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What's Py Oil Got to Do With It?

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About us

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OPIS began as a PRA & commodity markets news service in the late 1970s. It has many benchmarks in fuels, LP, feedstocks and now also renewable fuels & carbon. It has also grown by acquiring assets such as:

PetroChem Wire

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Price Reporting Agency (PRA)
- Spot Prices
- Calculate/Implied Prices
- News
- Market-wide/Multi-client

Chemical Market Analytics

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Consultancy Practice
- Analysis
  - Supply/Demand
  - Cost
  - Fundamentals
- Forecasts
- Single-client
- Multi-client

Getting to Green

Most “green” talk in the past 10+ has centered on plastics and recycling needs.

- Soft mandates from retailers
- Sword Law / China
- Legislative Mandates
- Media Focus on Trash Problem
- Shareholder Attention

Plastics are unique in the petrochemical supply chain because they are solids. What about the thousands of other downstream chems, the liquids & gases? How do they get to green?

Commoditization / Watershed Moments

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2015-2016: “Soft” Mandates

- Retailers began demanding recycled content in packaging, goods
- Sustainability was beginning to become a demand from shareholders

2017: Sword Law

- China’s ban of scrap plastic from the US caused massive pile-ups in US at first
- Other locations gained export popularity (Vietnam, Malaysia) but investment locally to expand US processing infrastructure began increasing

Commoditization / Watershed Moments

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2018-2020: Legislative Mandates

- States issuing minimum requirements for PCR content in beverage & food packaging; plastic bag bans enacted
- Chemical Market Analytics launches Circular Plastics Service

2020 Pandemic Trends

- More trash produced than ever, infrastructure could not keep up

2021 - Present

- Demand for post-consumer recycled plastic continues rising; shoreholder begin pressing for more aggressive ESG commitments from manufacturers

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Recycling has become a popular investment -- and there is no shortage of science to show the many ways to get plastics and packaging into a circular economy.

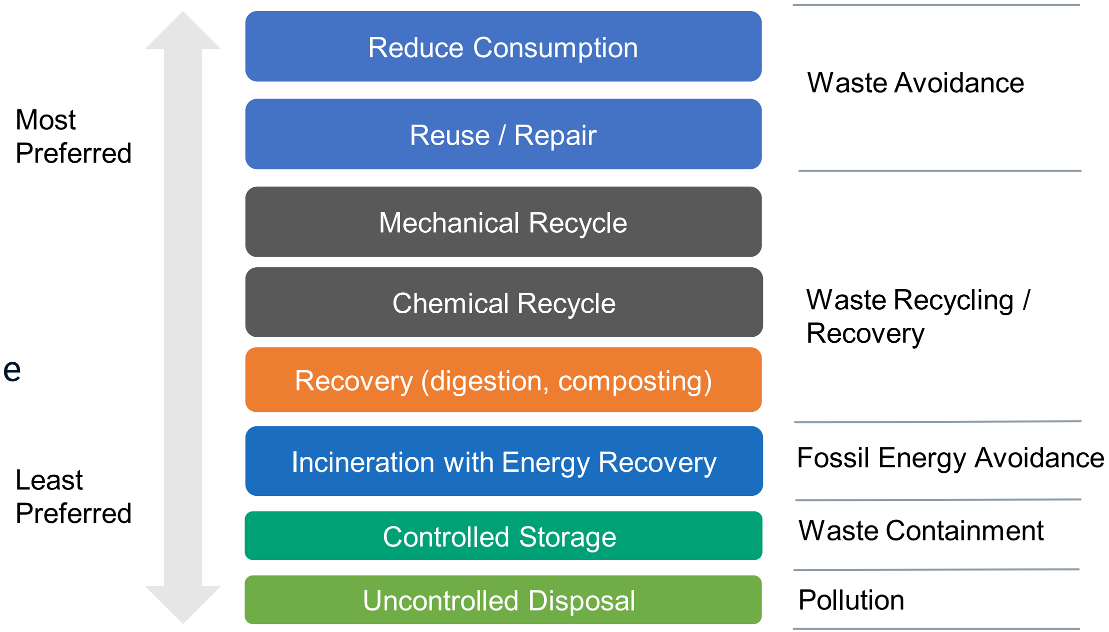
Definition of Circular Plastics

<u>"CIRCULAR PLASTICS"</u>

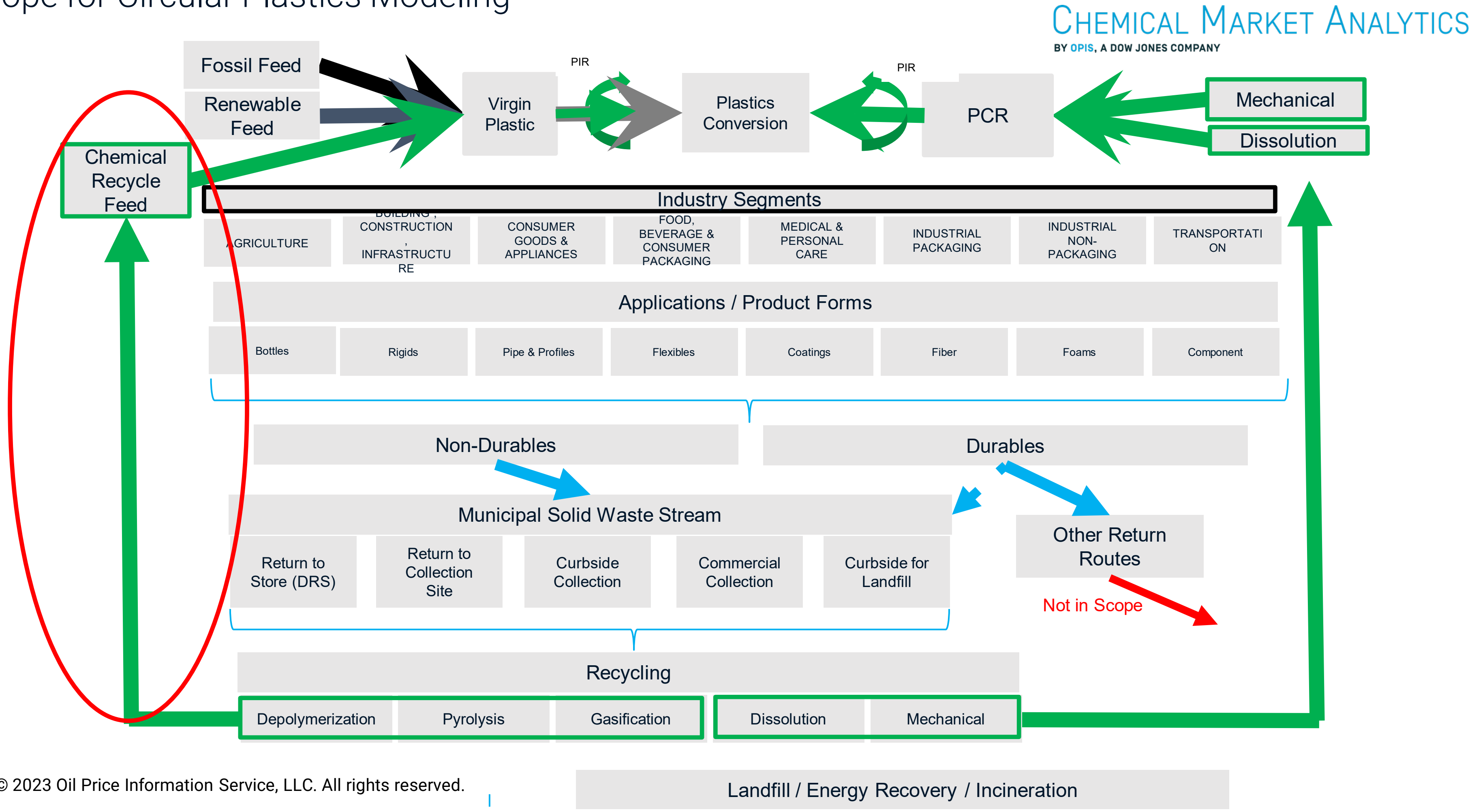
Alternative to traditional linear "make, use, dispose" model.

<u>Ecosystem in which we:</u>

- 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

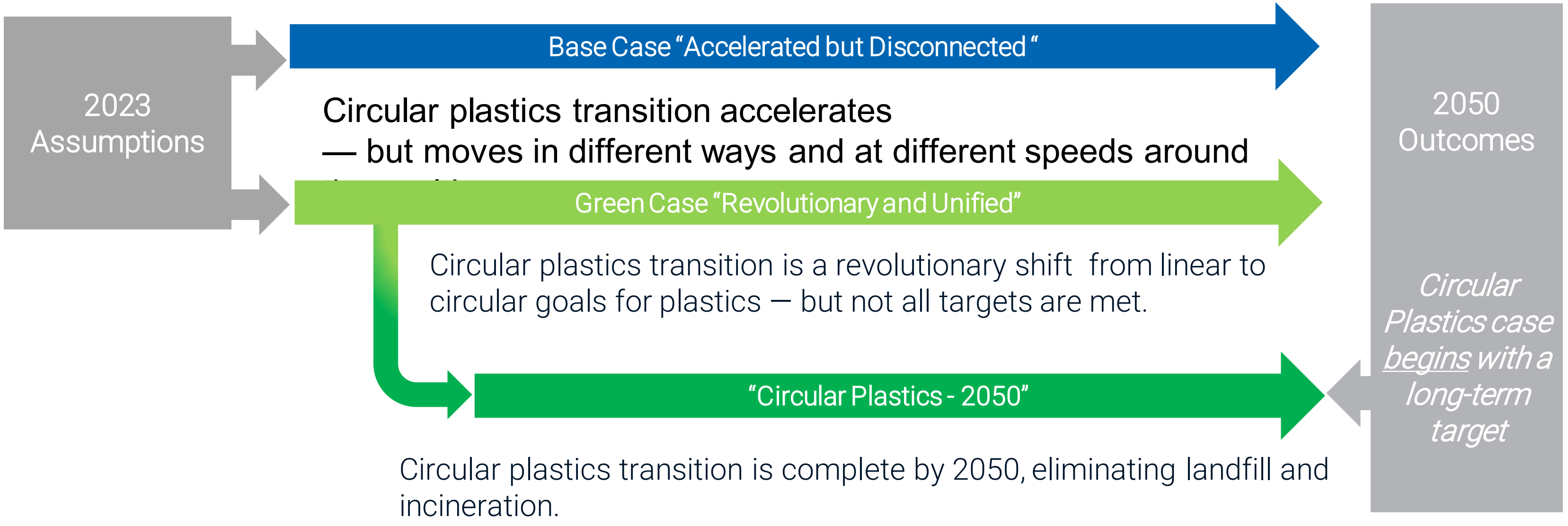


Scope for Circular Plastics Modeling



Circular Plastics Service: Two forward looking scenarios and a backcast case

IHS Markit integrated scenarios and circular plastics case for plastics



Source: Chemical Market Analytics

CHEMICAL MARKET ANALYTICS
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Race to developing commercially-viable chemical recycling technologies

Several chemicals and plastics producers are forming partnerships to pursue projects with technology developers - yet current commitments fall short in making significant impact in current decade

GASIFICATION

DEPOLYMERIZATION

- Hydrolysis
- Methanolysis
- Glycolysis
- Enzymatic reaction
- Mild pyrolysis

CRACKING

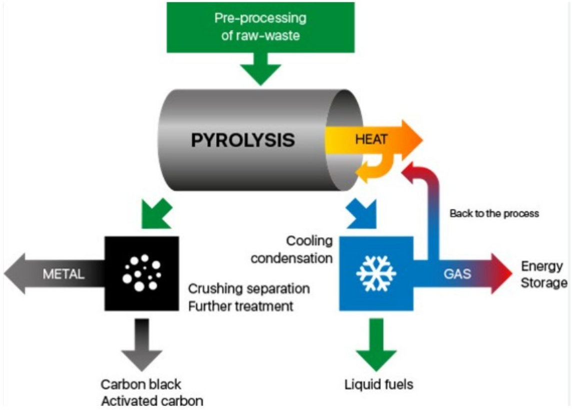
- Pyrolysis
- Catalytic
- Hydrocracking / hydrogenation
- Microwave pyrolysis

OTHERS

- Photo degradation
- Ultrasonic degradation
- Catalytic oxidation

Pyrolysis – a brief history

Pyrolysis is a chemical process that involves the decomposition of organic materials through heating in the absence of oxygen.



- Recognized as dry distillation
- Typical raw feedstocks - wood, coal, peat, etc
- Typical product – crude oil

- Pyrolysis of wood – 12th century
- Widely used in Russia to produce pine resin - tar-distillation.
- 16th century - The Swedes used the technology of impregnating shipboard wood with tanning pine resin from a simple pyrolysis process.
- In the 1930s, industrialization in the USSR was very rapid. Petrol & Diesel from Pyrolysis.
- The industrial application of pyrolysis technology was greatly boosted by the First World War.
- In the 20th century, a significant contribution to the development of new areas of wood pyrolysis was made

Pyrolysis – applications and step by step development

- **Coal Gas production through pyrolysis (19th – 20th Century):**
    - to produce a combustible gas for lighting and heating in cities.
- **Biomass Pyrolysis (20th Century):**
    - to convert biomass (such as wood and agricultural residues) into biochar, bio-oil, and syngas.
    - These products could be utilized for energy production and various industrial applications.
- **Plastic and Rubber Recycling (Late 20th Century - Present):**
    - as a solution to address plastic pollution and waste management challenges.
    - valuable products like fuel oil, gas, and carbon black.
- **Tire Recycling (Late 20th Century - Present):**
    - convert used tires into useful products like oil, carbon black, and steel.
- **Waste-to-Energy and Circular Economy Applications (21st Century):**
    - initiatives aim to convert various types of waste materials, including plastics, into valuable products like fuels, chemicals, and carbonaceous materials, contributing to both waste reduction and resource recovery.

The Game Changer

The option of creating a chemical feedstock from plastic waste or even biomass moves the conversation to beyond creating fossil-free plastics. Known now as “chemical recycling” or “advanced recycling”, pyrolysis enabled the possibility of creating ethylene and propylene (light olefins) from plastic waste.

Scrap plastic → Py oil → Chemical feedstock (e.g. naphtha) → Ethylene/Propylene

Ethylene and propylene are the feedstocks for many chemicals – solvents, additives, intermediate chems…

…the fossil-free label could be applied to anything produced from fossil-free olefins through

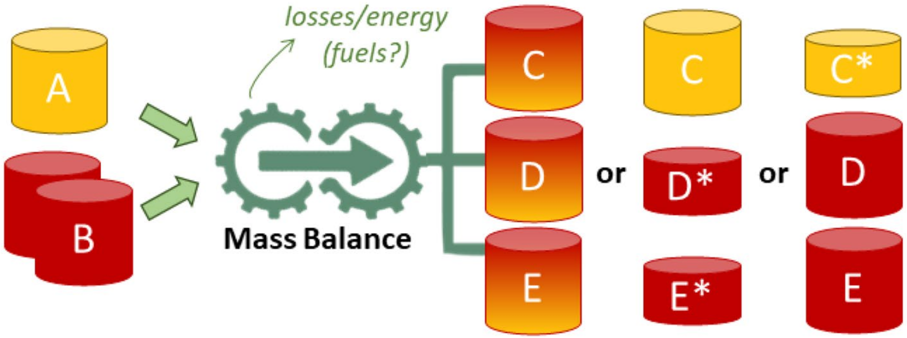
MASS BALANCING.

Mass Balance Approach

- The Mass Balance Approach allows for the integration of feedstocks from recycled plastic sources, along with conventional fossil feedstocks.
- To account for recycling, credits are produced when recycled raw materials are consumed, based on the mass entering the system.
- Credits are then decoupled during the production process (e.g., undergoing steam cracking), reassigned to physical materials, and applied to outgoing products.
- The Mass Balance Approach has long been applied to commodities:
  - Sustainable Timber using MB since 1993
  - Better Cotton Initiative since 2005
  - Sustainable Palm Oil since 2004
  - Biofuels since 2007
  - Tea, Cocoa, and Sugar since 1997

Source: NIST Special Publication 1500-206

Mass Balance Allocation refers to the proportion of inputs assigned to specific output products.



- ***Proportional***: This method is based on the assumption that recycled units flow the same way as non-recycled units and therefore have the same distribution among outputs.

- ***Non-Proportional (Free Allocation):*** Many chemical processes produce multiple outputs, many of which may not have a market for recycled content. Non-proportional allocation allows for credits to be freely assigned to any product.

- ***Non-Proportional – Fuel-exempt***: Some chemical recycling processes generate fuels as a product or by-product, a commodity that certain standards do not recognize as a recycled material (i.e., not part of the circular economy)

- ***Non-Proportional - Polymers only***: Under this allocation method, only outputs directly linked to the production of polymers can be freely allocated. Any non-polymer product outputs are lost and cannot be applied to other products.

Source: NIST Special Publication 1500-206

Not All Py Oil is Created Equal … and It's Not Py Gas

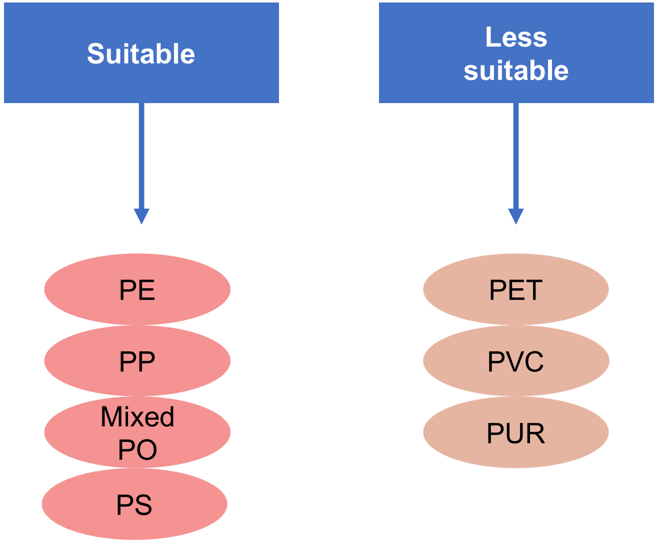
Py oil has grades itself which affect the yields: heavy py oil and light py oil.

Light grade py oil is the focus for many in the chemical markets as it yields the most chem feedstocks and blendstocks that can help companies achieve their ESG goals.

The label of "py" does not assign it as a fossil-free product. Py gas (pyrolysis gasoline) is produced during the heat-based (pyro = heat) cracking process of fossil-based naphtha. Py gas is an octane-rich liquid that can be further processed to make aromatics/BTX (benzene, toluene, xylenes). Many naphtha-focused steam cracker (olefins production units) have a benzene extraction unit on site for this reason.

The type of plastic waste is also a factor in producing py oil – some plastics are better suited to yielding a more desirable grade of py oil, as we'll see.

Most suitable plastic types for pyrolysis



- Polyolefin rich mixed waste plastic is the best feed
  - High oil yields
  - Aliphatic (paraffins + olefins) oil from PE+PP
  - Aromatics from PS
- Polyurethane (PUR), Polyesters, PVC, PET results in low oil yield and poor oil quality.
- PVC releases large amount of HCl
- Oil properties are determined by the waste feedstock composition

Pyrolysis of plastics

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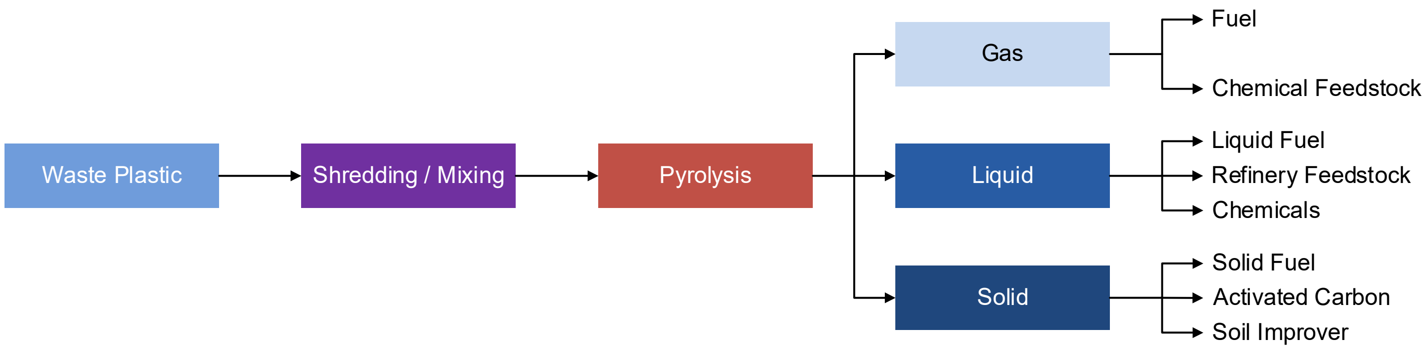

Product Yield (% wt.)		Thermal Pyrolysis	Catalytic Pyrolysis
Gas Fraction		13.0	63.5
Liquid Fraction	Total	84.0	35.0
	C6-C12	56.55	99.92
	C13-C23	37.79	0.08
	>C23	5.66	0.0
Solid Fraction		3.0	1.5

- *Py oil has grades itself which affect its yields - heavy py oil and light py oil.*
- *Light grade is the focus for chems as it yields the most chem feedstocks and blendstocks that can help companies achieve their ESG goals.*

Challenges

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Scale
There are currently ~8 plants producing py oil from scrap plastic. They vary in size from pilot plants to sites that are expanding to be world-scale. More than 10 new plants/sites are in development or under construction, but that volume isn't hitting the market soon.

Transport
Py oil itself is not universally usable as a chemical feedstock – but it can be processed into renewable naphtha and renewable LPG, depending on the technology used. No production site (so far) is connected to the Gulf Coast pipeline infrastructure. Transport is typically (so far) by truck.

Illiquid
With so little volume available, even the few transactions we've seen are priced in different ways. There is not yet a standard price and there are not regular bids, offers and trades. So far in the US, pricing has usually been set as a differential to a fossil-based product such as naphtha or even diesel. Almost no exports from the US have been seen.

Most chemical sites (steam crackers, PDH units, propylene splitters) have tested it in some form (raw if possible but usually as r-naphtha). But the lack of volume available is what's keeping this from commoditizing at this juncture.

Py-oil quality issues

- Contamination and impurities
- High viscosity
- Instability and aging
- Odor and volatile compounds
- Acidic compounds
- Solid particulates and sediments
- Heterogeneous composition

Pyrolysis technology scale – vs. Py-oil upgrading options

- 250 tpd of mixed plastic waste pyrolysis plant yield around 1700-2000 BPD of liquid fuels

- But such small volume may not make sense to put up a hydrotreater inside a pyrolysis plant considering the hydrotreater units turn down of 50%. So different options can be analyzed. Independent vs. integrated

- For little low-capacity plants, where net product liquid fuel generation is low; there is lack of commercial viability of implementing hydrotreating within the plant. In this case, following options are recommended to improve the economic viability of the plant:
  - Option-1: - Complete pyrolysis oil manufactured from waste plastic is handed over to the existing refinery for fractional distillation and hydrotreating
  - Option-2: - Petrol, Diesel, Kerosene & Base oil manufactured from plastic waste should be sold to refinery. Once the Sulphur content is reduced to less than 10 ppm, Petrol, Diesel, Kerosene & Base oil manufactured from plastic waste shall comply with Euro 5 or Euro 6 standards.
  - Option-3: - Distill pyrolysis oil to manufacture Heavy Fuel Oil, Gas Oil, and Marine Fuels. As per **Regulations S.I. No. 119/2008** - Sulfur Content of Heavy Fuel Oil, Gas Oil, and Marine Fuels should not exceed 0.1% or 1000 ppm. This can be achieved without hydrotreating.
  - Option-4: - Convert the pyrolysis oil into electricity by use of slow speed combustion engine.

Challenges with Py-oil hydroprocessing

- **Phosphorus** – Formation of deposit around catalyst pellets – Deactivation and pressure drops
- **Silicon** – Adsorption on metal sites of catalysts – Catalyst
- **Chlorine** – Formation of HCl and/ or NH4Cl – Corrosion and plugging issues
- **Variable feedstock** – Average vs. peak feedstock properties – Right balance between cost and flexibility

Chemical Recycling capacity expected to more than double in the near term globally

We will see language evolve around it as well, as we already have this year with the use of “Circular” versus “Renewable”

Global Waste Generation with Disposition

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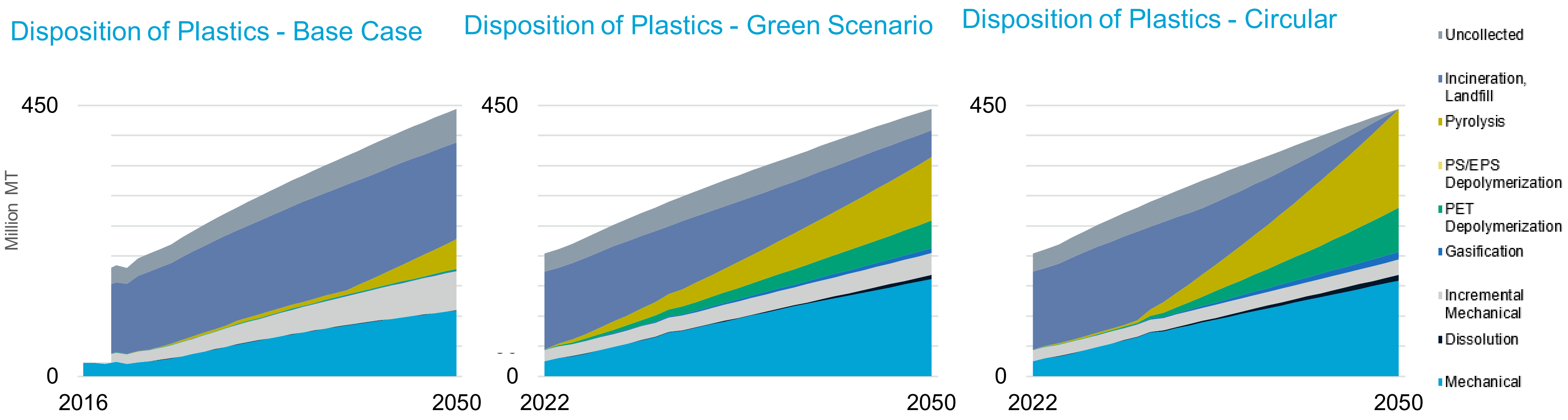
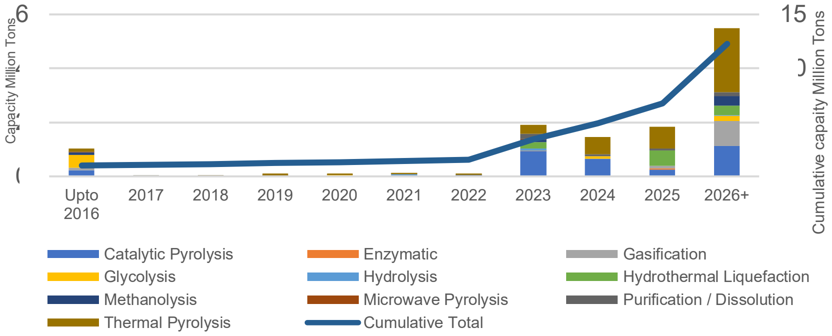


Capacity as MMTPA for plants currently in operation, under construction and feasibility for the near future

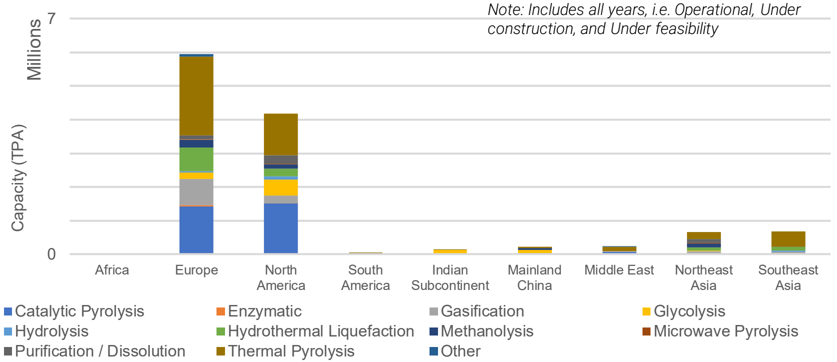
- With the latest update, we have 145+ technology companies in the chemical recyclers database, and **total operational capacity of 1.5 MMTPA** globally documented.
- Further we have recognized **2.4 MMTPA under construction** over the coming years, and over **8.3 MMTPA under some form of planning**.
- 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

Capacity by Region and Technology (MMTPA)



Note: Includes Current (operational) + Announced (under construction and under feasibility)

Count of Chemical Recycling Facilities by Technology and Plant Status

Technology	Operational	Under Construction	Under Feasibility
Pyrolysis	58	27	75
Enzymatic	6	1	3
Gasification	16	13	15
Glycolysis	16	5	4
Hydrolysis	11	3	4
Hydrothermal Liquefaction	3	6	15
Methanolysis	3	2	5
Purification / Dissolution	16	7	7
Total	**169**	**64**	**113**

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Q & A

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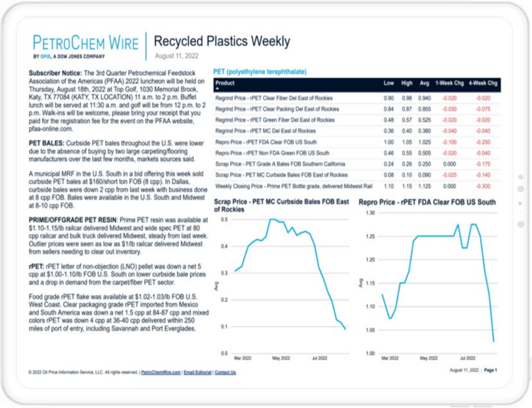
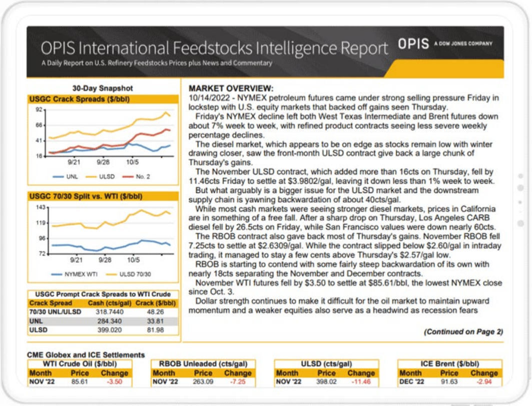
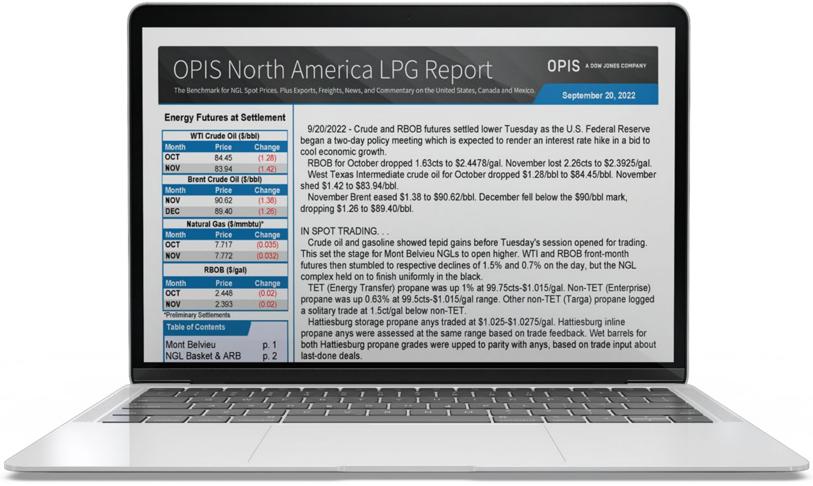
PetroChem Wire Recycled Plastics Weekly



OPIS International Feedstocks Intelligence Report





OPIS North America LPG Report

Circular Plastics Service

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A comprehensive, scenario-based evaluation of how the plastics value chain is expected to transition from a linear to a circular economy. It considers implications of carbon intensity and the magnitude of future capital investments within the context of energy transition, carbon valuation, changing policy and regulations. The Service Categories below are updated on a frequency basis relevant to each, and ranging from weekly, monthly, quarterly, to semi-annually.

Service Categories

Regulations, Policy & ESG

Global regulations, mandates & policies including extended producer responsibility, deposit return schemes, application & product use restrictions, recycle content & rate requirements

Demand Assessments

Scenario based demand databases, visualization & insight for virgin- and mechanically recycled plastics with regional and end use segmentation & feedstock implications.

Recycling Projects Database

Tracking over 4000 recyclers globally by project

- Mechanical – 3900+
- Chemical – 135+

Technologies & LIcensors

Chemical recycling – pyrolysis, gasification, depolymerization, dissolution

- 35 technology providers mapped and profiled
- Technology scans & holistic comparison of processes and licensors.

Plastic Waste Generation

Scenario modeling and insight for regional and global Generation, collection and preparation of plastics waste

Plastic Waste Deposition

Scenario modeling, material balance & insight for characterization of plastics waste recyclates and disposition via mechanical recycling, chemical recycling, landfill and incineration.

Techno-Economic Models

Virgin production, mechanical and chemical recycling, and selective solvent dissolution.

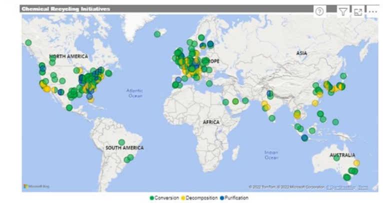
- CAPEX and OPEX evaluation
- Capital spending and cost curves
- Material balance

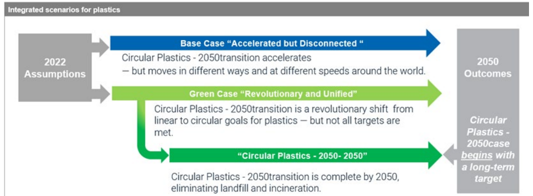
Carbon Emissions

Database and models for simulating CO2 volumes, using scope 2 & 1 emission for virgin resins production, mechanical & chemical recycling, as well as selective solvent dissolution

Delivery Platform

Circular Plastics Tool

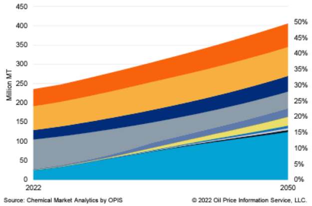




Plastic Recycling Technology Evaluation

Chemical recycling can further improve on economics and carbon emissions

Waste Generation & Disposition- Global – Base Case



Useful Links

[Information]

[Video]

[Webinar]

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Chemicals Sustainability Session, Tuesday, September 12

- **Circular Plastics:** structural evolution, alliances, forward integration and governing relationships from varied perspectives as innovation transforms the conventional plastics world into a more sustainable industry
- **CO2 & Greenhouse Gases:** the cost of carbon, including mechanisms to capture and store CO2, carbon offsets and other trading mechanisms, and how relative solutions will influence the strategic paths petrochemical producers choose.
- **Energy Transition:** perspectives and initiatives expected to influence the direction and pace of transition.
- **Financial Considerations:** insights from the financial market and related community regarding the evaluation of sustainability opportunities, risks and pathways.

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