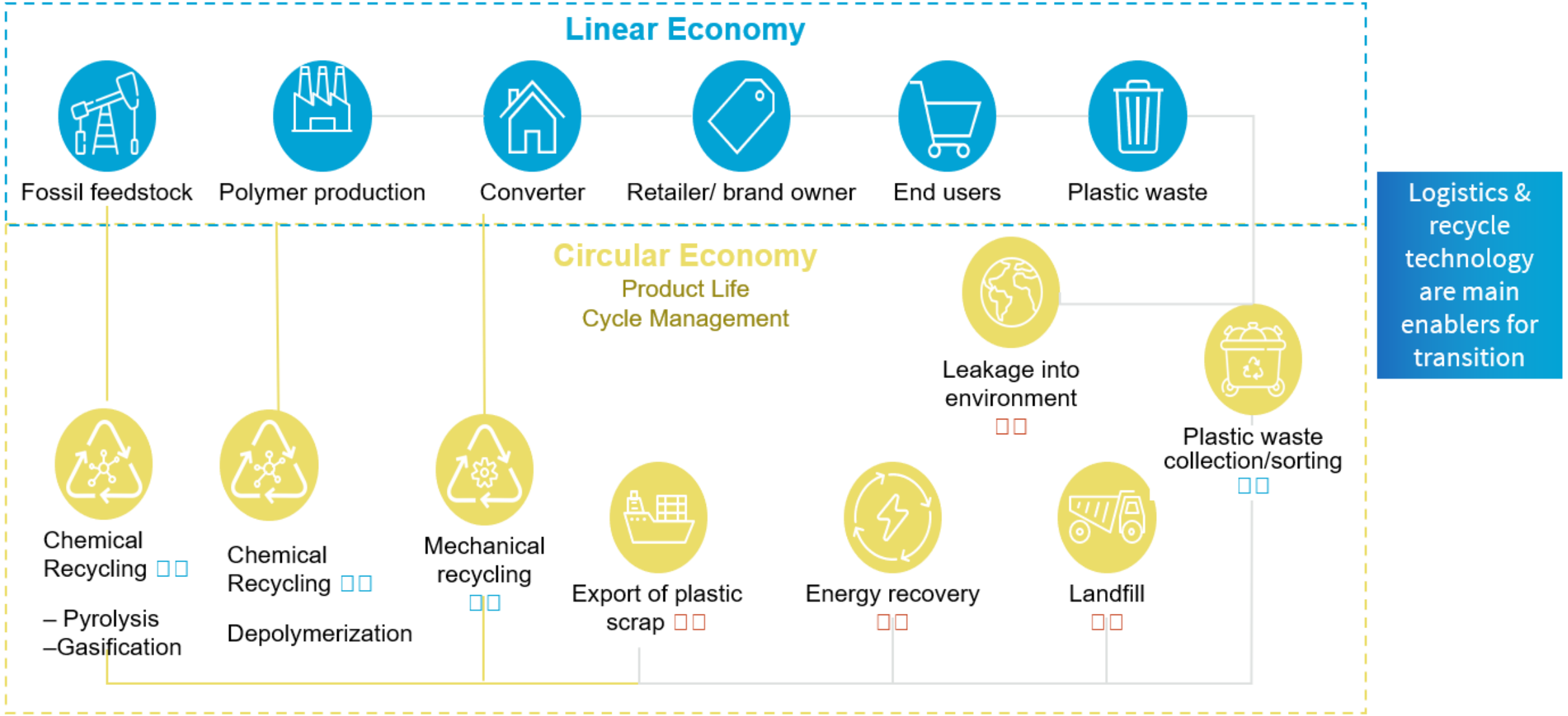

Path to sustainable plastics requires alignment of priorities and complicated deployment of resources

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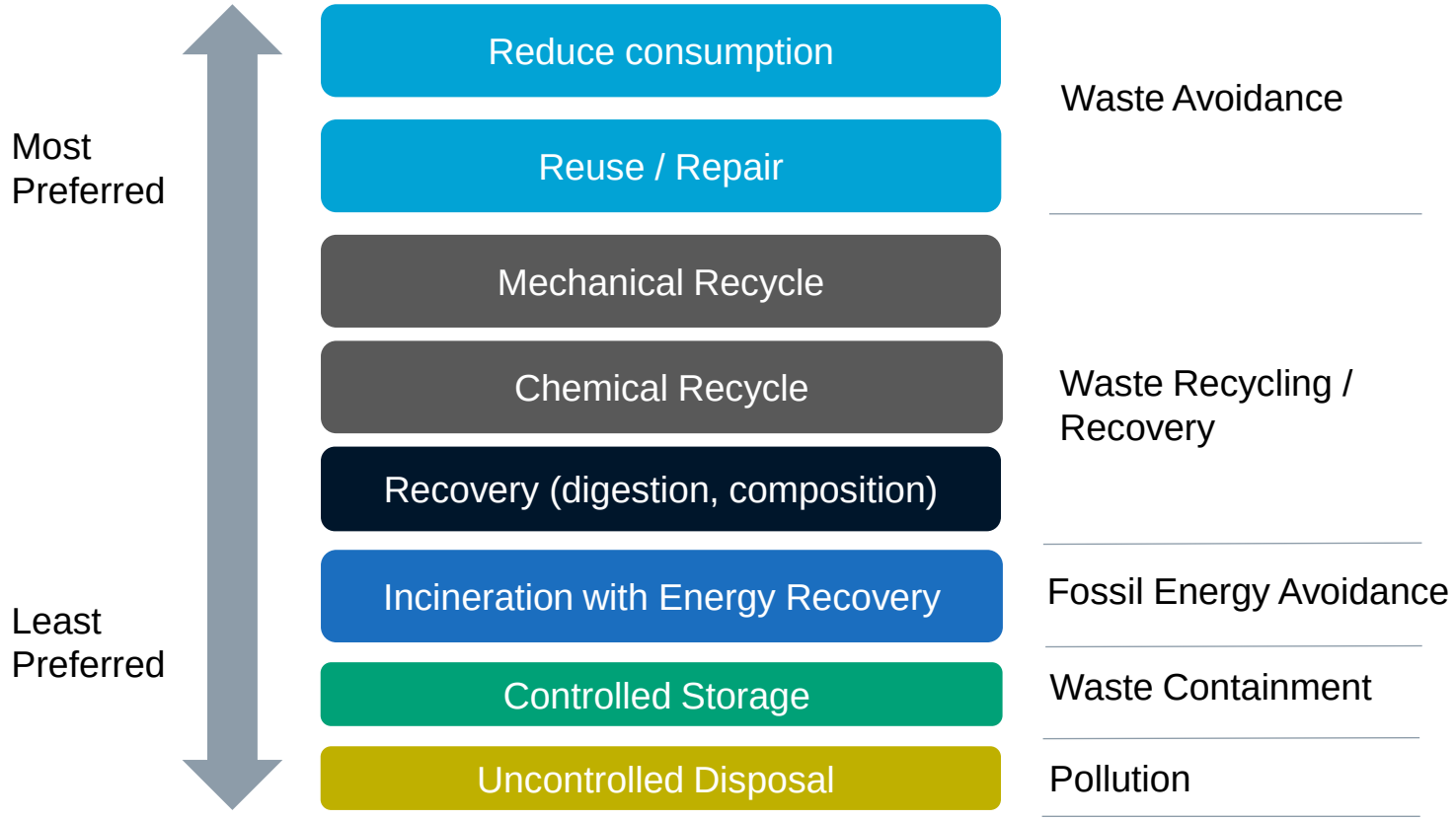
“CIRCULAR PLASTICS”

Alternative to traditional linear “make, use, dispose” model.

Ecosystem in which we:

- minimize consumption of resources
- keep resources in use as long as possible
- extract maximum use value
- then recover & regenerate valuable materials & products at end of each service life



The transition to a sustainable model for polyolefins will be a disruptive journey

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- The quantity of plastic waste will increase by 70% over the next 30 years
- Cannot Ban Away the Problem
- Current pace of recycling is on a trajectory toward failure. Infrastructure projects envisioned today fall short.
- Reverse supply chain for plastics disconnected from build to export model
- Critical bottleneck is feedstock supply, not demand
- Achieving a circular economy for plastics is not always aligned with net zero goals.
- Eliminating plastics waste to landfill and incineration does not equate to eliminating fossil-based production.

Bans have minimal impact

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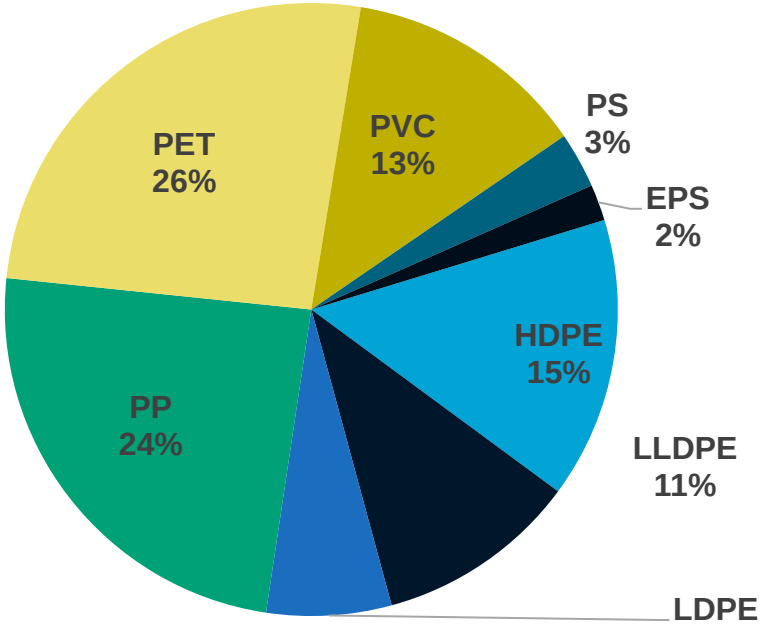
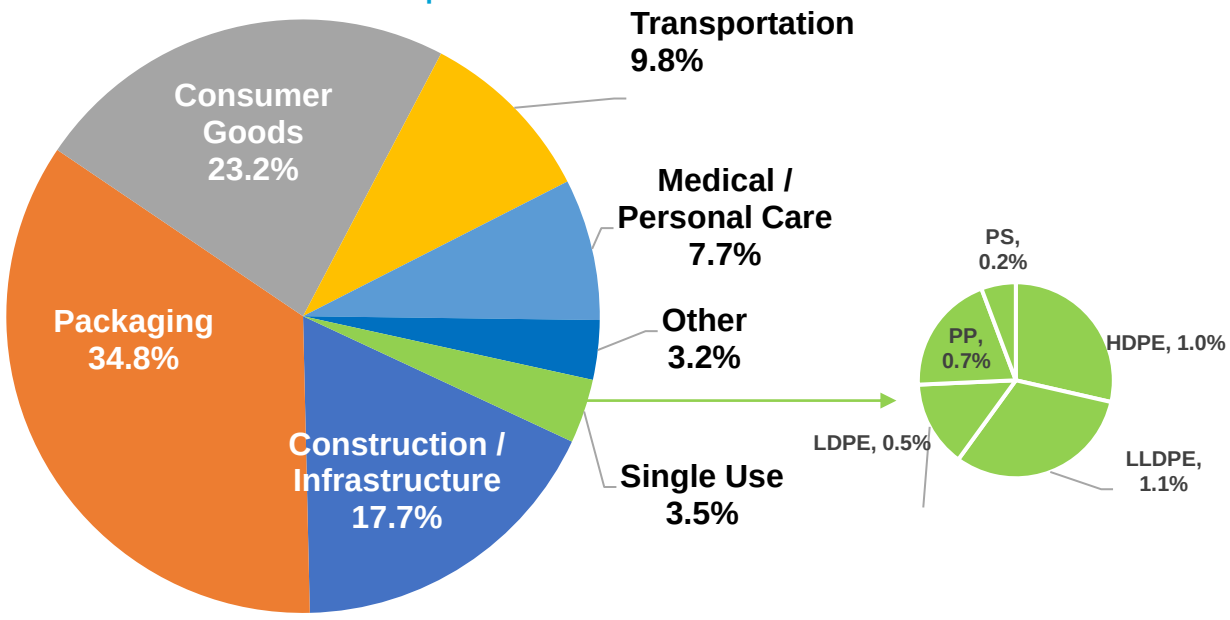
Large Proportion of Plastics Consumed in Packaging but Limited Volume in Single Use Food Service & Retail Bags

Global demand for volume plastics



Source: Chemical Market Analytics by OPIS

Global demand for volume plastics



Source: Chemical Market Analytics by OPIS

- Other includes wide range of durable and non-durable industrial applications

Incremental plastics waste growth disconnected from plastics production infrastructure

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Challenging in "build to export" world

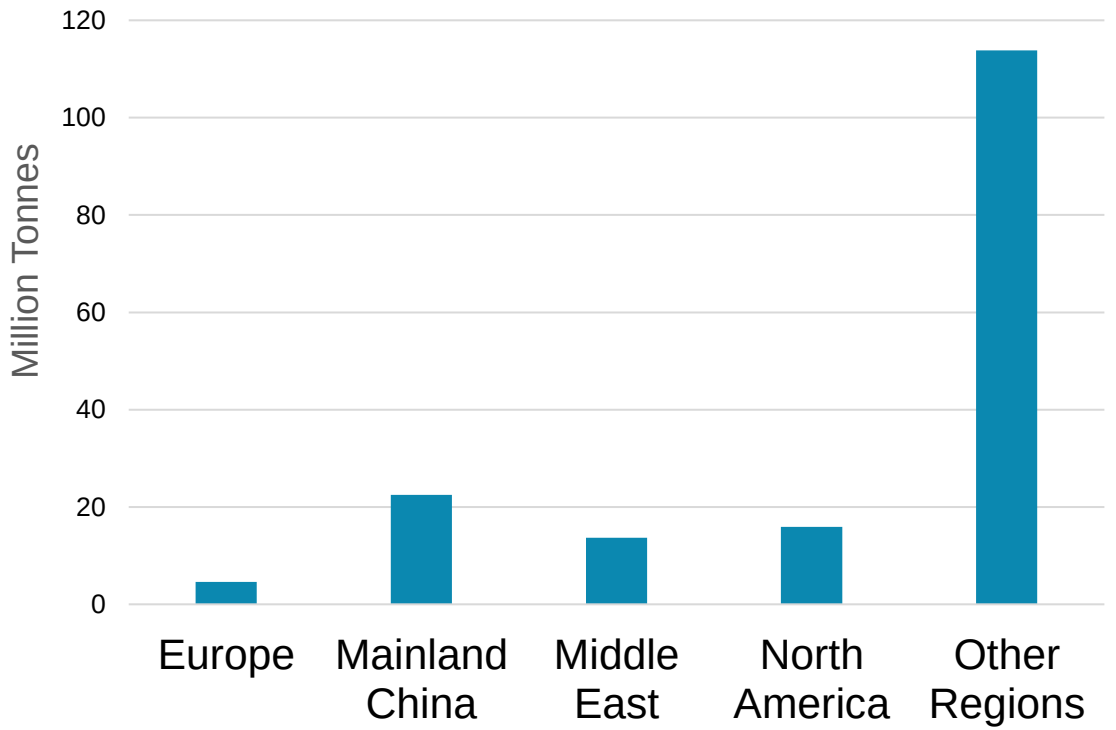
Options based on local circumstances

- **Increase volumes to infrastructure**
- **Export chemical recycled feedstocks**
- **Directing output to fuels**

Repeat of historical, per-capita waste Generation

Pace and extent of recycling technology transfer

Growth to 2050 of plastics waste in municipal solid waste



Source: Chemical Market Analytics by OPIS

Chemical Market Analytics takes a scenario approach to measure the impact

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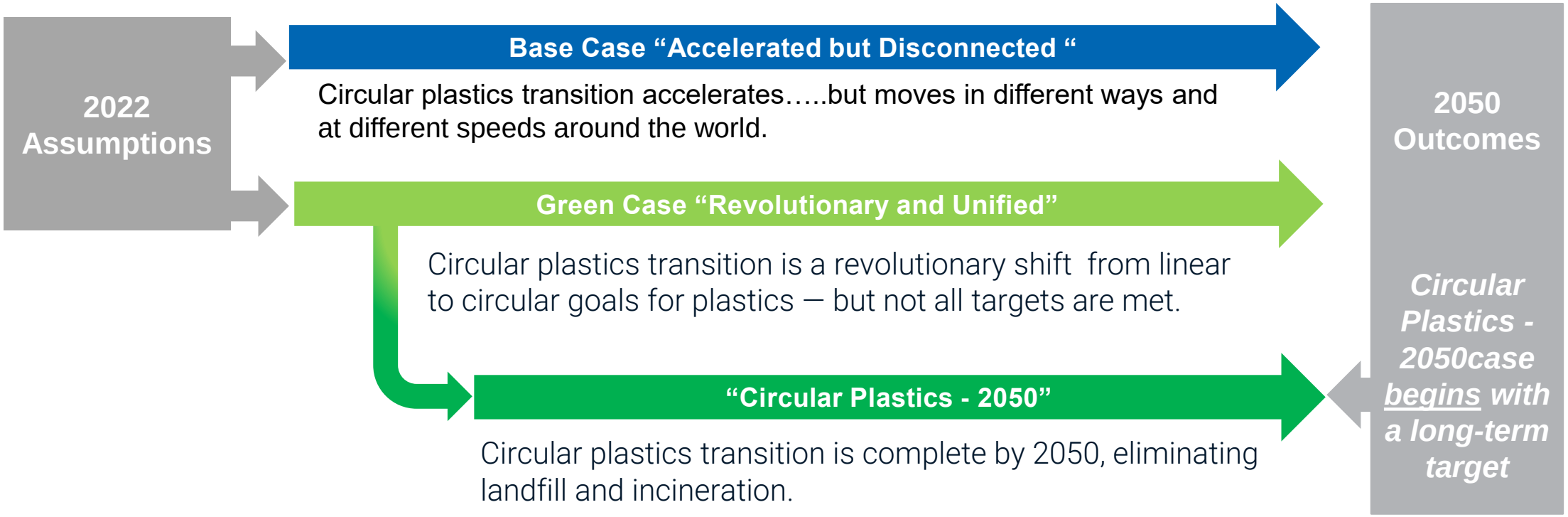
Integrated scenarios for plastics



There are multiple paths leading to Plastics Circularity

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	Base Case Circular plastics progression at current pace (balancing policy response and economics)	**Green Case** Sustainable global footprint: Accelerated progression to circular plastics model	**Circular Plastics - 2050** Sustainable global Circular Model achieved by 2050 with no further use of Incineration or Landfill
Mechanical Recycling	PCR Recycling rate limits defined by CMA via segmented demand forecast for virgin and post-consumer polymer	PCR Recycling rate limits accelerate in lagging regions, directionally towards proxy EU	PCR Recycling rates are viewed as maximized, and maintained at Green Case levels
Chemical Recycling	Capacity projections based on current pace of technology development	Capacity projections reflect experience curves for scale and economics	Objective is to quantify the level for each solution needed to achieve the 2050 target of no Incineration or Landfill

HDPE and PP drive value proposition for circular mechanical recycling

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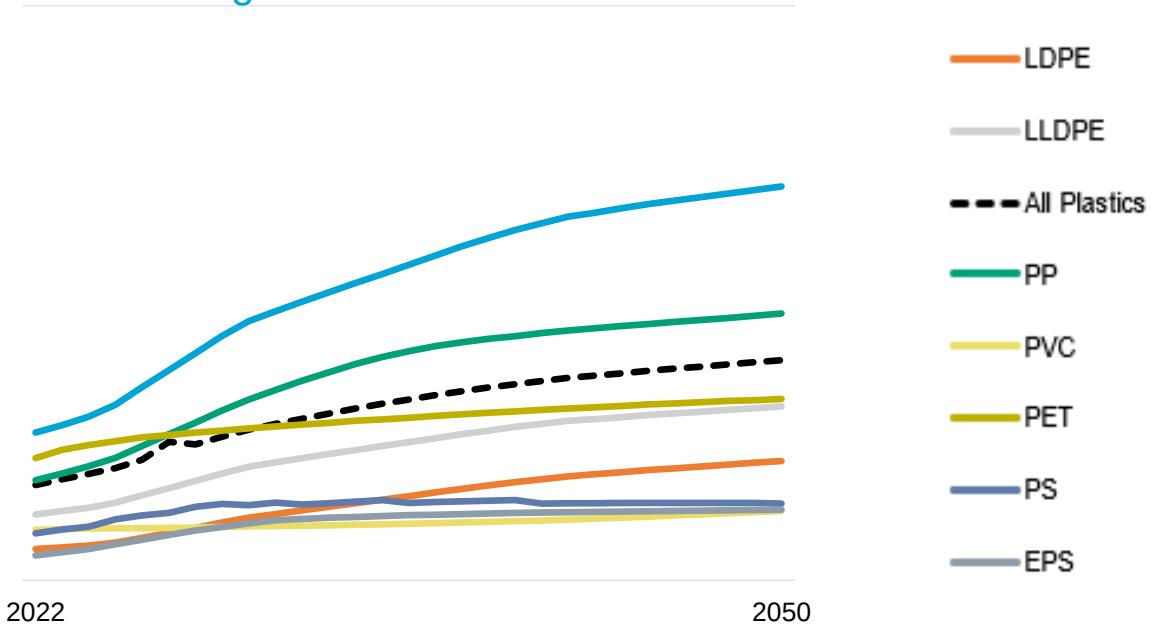
- HDPE holds highest potential for incorporation of PCR followed by PP. Both HD and PP demand have higher percentage of rigid compared to LD and LLDPE with higher exposure to flexibles
- rPET share is impacted by fiber volumes

PCR as % of Total Demand - Global - Incremental Progressive Base Case



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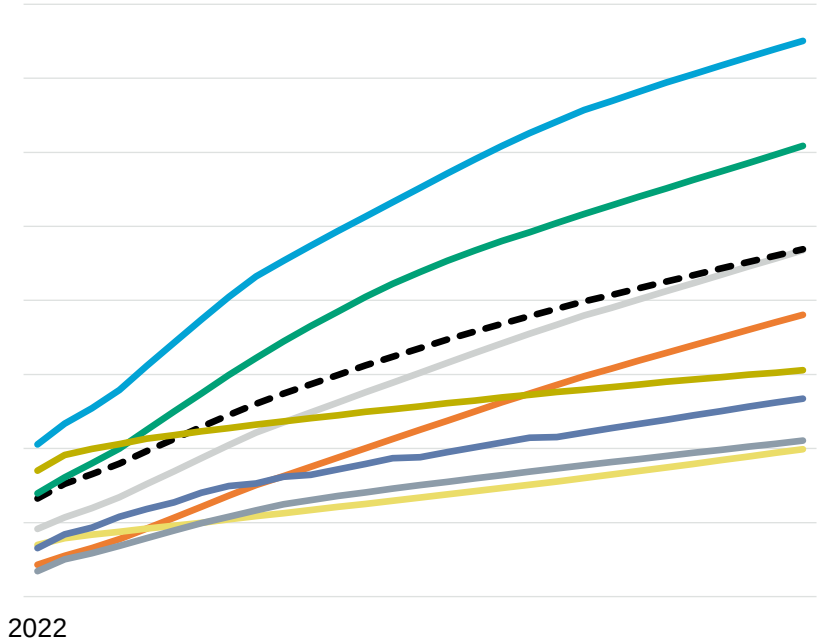
PCR as % of Total Demand - Global - Green



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Chemical recycling capacity doubling from small base

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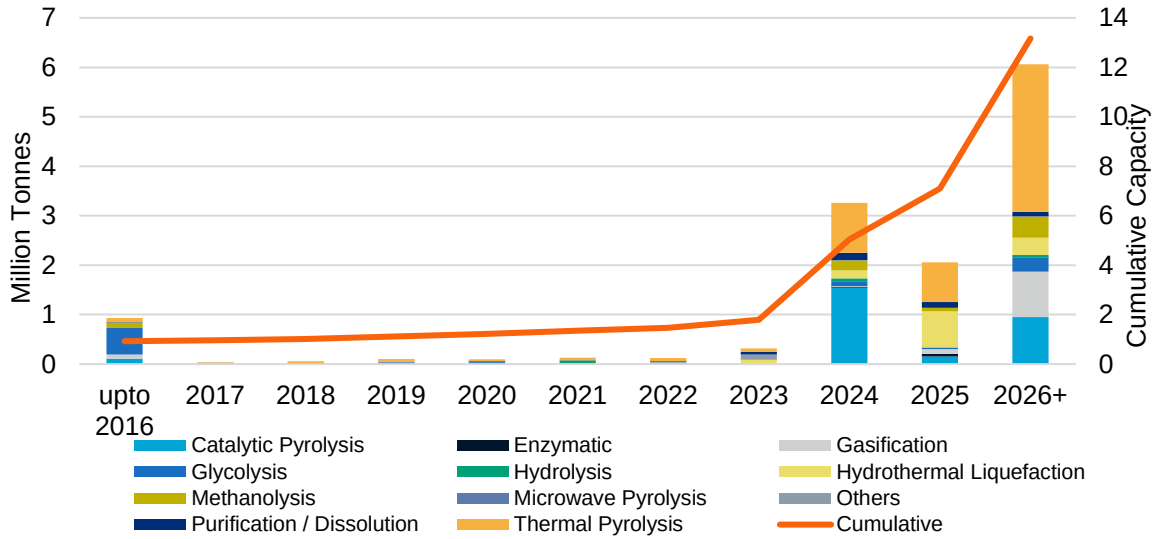
1.8 mtpa Operational
2.6 " Under construction
8.4 " Under some form of planning

164 Technology companies
437 Facilities
552 Unique companies in collaborations

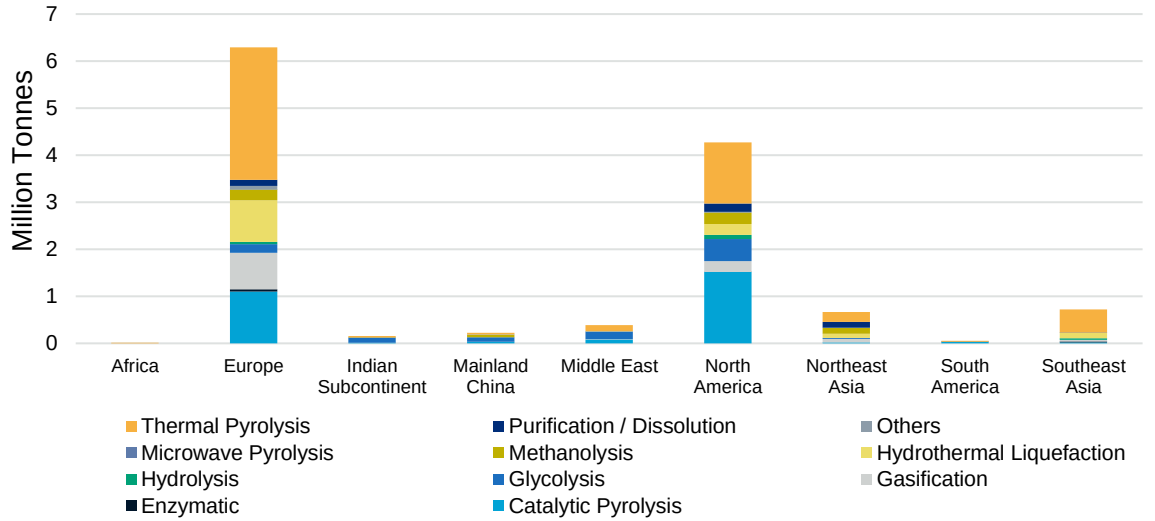
Cumulative capacity by date of commissioning



Source: Chemical Market Analytics by OPIS

Note: Unknown timeline projects included in 2026+ section

Capacity by Region and Technology

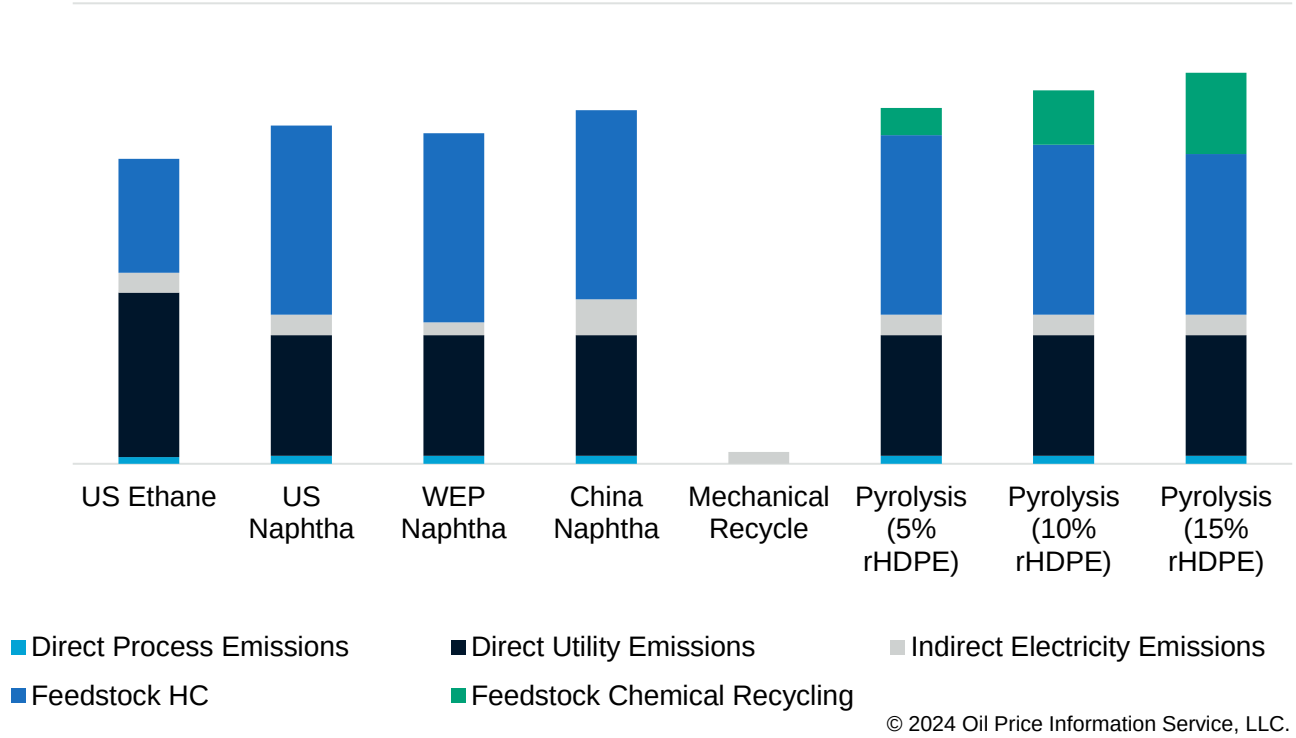


Note: Includes all years, i.e. Operational, Under construction, and Under feasibility

Achieving a Circular Economy for Plastics is not always aligned with net zero goals

Comparative Carbon Emissions

HDPE comparative emissions ($MTCO_2/MT$)



Note: Integrated Chemicals Processes CO_2E breakdown as Direct Process, Utility and Indirect Emissions
- Feedstock HC (Hydrocarbon) represent Well-head to Crude Oil/Natural Gas to Naphtha/Ethane Processes Emissions
- Feedstock Chemical Recycling represent emissions from Pyrolysis feedstock
- Process Routes based on US Emission Factors unless declared otherwise

** Mechanical recycling does not include collection and sorting processes

- Scope 1&2 emissions: Mechanical recycling advantaged while viable offsets needed for chemical recycling
- Footprints shown cover Scope-1 and Scope-2 emissions to process clean stream of recycled material

  - Does not include carbon emissions associated with collection and sorting

Chemical recycling of mixed plastics via pyrolysis is energy-intensive and has higher emissions compared to virgin production from hydrocarbon feedstocks

Business-as-usual risk increases with transformation

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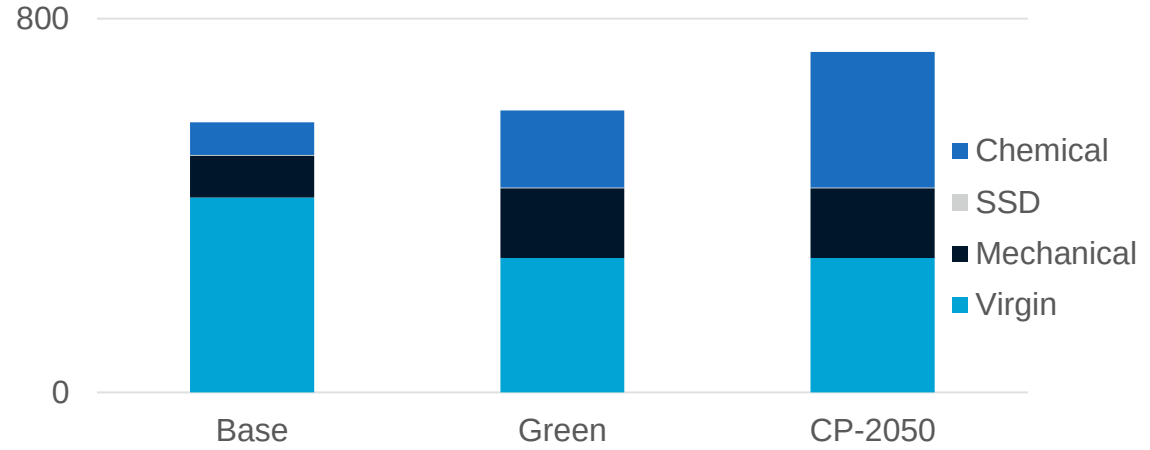
$1.3 trillion: total processing investment required for “”Circular Plastics 2050”

Incremental spend $0.3 trillion

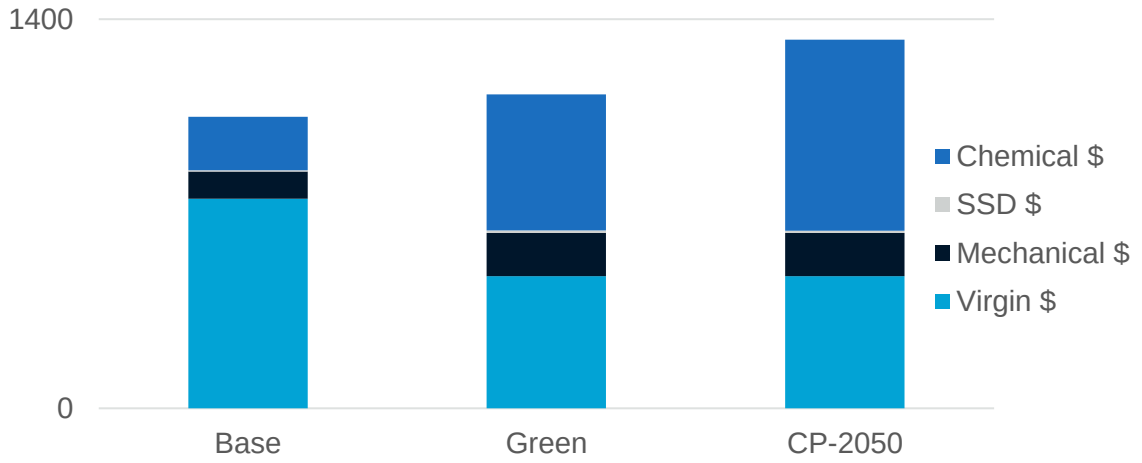
Increasing risk /opportunities from potential economic impact of carbon valuation and ecosystem costs

Capacity Additions (MMT)



Source: Chemical Market Analytics by OPIS

Capital Spending (USD Billion)



Source: Chemical Market Analytics by OPIS

Contribution from chemical recycling lagging despite doubling in the near term globally

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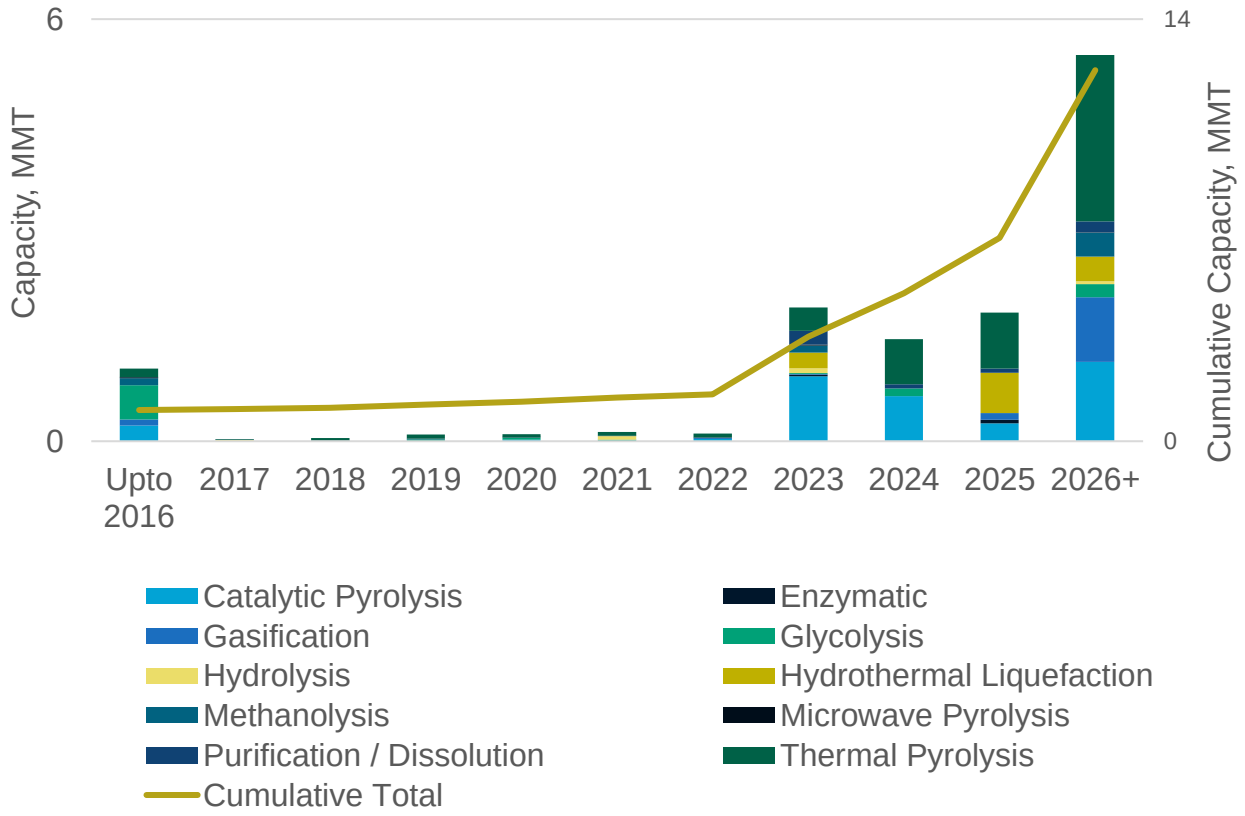
Capacity in operation, under construction and feasibility for the near future

- 145+ technology companies
- Total operational capacity of 1.5 MMTPA
- 2.4 MMTPA under construction over the coming years
- 8.3 MMTPA under some form of planning.
- Europe and North America accounts for more than 75% of the global capacity`

Capacity (MMTPA) running total by Date of Operation/Commissioning



Note: Now includes unknown timeline projects in 2026+ section

Demand for recycle content supply primarily from non-durables but recycle demand also comes from durables

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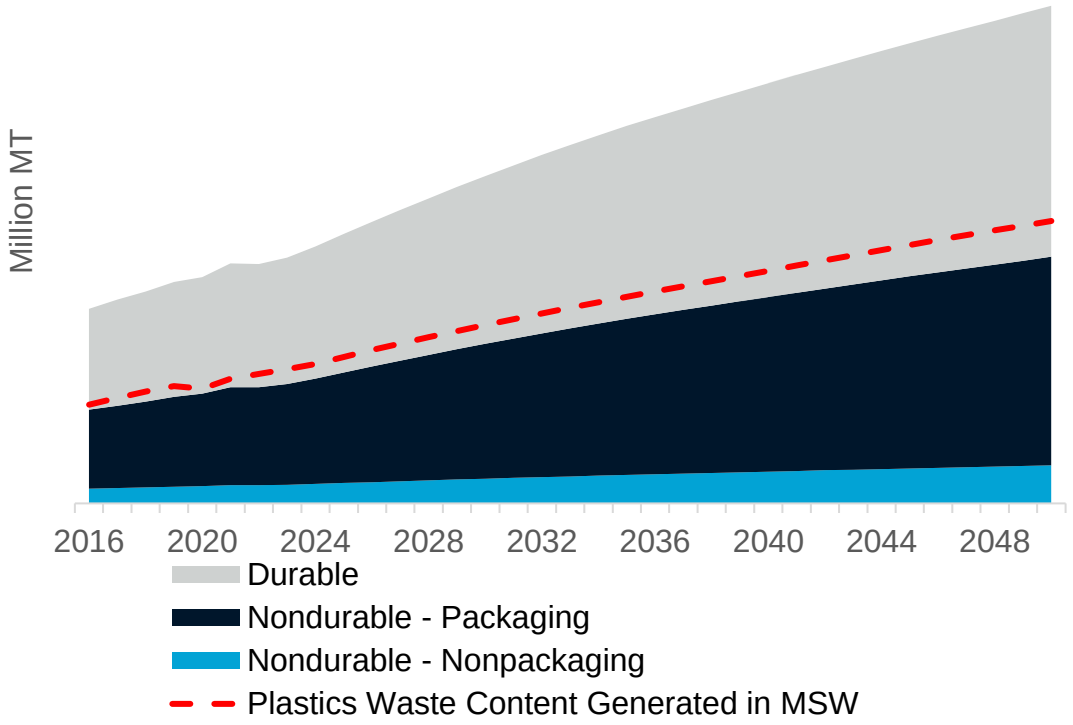
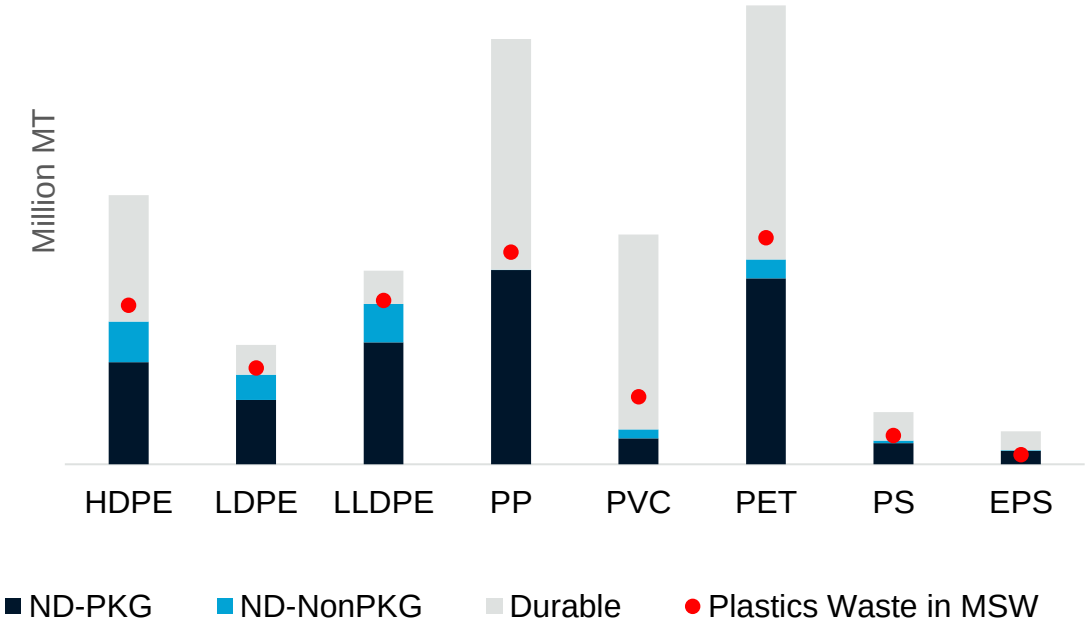
Plastics waste generation and polymer demand comparison

Global Plastics



Source: Chemical Market Analytics by OPIS

Global Waste Analysis by Polymer Type 2022



Source: Chemical Market Analytics by OPIS

Eliminating plastics waste to landfill and incineration does not equate to eliminating fossil-based production

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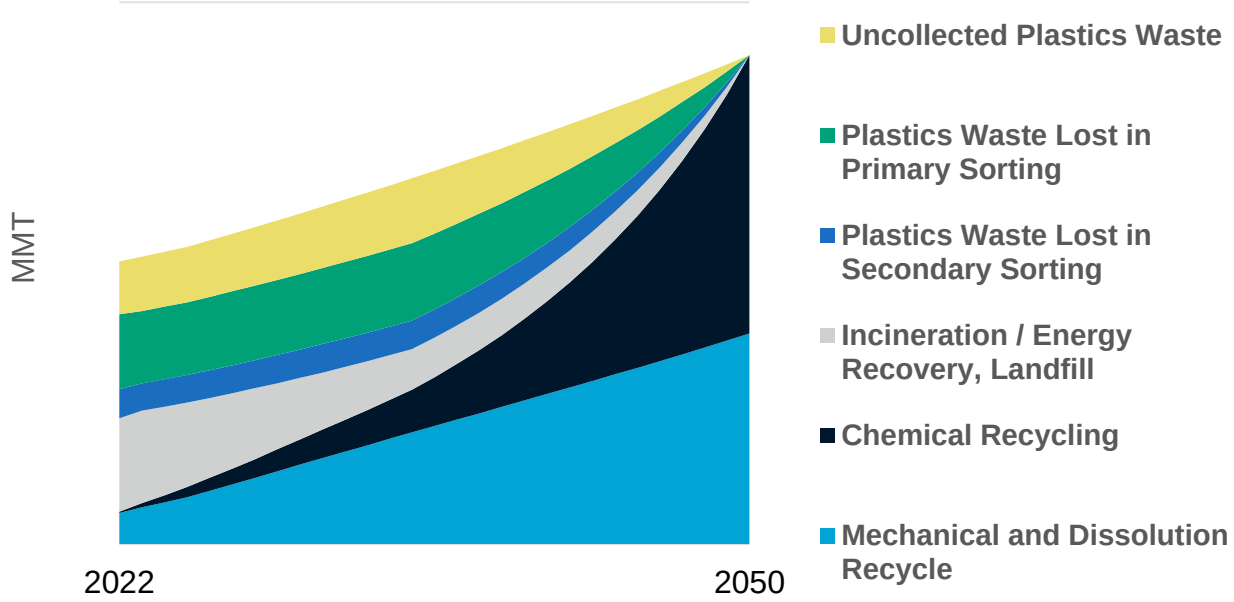
Peak use of fossil-based feedstocks in plastic production is in view but fossil-based feedstocks remain

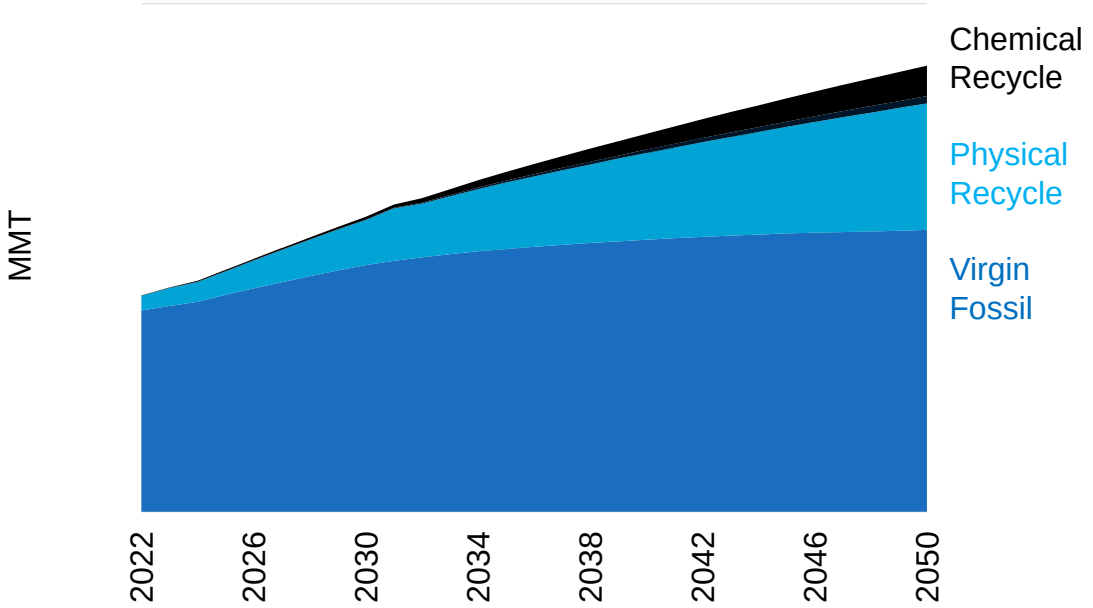
Proportional contribution of plastics waste volumes into chemical recycling - Pyrolysis to rNaptha

Global Disposition of Plastics - Circular Plastics



Source: Chemical Market Analytics by OPIS

Polyolefins Demand by Feed - Circular Plastics - 2050



Combined global view of plastics waste from MSW: LDPE, LLDPE, HDPE, PP, PET, PVC, PS, EPS

Source: Chemical Market Analytics by OPIS

Near Term disruptors

Virgin production cycles challenge economics of recycling

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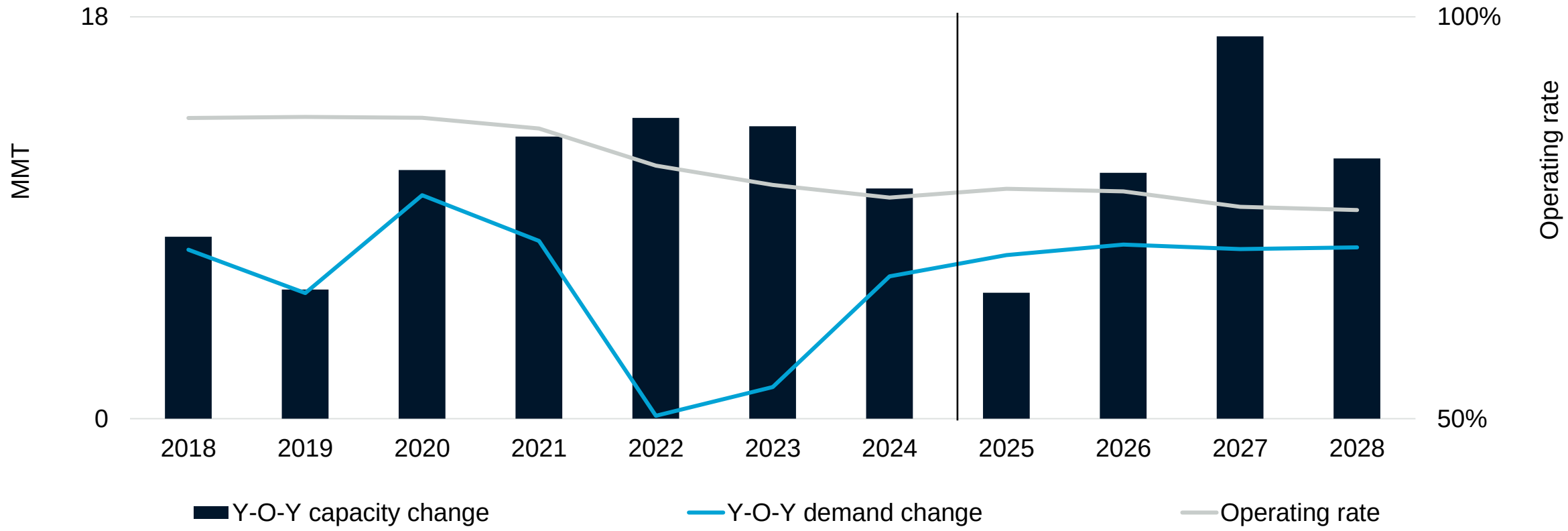
Too much capacity chasing too little demand

Global PO Y-O-Y Total Capacity Growth %



Source: Chemical Market Analytics by OPIS

Future Polyolefin virgin demand growth expected to be slower but from a larger base

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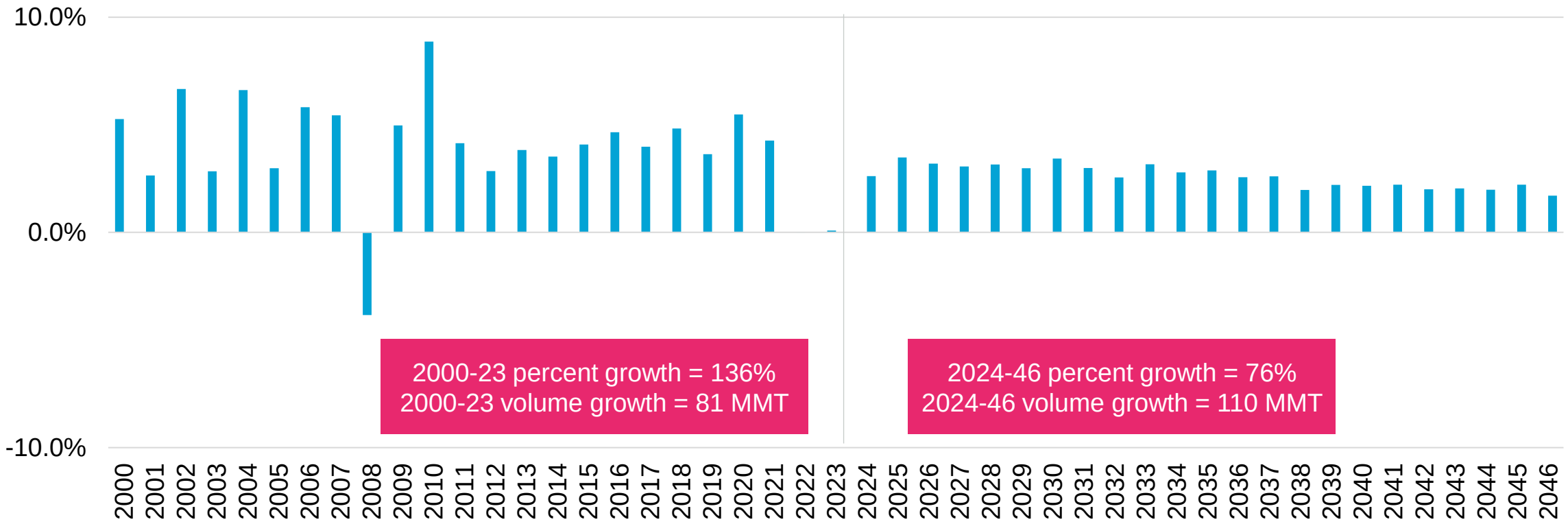
Polyolefin demand growth



Source: Chemical Market Analytics by OPIS

Longer Term disruptors

Declining virgin demand growth rates point to longer term impact of virgin prices on recycling

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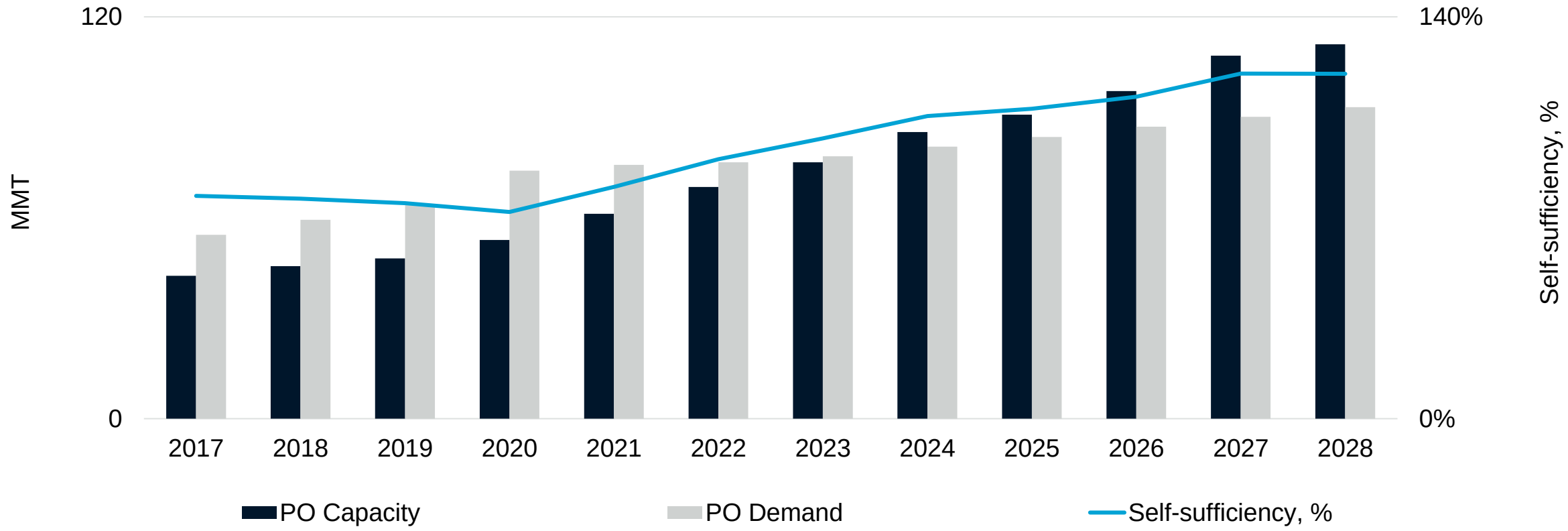
Slower virgin demand growth in China amid rising capacity

Mainland China PO Self-sufficiency (capacity divided by domestic demand)



Source: Chemical Market Analytics by OPIS

Asian operators in survival mode through the forecast

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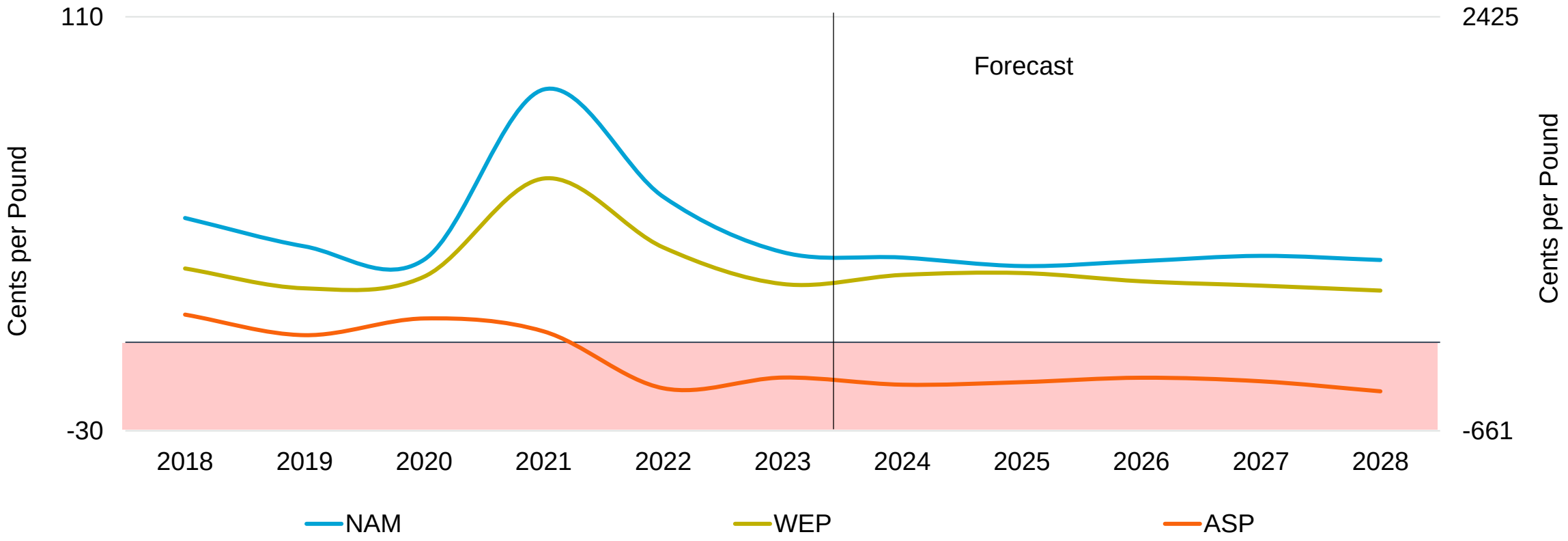
PE-PP Combined Margins

NAM is mixed feed based
WEP and ASP are naphtha based



Source: Chemical Market Analytics by OPIS

Recycle impact likely delayed to virgin oversupply

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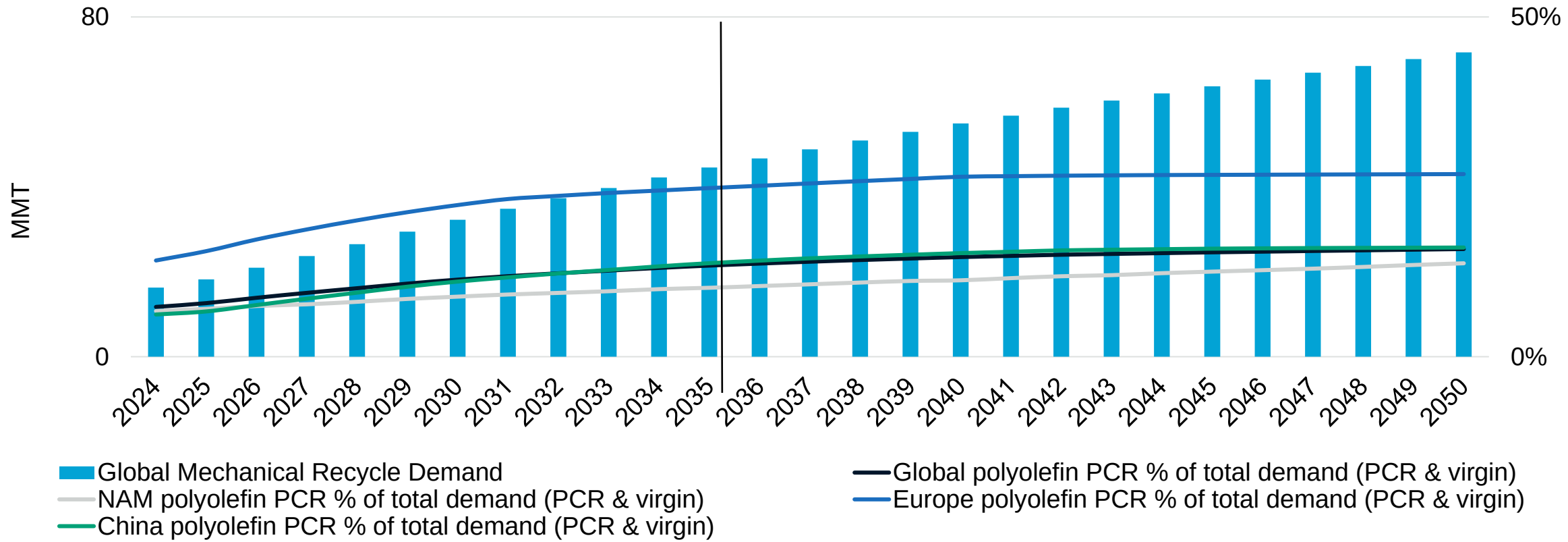
Global Recycled Polyolefin Demand



Source: Chemical Market Analytics by OPIS

If PCR % were to stay flat from current level through 2050..

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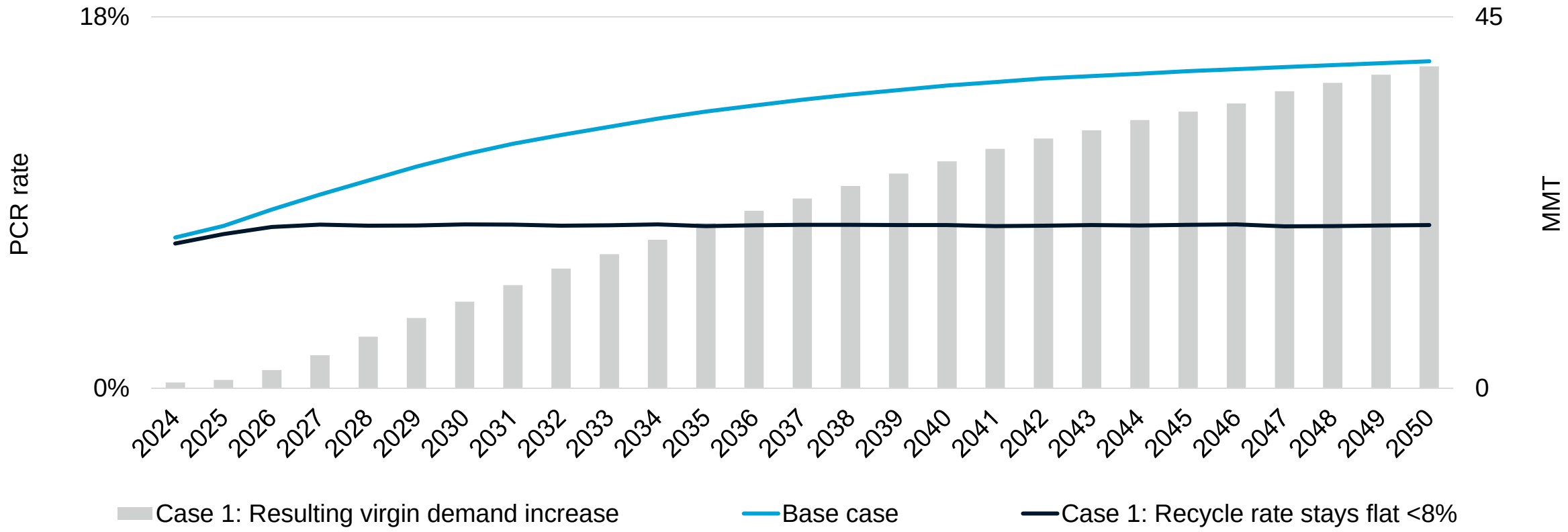
Scenario case : If PCR % stays <8% through 2050



Source: Chemical Market Analytics by OPIS

Scenario 2: PCR % reaches 24% by 2050

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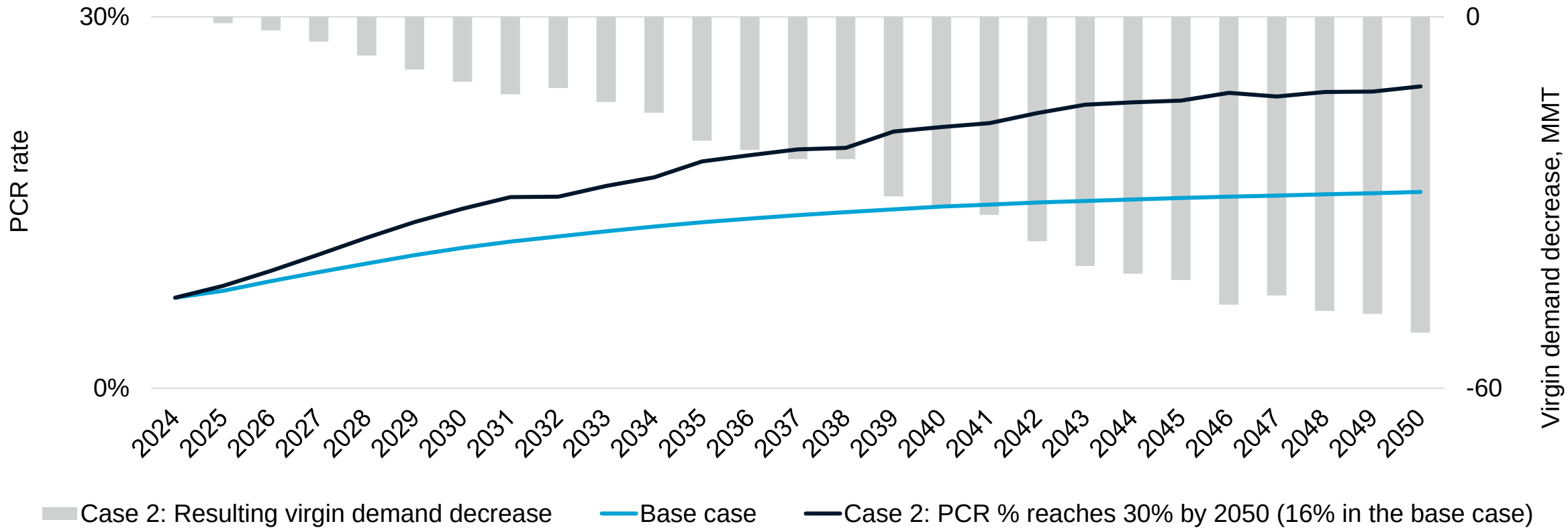
Scenario case: PCR % reach 24% by 2050



Source: Chemical Market Analytics by OPIS

Summary: Challenges ahead

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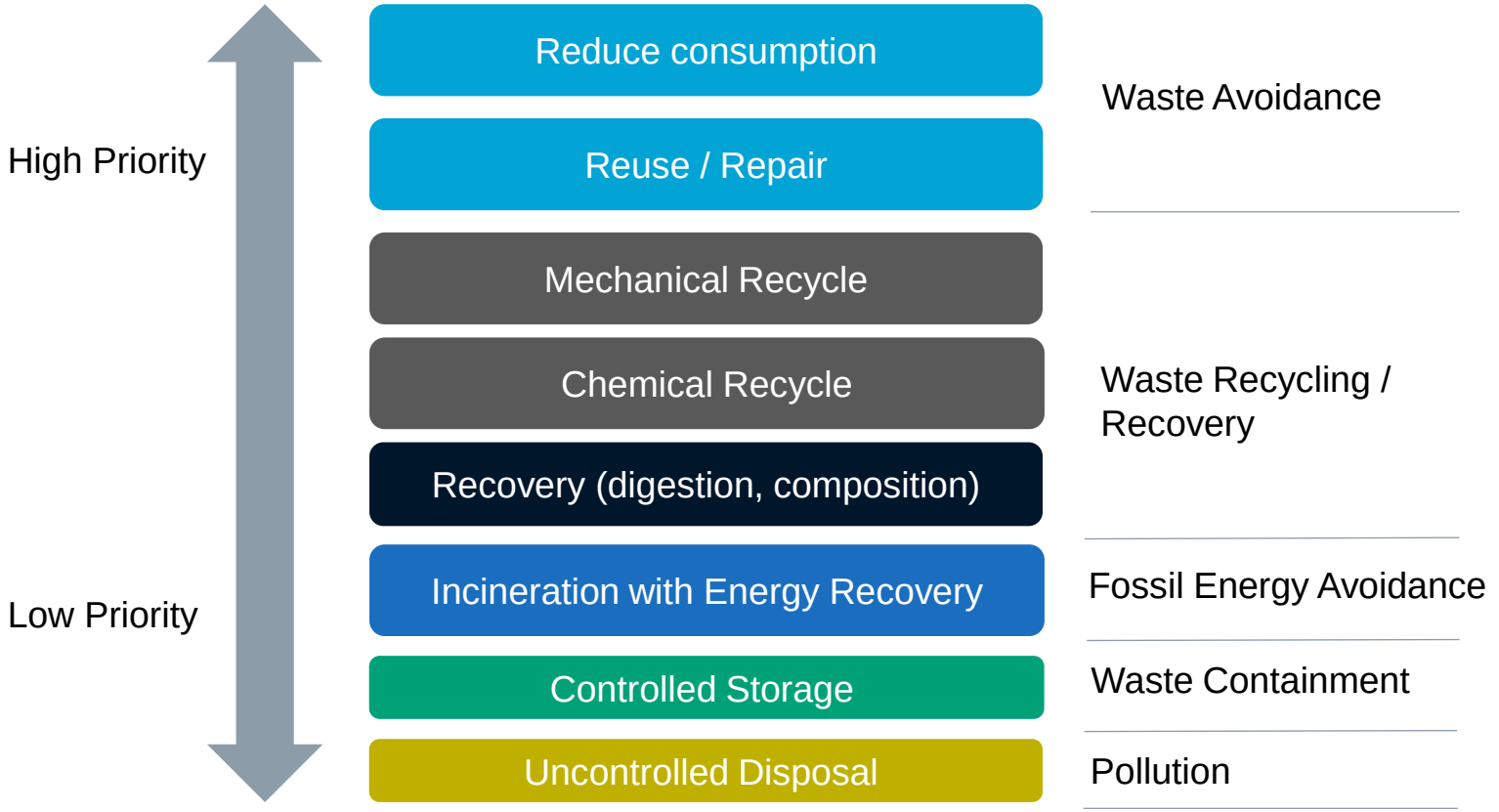
- Recycle trend not going away but neither is virgin demand
- Long virgin markets will slow recycle growth rates near to medium term
- Recycle incorporation will differ by region
- Recycle will require many solutions to be successful



PCR market in China

Output of recycled plastics and recycling rates changed slightly in the past seven years

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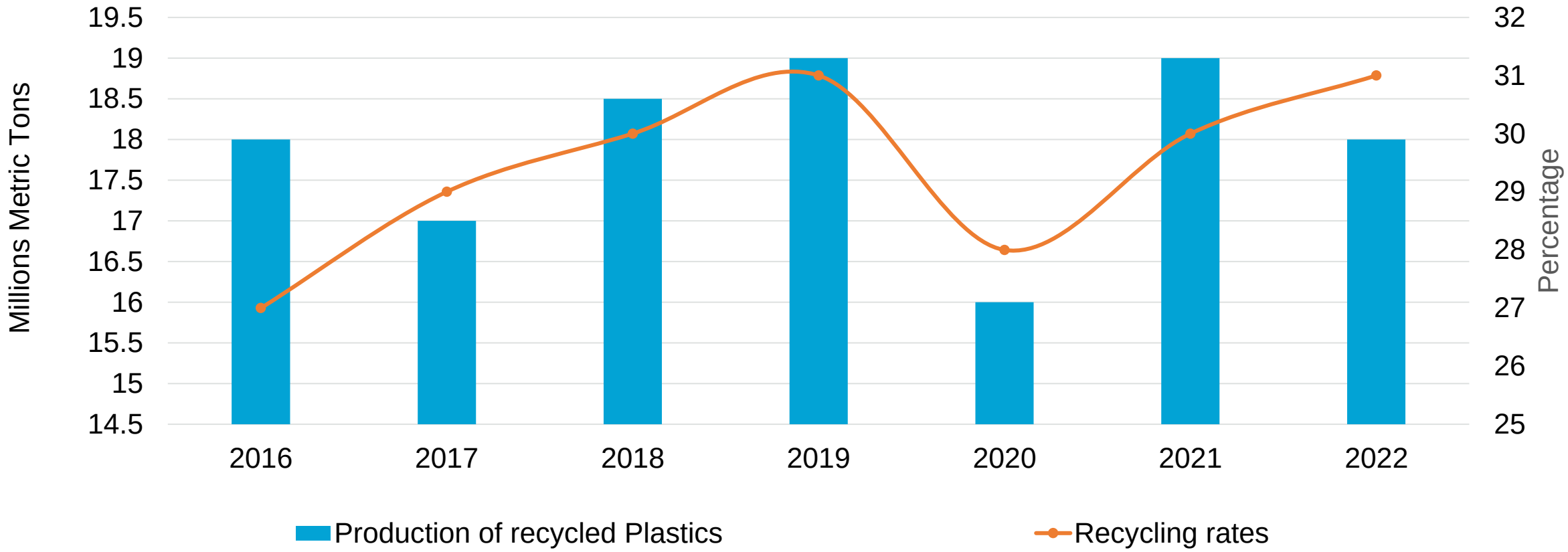
China Mechanical Recycling Market



Source: Ministry of Commerce of PRC, Chemical Market Analytics by OPIS

rPET, rPP and rPE dominated the output of recycled plastics

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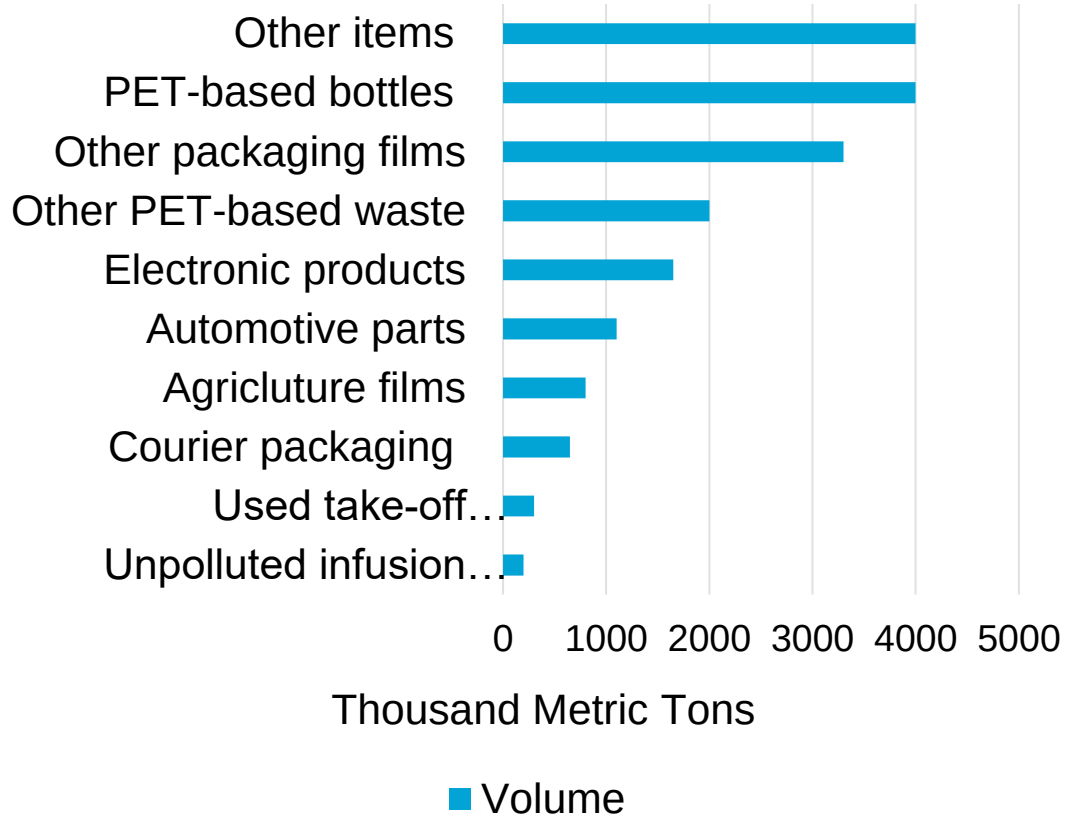
Source of Waste Plastics in 2022



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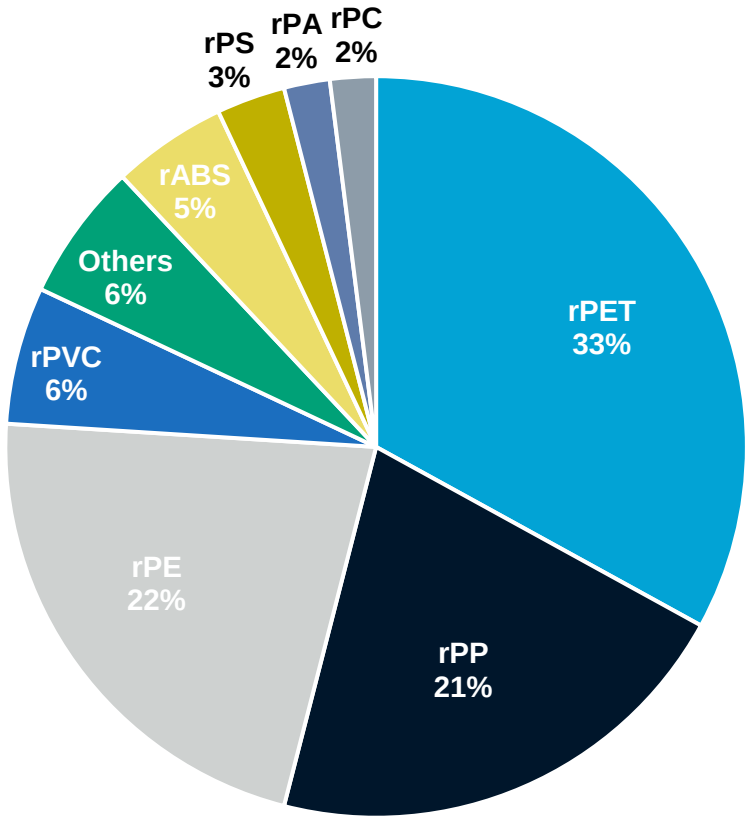
Recycled Plastics by category in 2022



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Key issues facing waste plastics recycling in China

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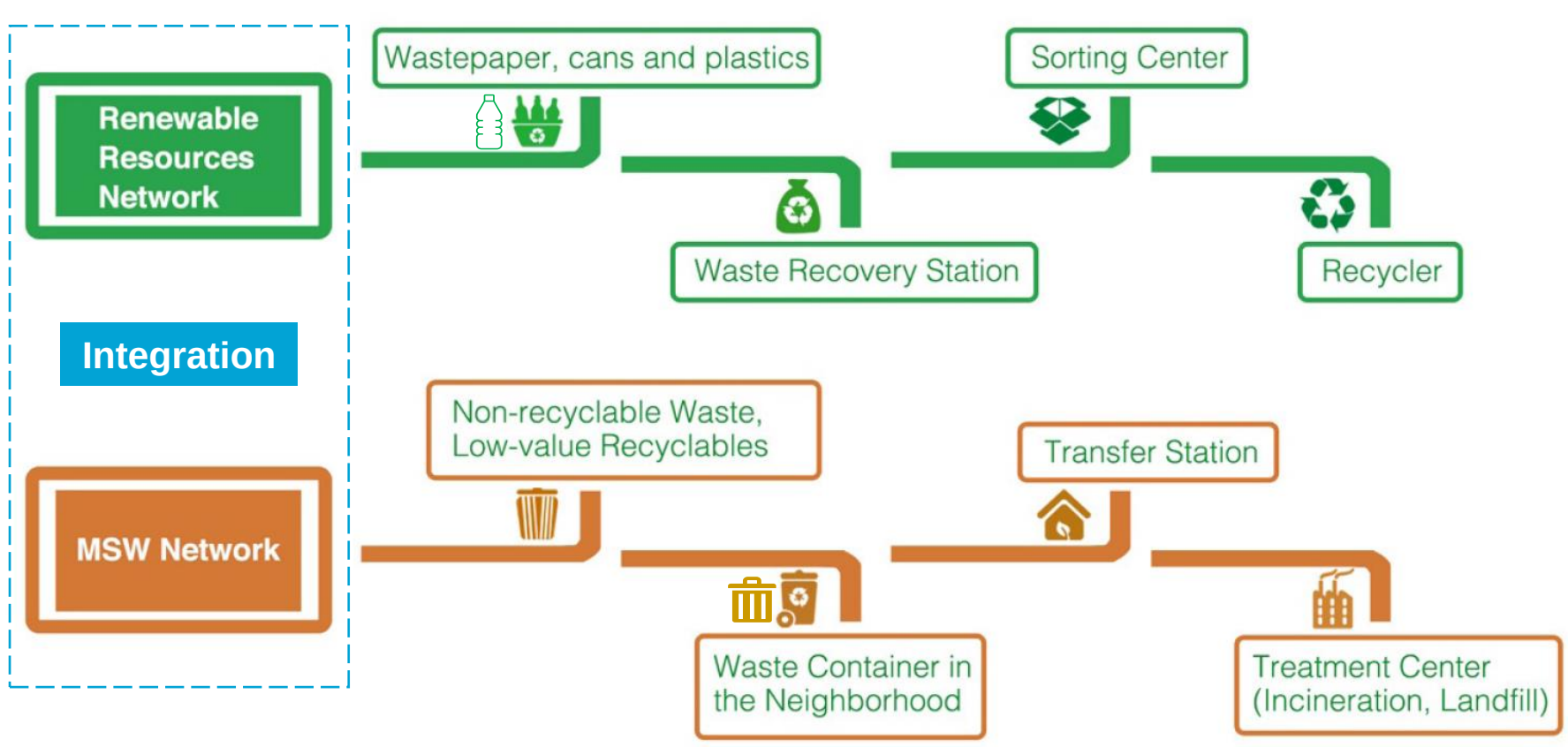
- Plastic waste is short
- Weak collection and sorting capability are challenges to reprove recycling rates.
- More favorable tax incentives are highly expected
- Chinese regulations now do not allow recycled materials to be used in food packaging
- High labor cost required
- Chemical recycling technology is immature
- Value chain members mainly are small-scale
- Low recycling rates for low valued waste plastics

Two Networks Integration



Government is exploring the integration of two systems, with an aim to remove the burden of MSW treatment and grow the utilization of low-valued waste plastics.

Overview of mechanical recycling market in China

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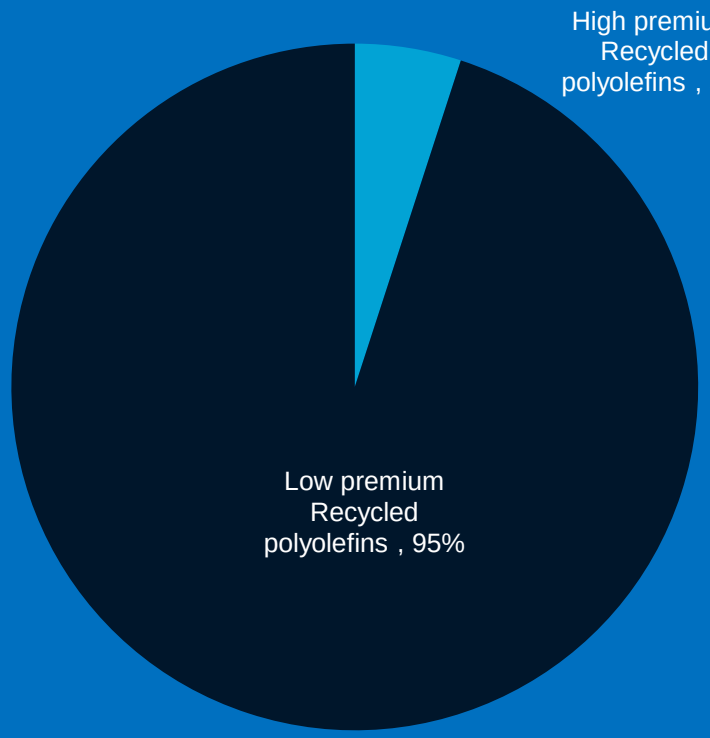
Composition of Recycled polyolefins in China



Source: Chemical Market Analytics by OPIS

- Recycled polyolefins are categorized into two ingredients
- Low-premium recycled Polyolefins is defined as downgraded recycled polyolefins
- Recycled polyolefins are mainly produced by Mechanical recycling technology in China
- Demand of high-premium recycled polyolefins is expected to double by 2030
- Demand growth is driven by brandowner pull, competitive cost, Law and regulations, and economics
- Output variation is highly affected by price gap between virgin and recycled resins
- Some polyolefins suppliers proactively invested in the production to achieve a ‘close-loop’ system

A disruptive journey ahead

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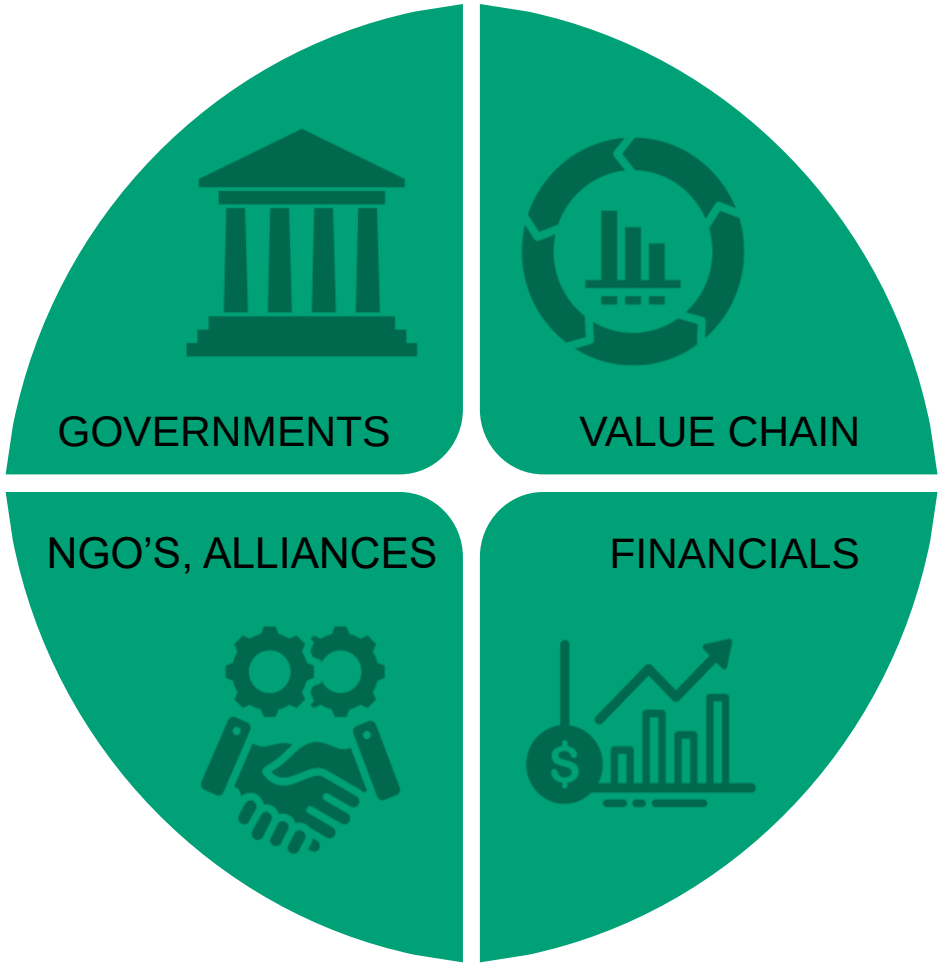

- **Annual generation of plastic waste will increase**
- **Current pace inadequate**
- **Waste generation & "build to export" disconnected**
- **Critical bottleneck is supply, not demand**
- **Reverse supply chain increasingly bypass MSW**
- **Fixing the plastics waste problem does not equate to elimination of fossil fuels**
- **Risk assessment takes on new meanings**

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