



The Future of Petrochemicals

Emerging Feedstock Analysis & the Path to Plastic Circularity for Profitability

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Profitability vs. Sustainability



Trends, market forces & regulations in chemical industry

Emerging new feedstocks

Closer look at plastic circularity

Challenges with waste plastic pyrolysis oil (WPPO)

Micro-Distillation by 10mL sample under 10 min vs D86

Group-Type analysis above C11 by GCxGC

Ppb level combined S&N analysis by process analyzers

Total S&N analysis by chemiluminescence

What You Will Learn Today



Moving the World Forward, Safely and Sustainably

Global Coverage

We are committed to delivering superior service with:

- 15 sales and support offices worldwide
- Global network of over 140 distributors



PAC Offices



Channel Partner Offices

Moving the World Forward, Safely and Sustainably

PAC Brands



PAC Technologies

- Flow Behavior
- Spectroscopy
- Leak Testing
- Microscopy
- Distillation
- Viscosity
- Thermal Stability
- Combustion
- UVF
- GC, GC-MS, CL
- Flash Points

Industries

Laboratory and process applications based on strong analytical expertise that ensures optimal performance.



Refinery & Petrochemical



Pipelines & Terminals



Upstream Oil & Gas



Automotive



Aviation



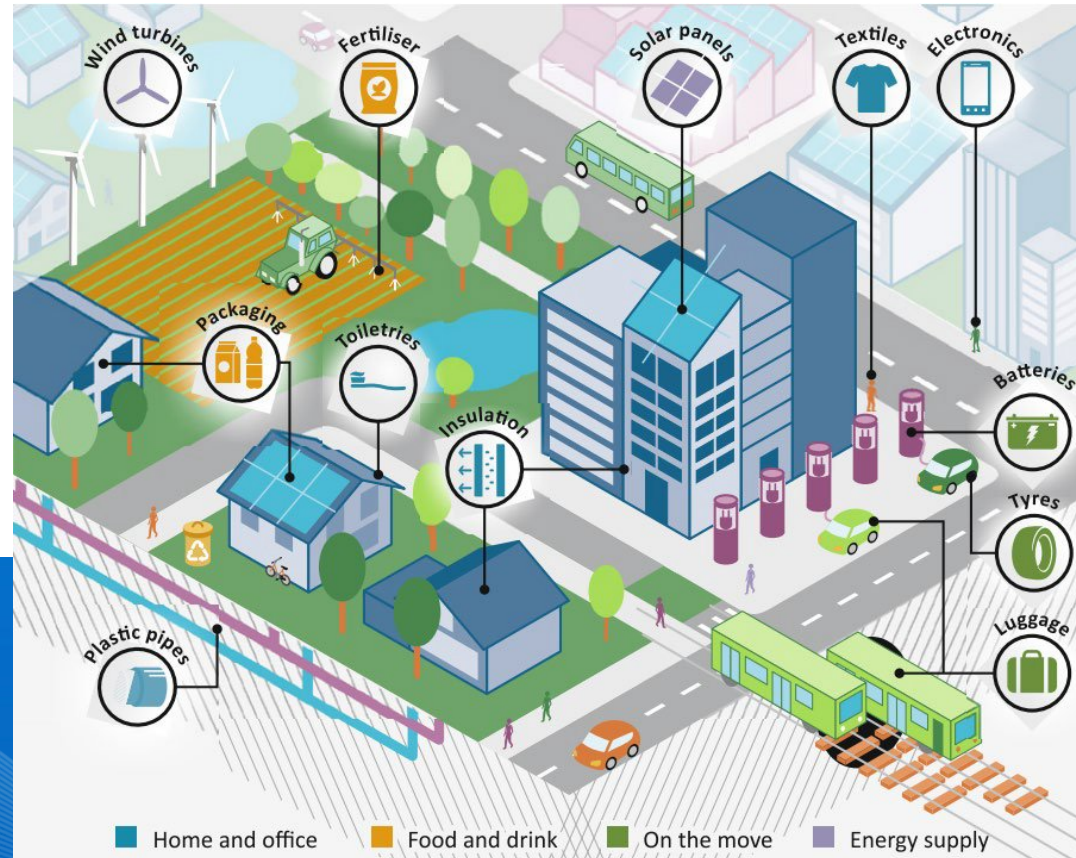
Biofuels



Lubricants

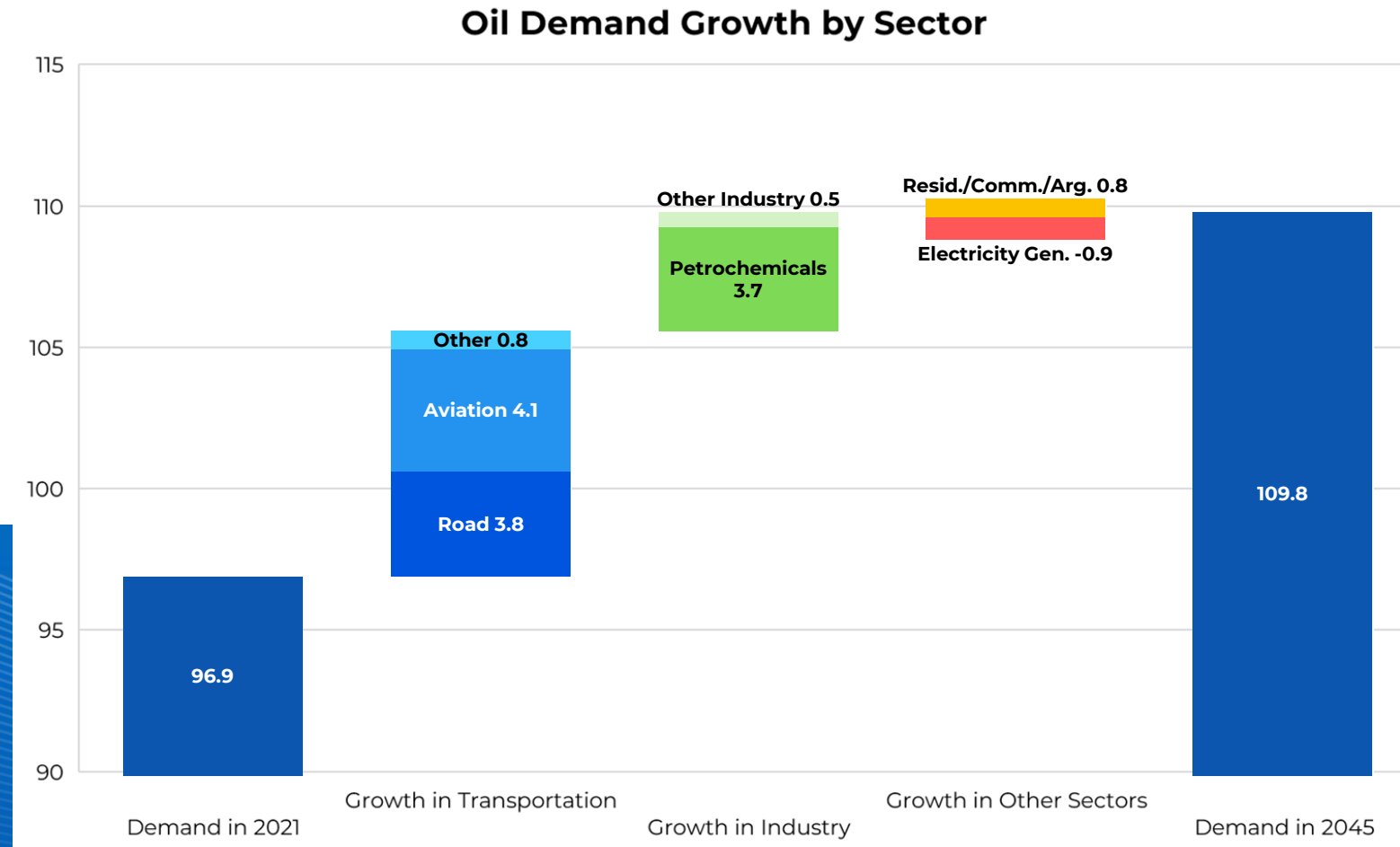
Petrochemical Market Insights

Petrochemicals are everywhere with increasing consumption.



Source: 'Future of Petrochemicals' by IEA, 2022.

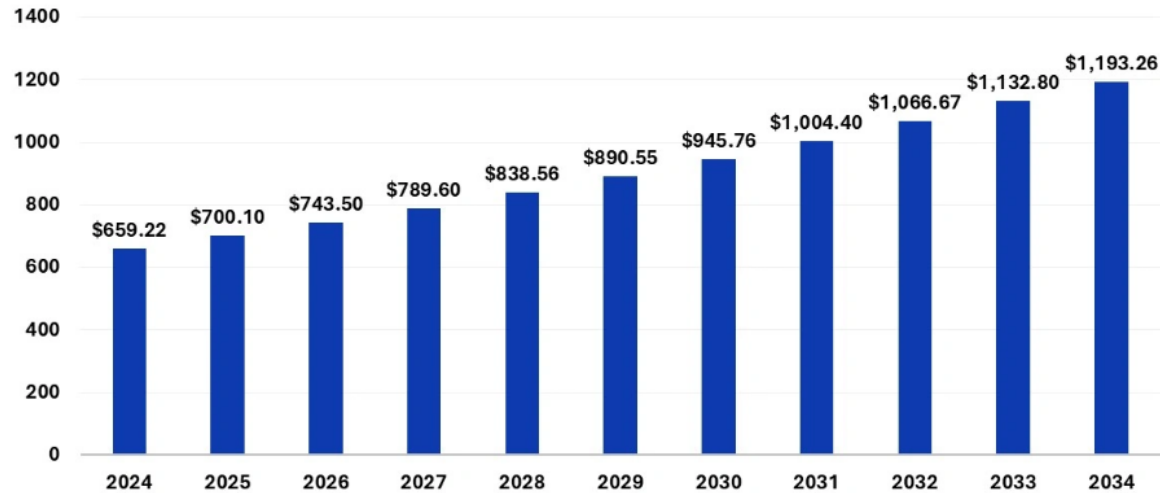
Petrochemicals are becoming a major oil demand driver.



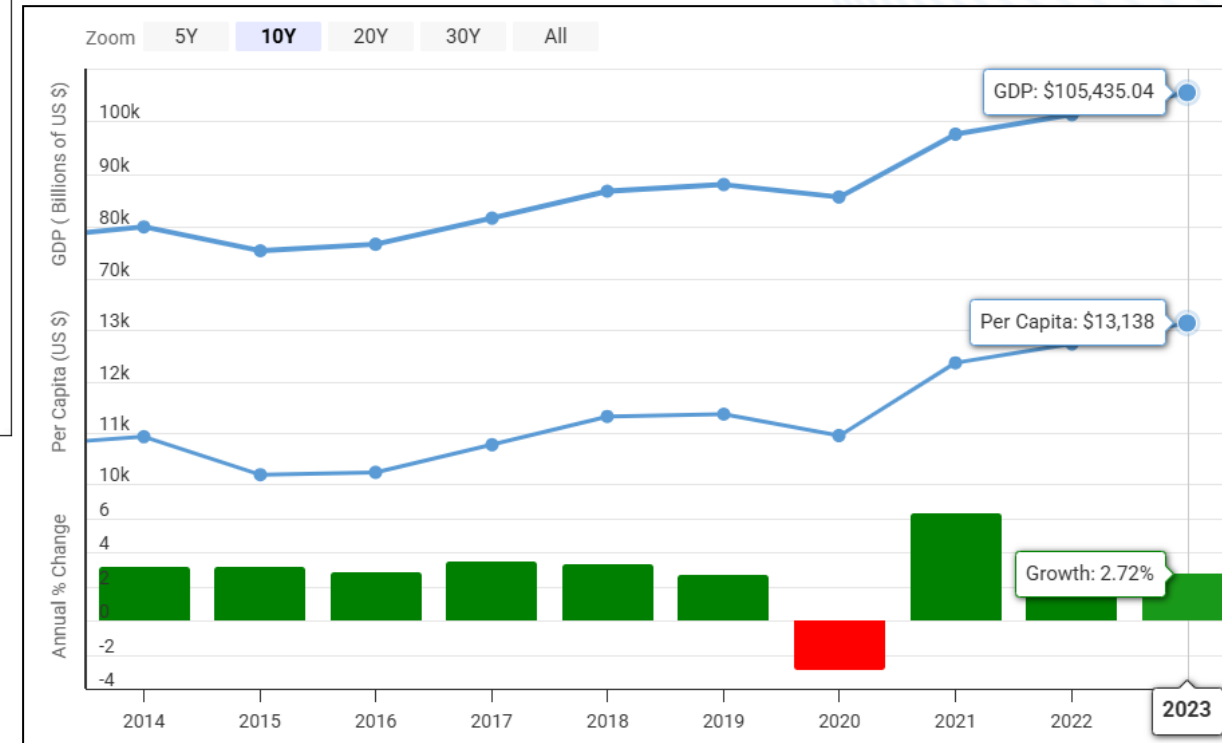
Source: 'World Oil Outlook to 2045' by OPEC, at 2022.

~\$1000 Billion market size by 2031 with ~6%CAGR which is x2 of World GDP for last 10 years

Petrochemical Market Size 2024 to 2034 (USD Billion)



Source: <https://www.precedenceresearch.com/petrochemical-market>



Source: www.macrotrends.net

Recent Trends & Market Forces



Profitability & Demand

Europe's refining sector braces for major downsizing as margins stall

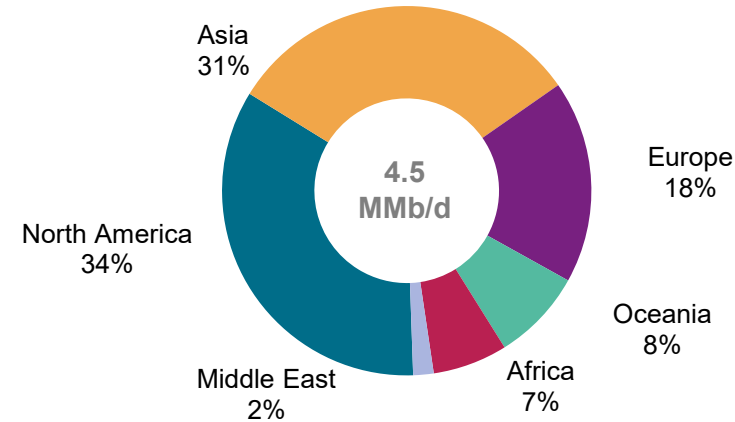
S&P Global Global refinery rationalization since January 2020

HIGHLIGHTS

European refining capacity closures back in focus as margins cool

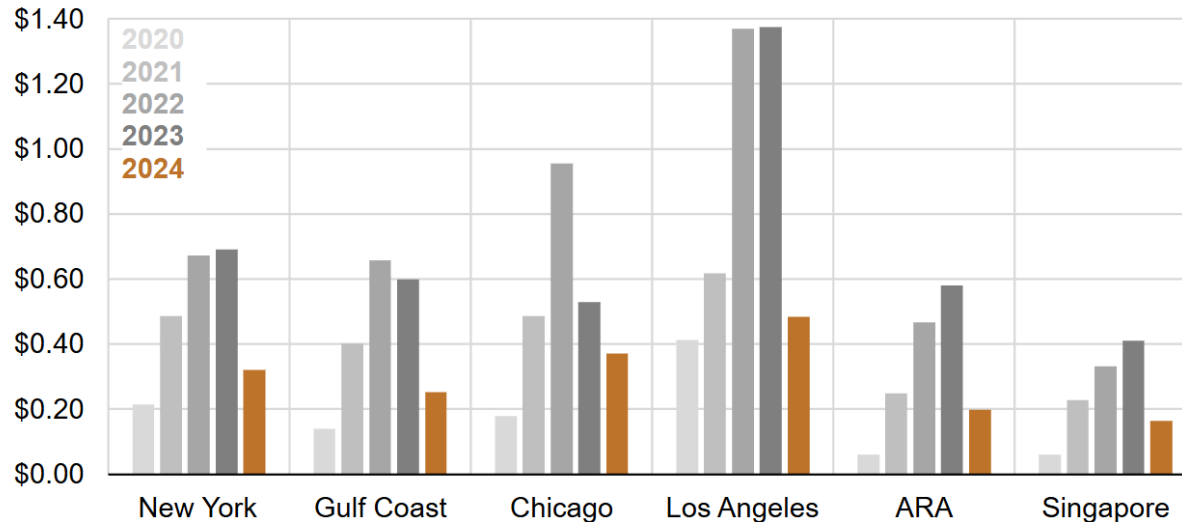
Energy transition to erode demand from 2025, global competitors loom

IEA forecasts 1-1.5 million b/d at risk of closure in Europe by 2030



Source: S&P Global Commodity Insights, May 2023

Regional September refining margins (2020–2024)
dollars per gallon



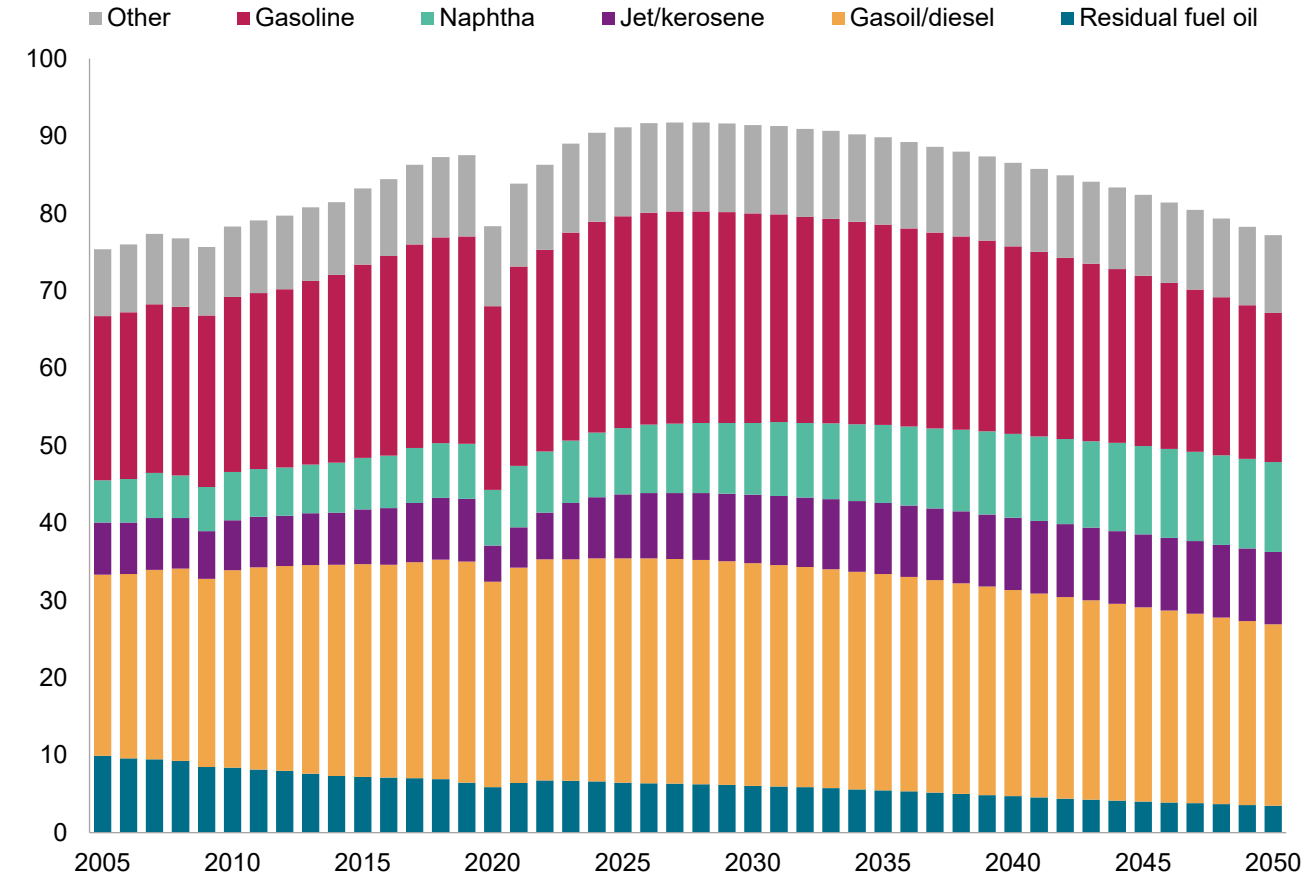
Data source: Bloomberg L.P.

**Shrinking Refining
Margins**

Profitability & Demand



World refined product demand (Million barrels per day)



Decreasing Fuel Demand

Profitability & Demand



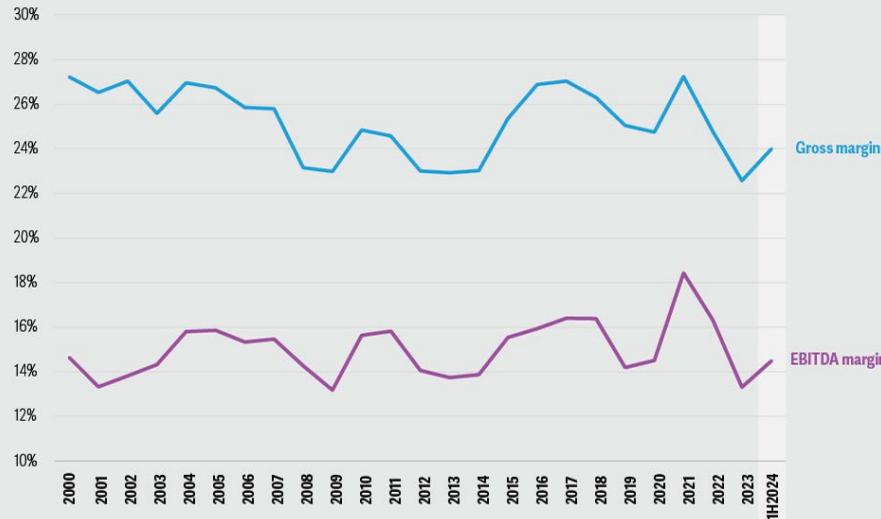
Increased Fuel Efficiency
E-mobility
Home Office Trends

Profitability & Demand



Figure 1

Chemical industry margin decomposition



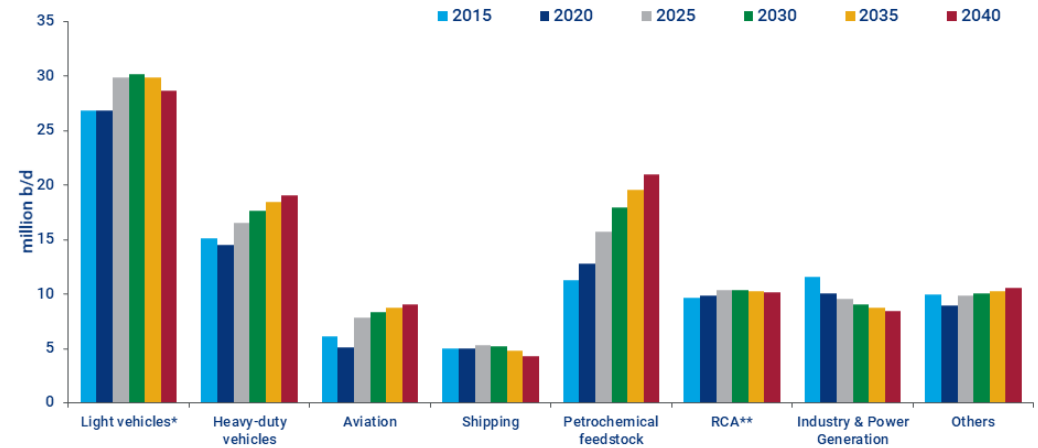
Note: EBITDA stands for earnings before interest, taxes, depreciation, and amortization.

Source: Deloitte analysis of Capital IQ data.

Deloitte | deloitte.com/us/en/insights/research-centers/center-energy-industrials.html

Petrochemicals feedstock leads demand growth in the long run – while fuel demand from light vehicles will start to fall

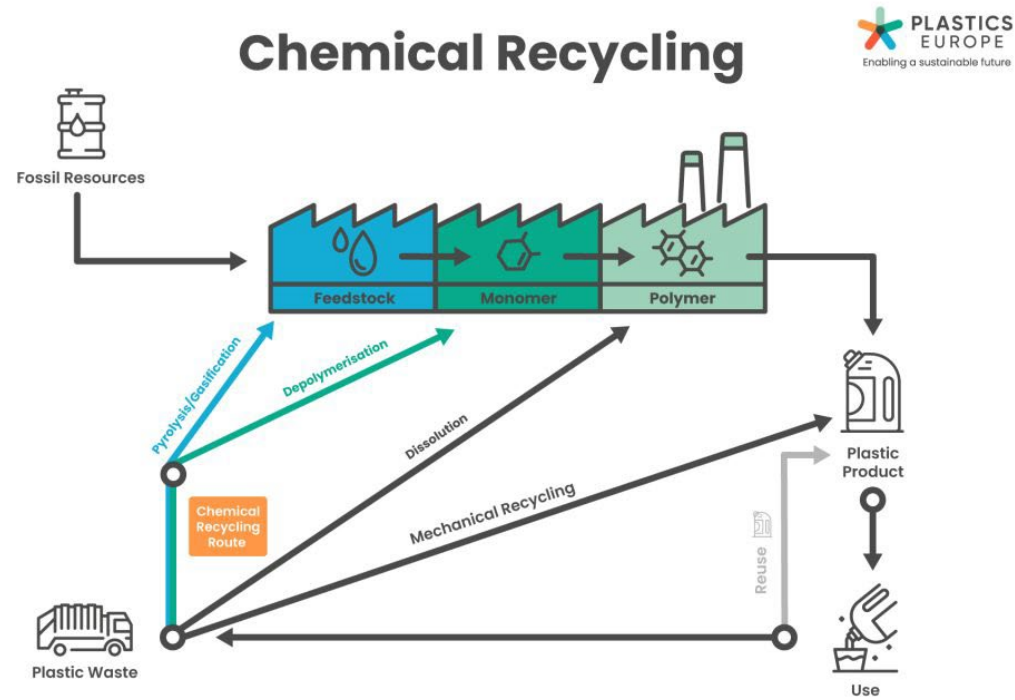
Global liquids demand by sector



Source: Wood Mackenzie Macro Oils Long Term Outlook H1 2020 * includes two-wheelers ** Residential, Commercial and Agriculture *** includes non-energy use (other than petrochemical feedstock) and refinery fuel, etc.

High margins of chemicals
Increasing Demand

Sustainability Targets



**10 billions tons of waste
with 9% recycling rate
and 500 m t/y generation**

ROTTERDAM, The Netherlands – March 10, 2025 .

**Dow boosts access to circular feedstocks
with strategic investment in Rotterdam-
based advanced recycler Xyle**

Rising interest on WPPO

Sustainability Targets

Neste introduces co-processed renewable Neste RE feedstock for the polymers and chemicals industry

Neste RE co-processed renewable feedstock

Neste Corporation, Press Release, 17 December 2024 at 9 a.m. (EET)

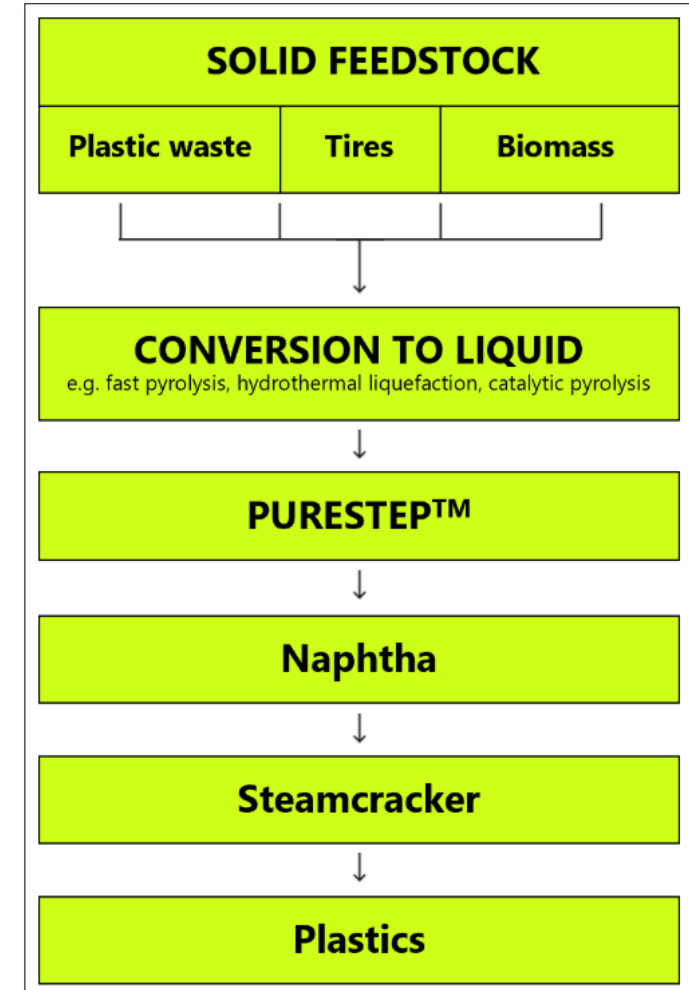
BASF's biomass balance approach

Reduce CO₂ emissions and save fossil resources

BASF's biomass balance approach contributes to the use of renewable raw materials in BASF's integrated production system and can be applied to the majority of BASF's product portfolio.

BioTCat™ Project

IFPEN and Axens joined forces with the American company Anellotech to develop BioTCat™, a bio-aromatic production technology (BTX for Benzene, Toluene and Xylene) based on renewable raw materials.



Co-blending bio-based / renewable feedstocks

Sustainability Targets

Shell and Dow start up e-cracking furnace experimental unit

16 Jun 2022

Milestone demonstrates significant step toward decarbonising a critical petrochemical manufacturing process.

8.3.2023

Coolbrook and Linde Engineering start collaboration on electrification of steam crackers in the petrochemical industry to achieve CO₂-free ethylene production

Business & Financial News | April 17, 2024

BASF, SABIC, and Linde celebrate the start-up of the world's first large-scale electrically heated steam cracking furnace

Electrification of crackers

Sustainability Targets

OCTOBER 08, 2024

Lummus Launches PFAS Analytical Services

New capabilities can detect, measure and assess "forever chemicals," helping customers manage water and wastewater contamination challenges

JULY 23, 2024

Lummus and Element Six Announce Global Partnership for PFAS Destruction

Partnership introduces scalable and viable solutions to treat, destroy and eliminate PFAS from water

Yokogawa and Synergen Met to Partner on Water Treatment Technology in North America

- Collaborating to address PFAS "forever chemicals" -

← THE BEST INVENTIONS OF 2024

TIME

Absorbing PFAS Pollution

Regenesis SourceStop

← THE BEST INVENTIONS OF 2024

TIME

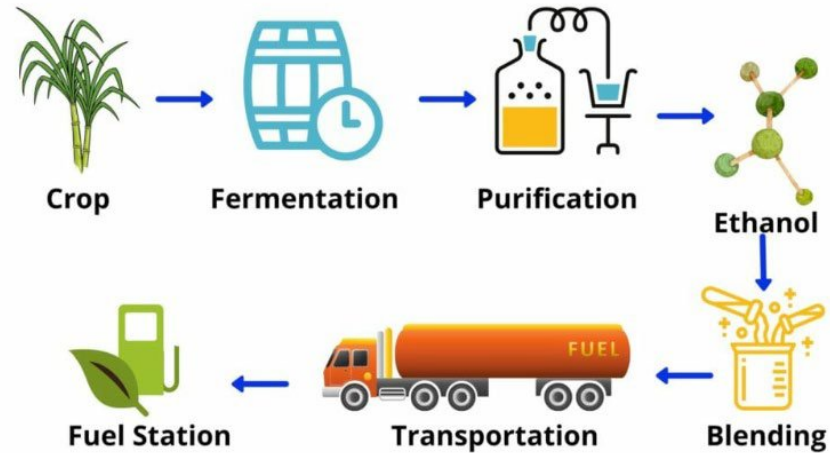
Zapping PFAS Away

Gradient ForeverGone

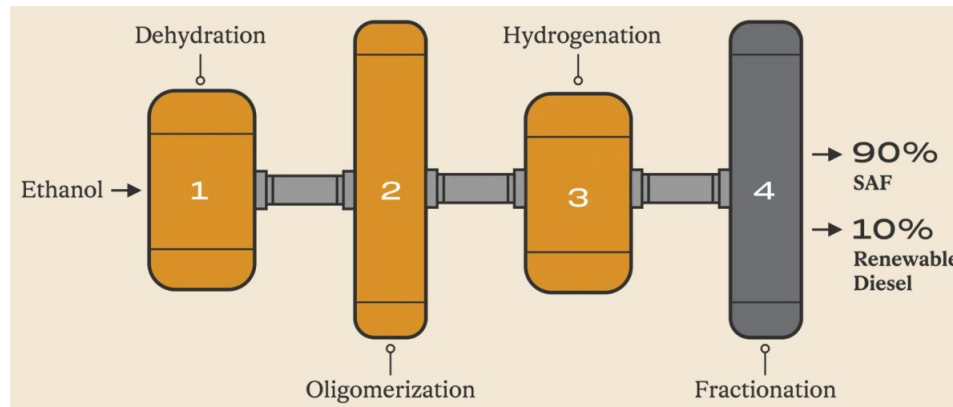
Destruction of Forever Chemicals

Sustainability Targets

Source of image: www.motoroids.com



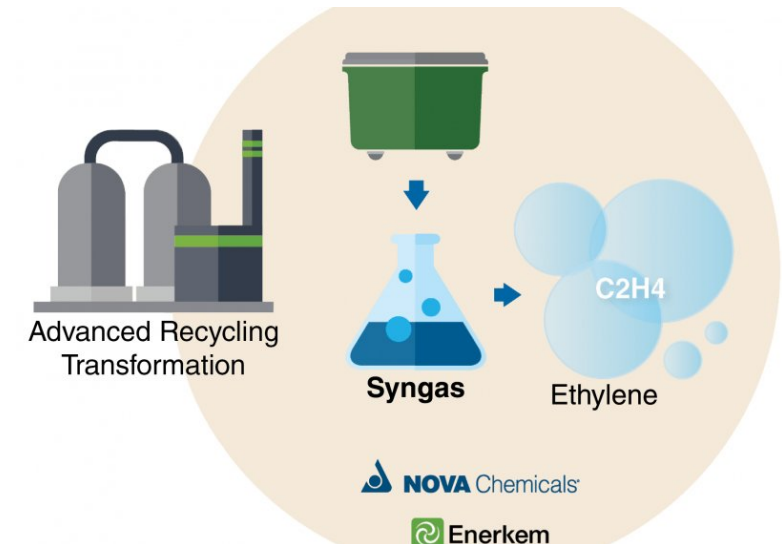
Source of image: www.lanzajet.com



FINANCIAL TIMES

Braskem bets on growing demand for bioplastics

The petrochemicals giant is making climate-friendly polyethylene out of sugarcane



Ethanol as a platform for chemicals

Regulations & Preferences

A European Green Deal: **Reducing** net greenhouse gas emissions by at least 55% by 2030

Figure 1 – Recycling and recovery rates of packaging waste in the EU (%)



Data source: [Eurostat](#), 2022.

Recycling target deadlines		
	31 December 2025	31 December 2030
All packaging waste	65 %	70 %
Glass	70 %	75 %
Paper and cardboard	75 %	85 %
Metals	70 % (ferrous metals)	80 % (ferrous metals)
	50 % (aluminium)	60 % (aluminium)
Wood	25 %	30 %
Plastic	50 %	55 %

Overall recycling for **packaging** (65 % in 2025 and 70 % in 2030) with material-specific targets (such as **55 % for plastic by 2030**)

Collection of plastic bottles of 77% by 2025 and 90% by 2029

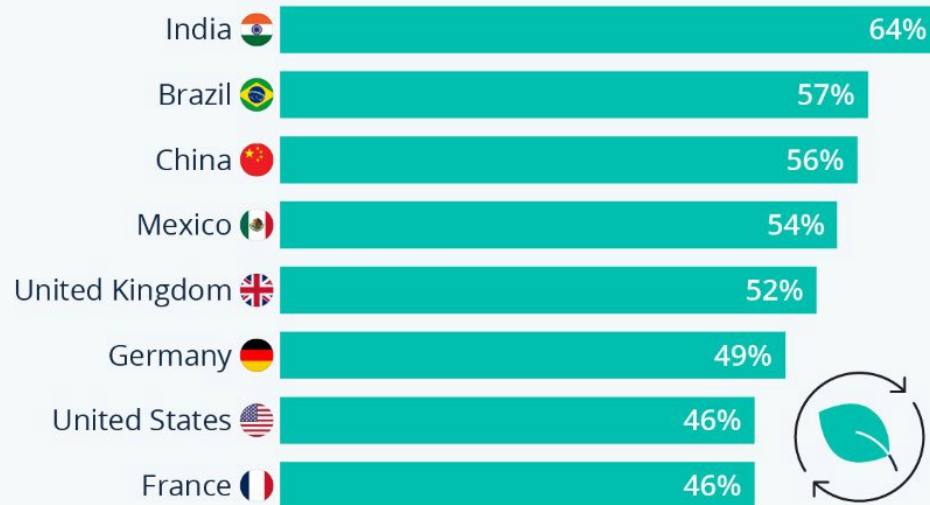
Using 25% of recycled plastics in PET bottles as from 2025 and 30% in all plastic bottles as from 2030

Regulations boosting chemical recycling demand

Regulations & Preferences

Consumers See the Need for Eco-Friendly Packaging

Share of respondents saying that eco-friendly packaging is an important aspect of sustainable consumption



~1,000 consumers (18+) surveyed per country in June 2023

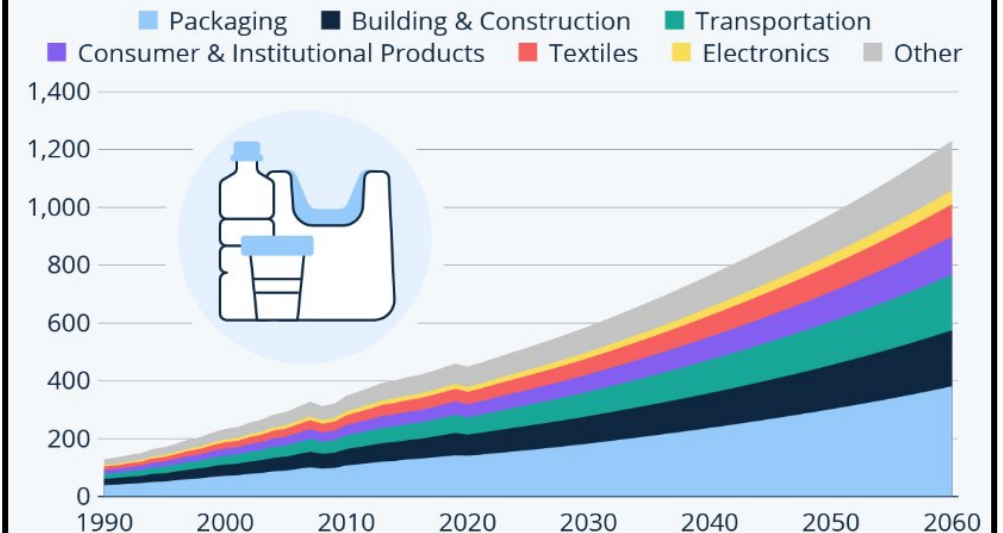
Source: Statista Consumer Insights



statista

Packaging Is the Biggest Driver of Global Plastics Use

Estimated/projected global plastics use by sector/application (in million tonnes)



Data from 2019 onwards is based on OECD projections

Source: OECD



statista

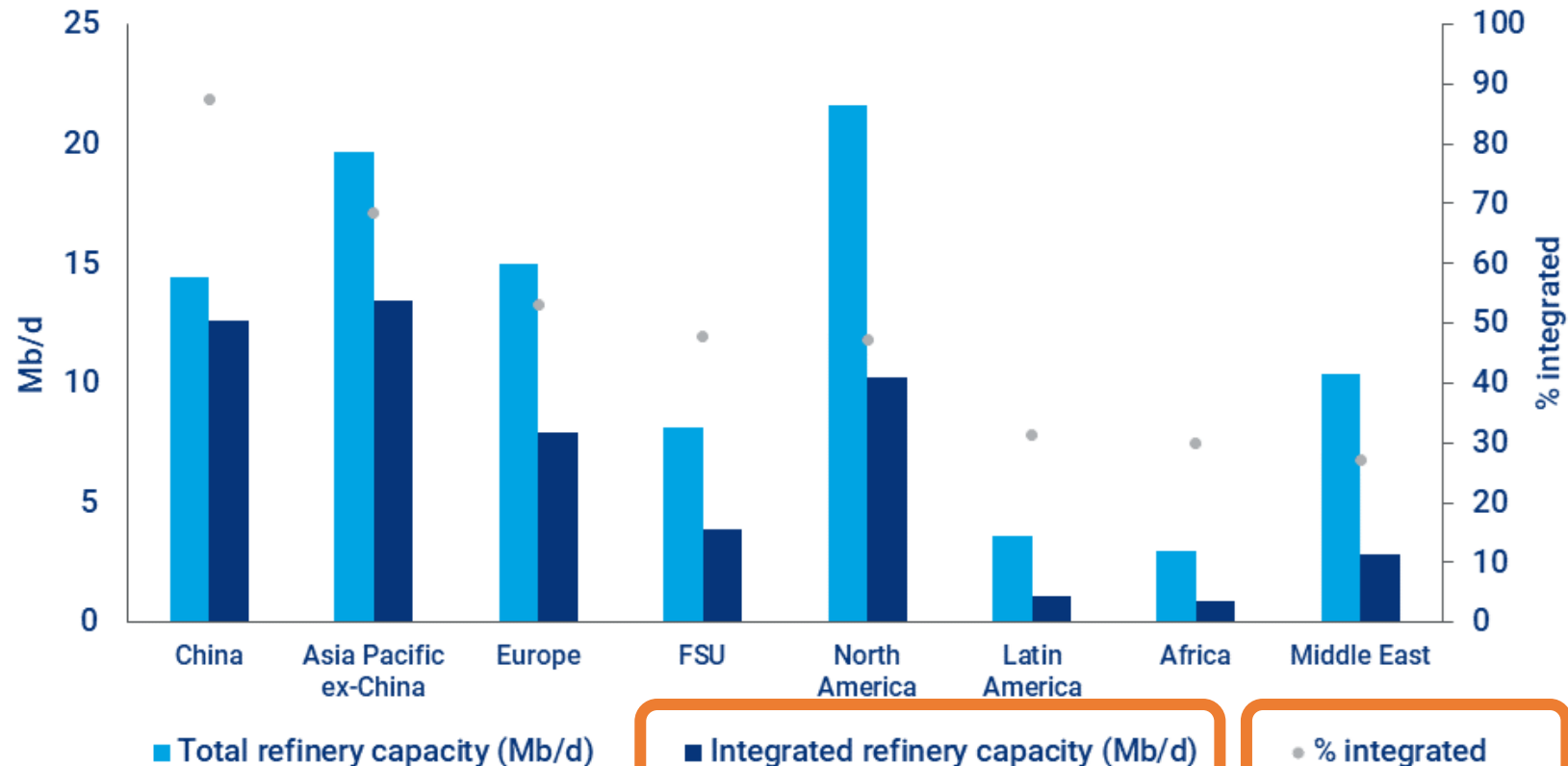
Source of image: <https://www.statista.com/chart/32141/perceived-importance-of-eco-friendly-packaging-for-sustainable-consumption/>

Source of image: <https://www.statista.com/chart/32140/global-plastics-use-by-application/>

Consumer preferences bolstering WPPO investment

Repurposing Oil Refineries

Regional crude oil distillation unit (CDU) capacity and integrated refinery capacity (million b/d)



Source: Wood Mackenzie REM-Chemicals

High integration at ASIA

Promising future for North America & Middle East

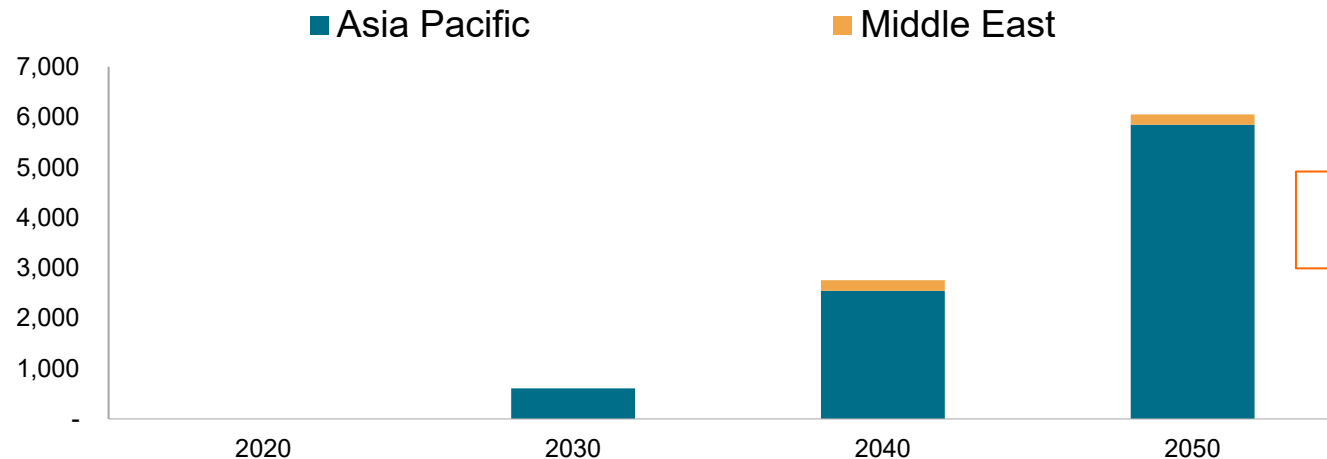
Repurposing Oil Refineries

Energy transition limits the need for conventional refinery capacity

Switching to focus on petrochemicals and 'crude oil to chemicals' production

6mb/d capacity on COTC by 2050

Consumption of crude oil to chemicals (Thousand b/d)



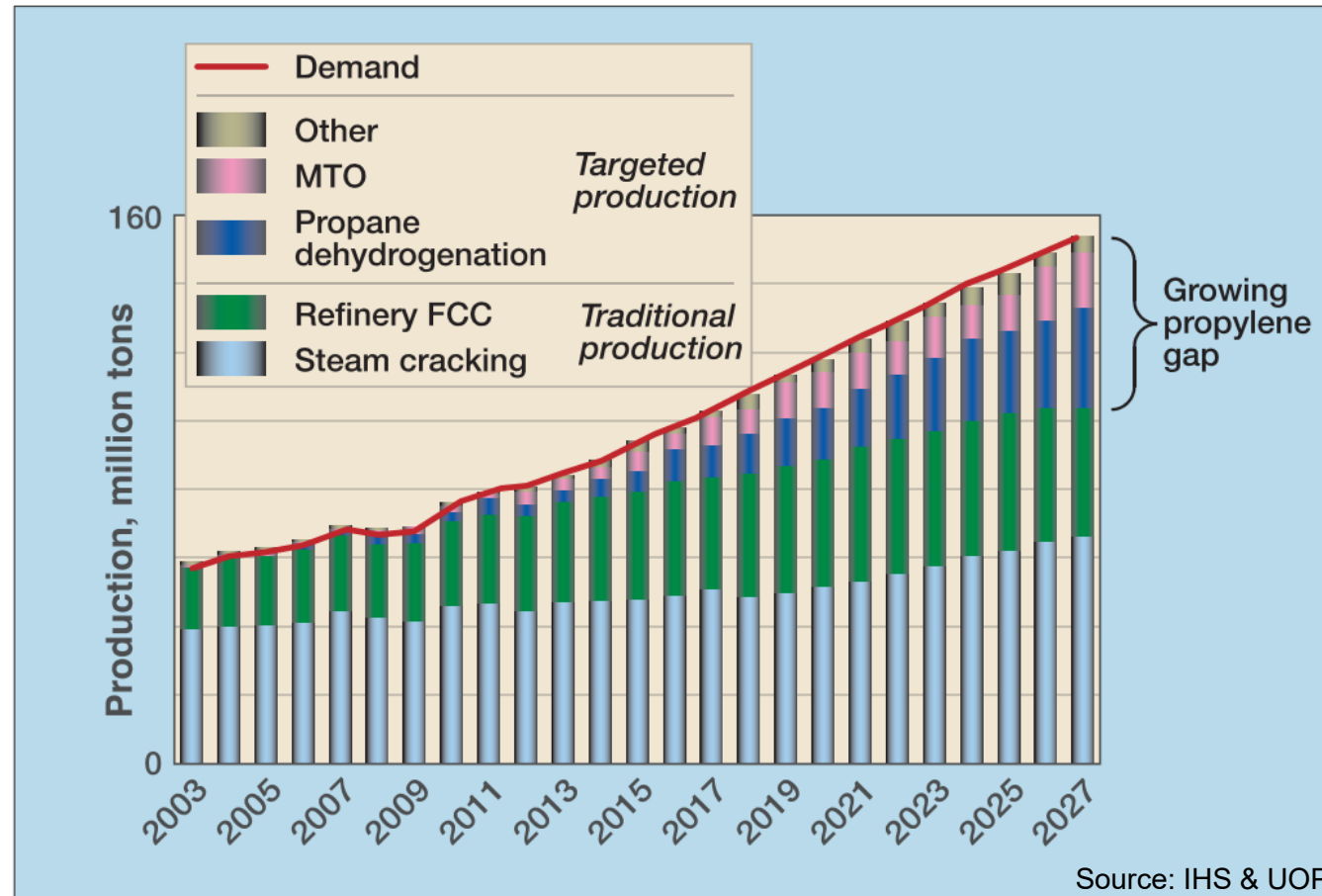
No more doubts on COTC

Source: S&P Global Commodity Insights, May 2023.



SINGAPORE (ICIS)—S-Oil's Shaheen crude-to-chemical project in Ulsan, South Korea is now 55% complete and is expected to start commercial operations in the second half 2026, the producer said on Monday.

Repurposing Oil Refineries



Triggering investments to boost the profitability

- **Petro-FCC: Co-processing renewable feeds**
- **PDH: Propane Dehydrogenation Units**

Global Trends & Market Forces

1

Profitability Concerns

Shrinking Refining Margins
High Margins of Chemicals
Increasing e-mobility & home office trends
Increased fuel efficiency
Decreasing fuel demand
Increasing chemicals demand

3

Regulations & Consumer Preferences

Bans on single use plastics
ESG policies influencing investments
Consumer leaning to recycled plastics

2

Sustainability Targets

Circular Economy | WPPO
C-foot print | biobased co-blends
Sustainable Chemicals | Ethanol
Electrification of Crackers
Distraction of forever chemicals

4

Repurposing Oil Refineries

Crude-to-Chemicals | Higher margins
Use of heavier feeds for increased profitability
Refinery Integration to Chemicals
Petro-FCC & PDH | Propylene Demand

Regional Pros & Cons

AMERICAS

- ✓ Key exporter of ethylene | thanks to shale gas
- ✓ Well-developed infrastructure | pipes & refineries etc
- ✓ Leads & owns the technological developments
- ✓ LATAM | Growing population triggering demand
- ✗ Cost of labor | Compared to APAC & Middle East
- ✗ Trade sanctions may affect cost & profitability
- ✗ ESG policies | Effect on expansion plans & profitability

Regional Pros & Cons

APAC

- ✓ Largest consumer of petrochemicals
- ✓ Consistent future demand
- ✓ Economies of scale | low-cost manufacturing
- ✓ Heavy government investments
- ✗ Relying on exported feedstocks
- ✗ Coal-to-chemicals | China's emission policy
- ✗ US-China trade tension

Regional Pros & Cons

EMEA

- ✓ KSA, UAE, Qatar | Enjoying cheap gas & crude
 - ✓ EU leads circular economy | Strong R&D
 - ✓ Egypt, Nigeria, South Africa | Growing population & development triggering demand
 - ✓ EU & ME are in the proximity of key markets | Asia-Africa-Americas
-
- ✗ Cost of energy sky-rocketed after Ukraine war | Loosing competitiveness
 - ✗ EU heavily relying on exported feedstocks
 - ✗ Shift to renewables | Jeopardizes Middle East's dependence on crude
 - ✗ Political instability of Africa | Delaying investment on limited-infrastructure

Regional Pros & Cons



The Americas, especially the U.S., leverage shale gas but may face ESG and labor cost challenges.

APAC dominates demand and manufacturing but depends on imported feedstocks.

EMEA has a cost-competitive Middle East but faces high energy costs in Europe and infrastructure issues in Africa.



How Can PetChem Players Ride the Wave of Growth?



Gaps in Your Testing for Emerging Feeds

Digital twins & minute based **process analyzers** with improved LOD

Sampling solutions **from severe reaction environment**

Characterization of **emerging feedstocks** & accompanying end-products

- Heavier oils / crude, plastic py oil, bio-feed co-blends

Group type analysis for improved process efficiency

Purity analysis such as **S & N** for product quality & catalysts lifetime

- Both for feed and product streams, at lab & process

Securing the product quality amid changing feeds

Physical property measurements such as **distillation**

Bridging the Gap: Increasing Your Profitability

Group Type Analysis Above C11
ppb level analysis of S & N: lab & online
Micro-distillation by 10mL under 10 min

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Micro-distillation by 10mL under 10 min

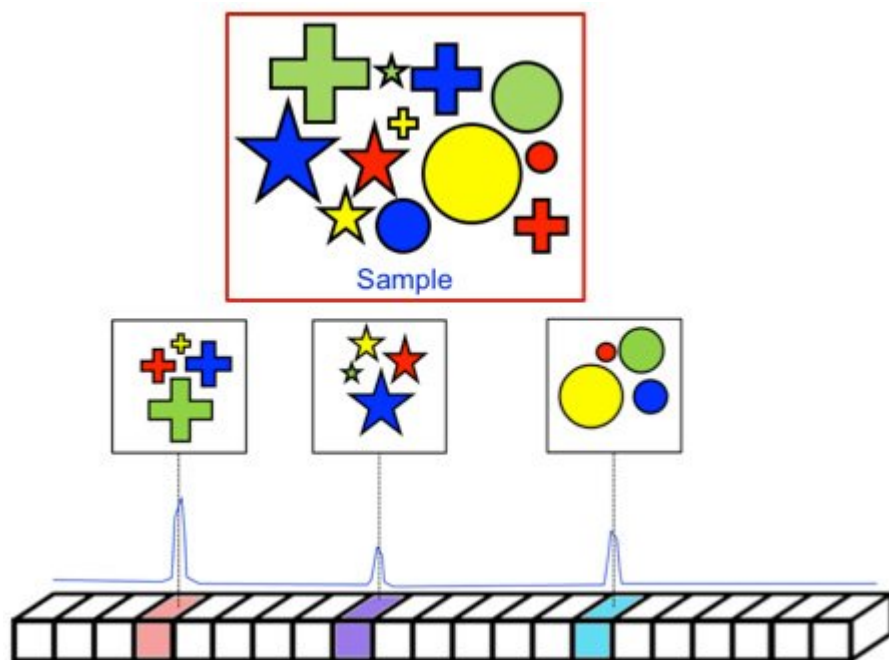
Flow Modulated GC x GC-FID with Easy-to-Use Software

- Are you using GC x GC?
- What led you to use GC x GC?

Flow Modulated GCxGC-FID: Separation Challenge

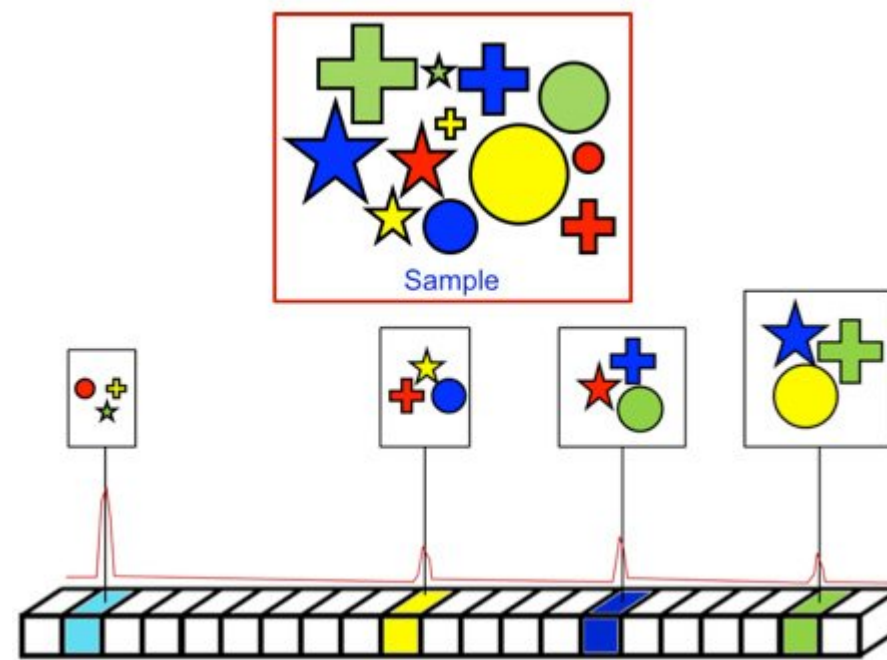
One dimension separation by
shape

(Polarity)



One dimension separation by
size

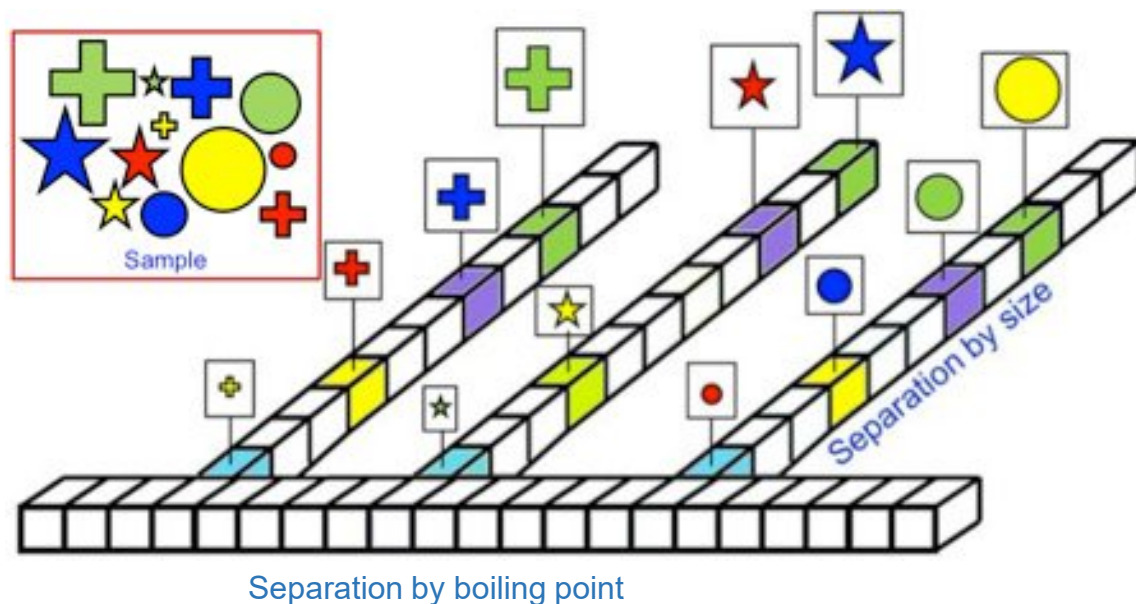
(Boiling Point)



Note that neither of the two separations can separate all analytes within the sample.

Flow Modulated GCxGC-FID: Shape and Size Separation

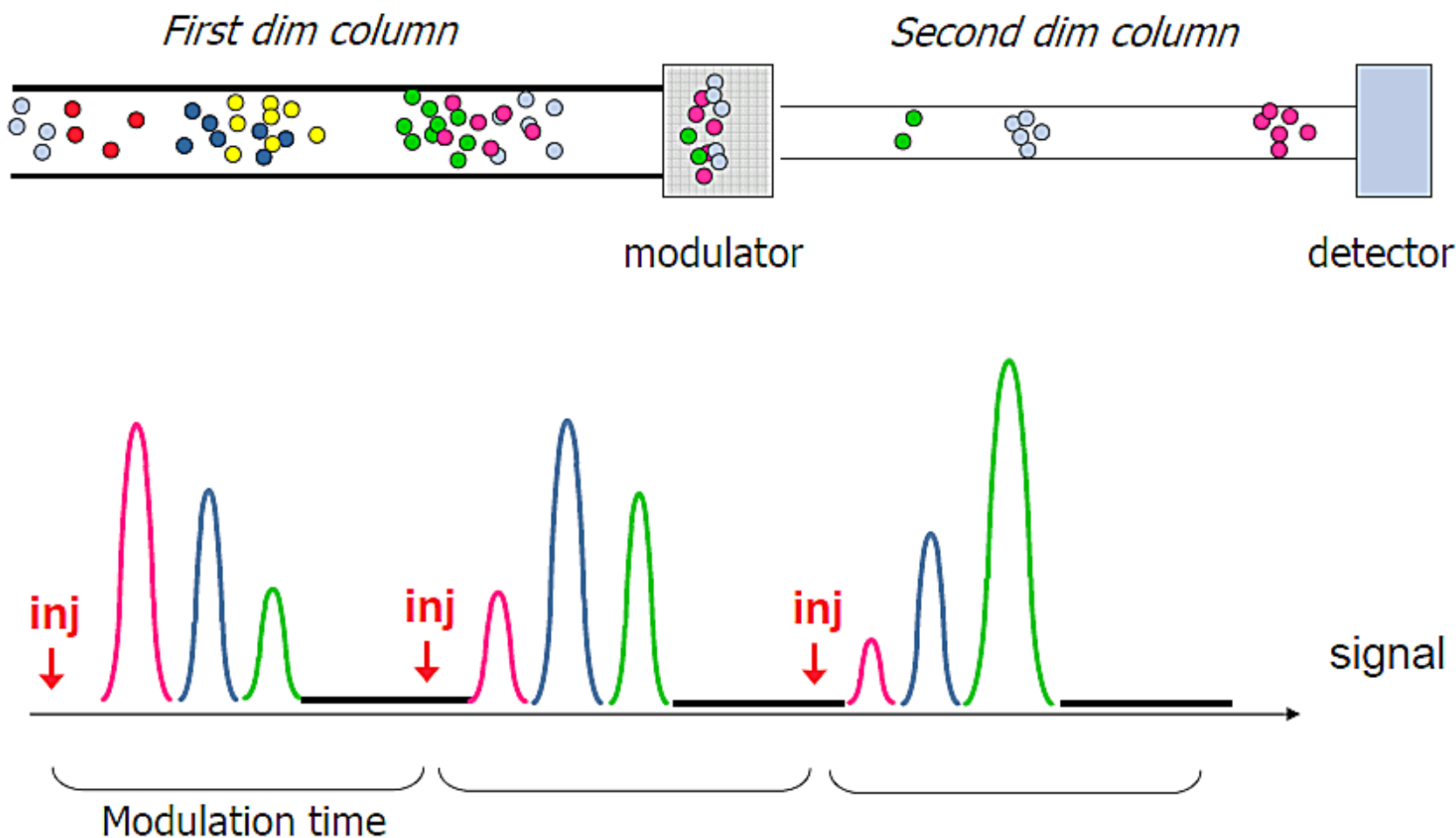
Two-dimension separation by
shape and size
(Polarity and Boiling Point)



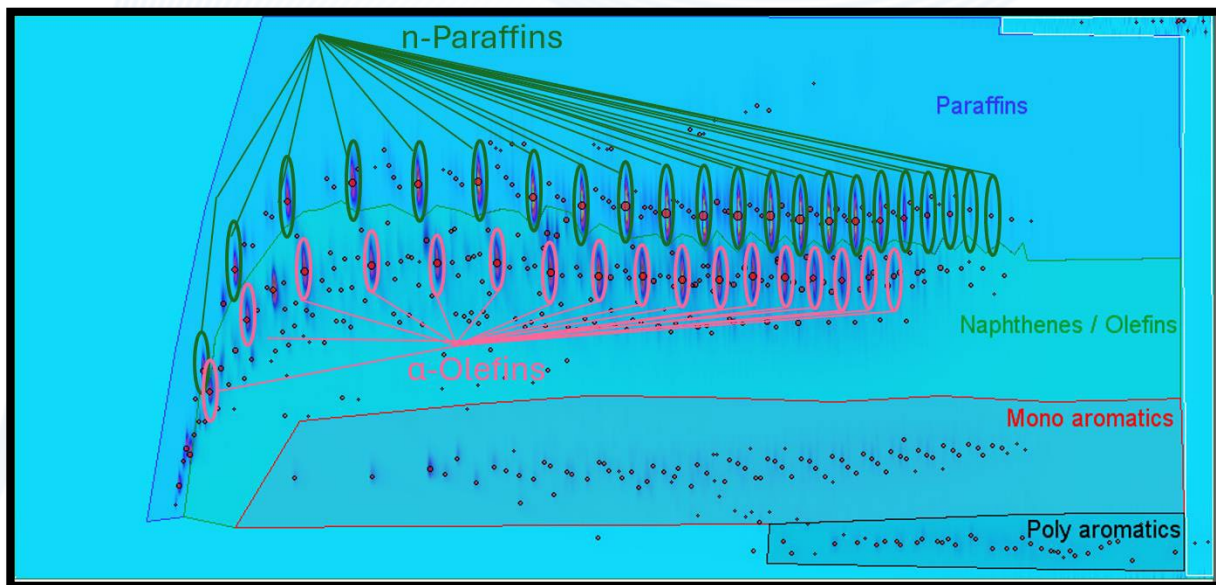
Combination of separation types:

- “Orthogonal” column chemistries – e.g. polarity & boiling point
- Every portion of the eluate coming from the 1st column undergoes a further 2nd separation
- Significantly improves separation power of the chromatographic system

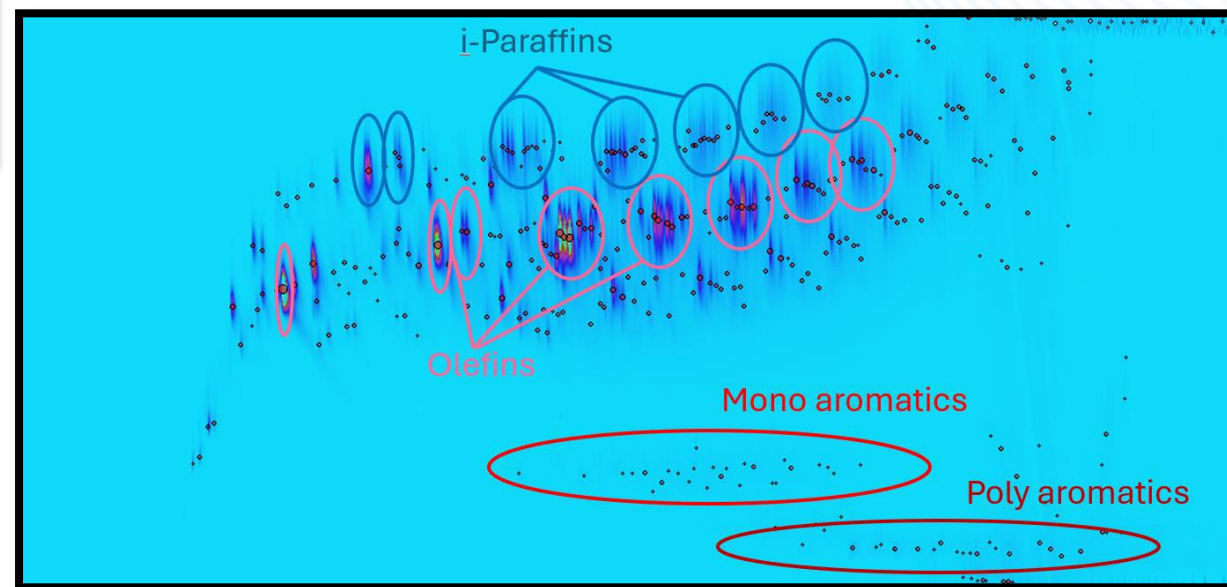
Flow Modulated GCxGC-FID: Twist by Modulator



Flow Modulated GCxGC-FID: Real WPPPO Data



GCxGC 2D-plot of a PE-rich pyrolysis oil containing high amount of n-paraffins and α -olefins



GCxGC 2D-plot of a PP-rich pyrolysis oil

Bridging the Gap: Increasing Your Profitability

Group Type Analysis Above C11

ppb level analysis of S & N: lab & online

Micro-distillation by 10mL under 10 min

Nitrogen as a Catalyst Poison

WPPO is rich in Nitrogen & Sulfur | Co-blending to Crackers

N deactivates ZSM5 at FCC & Ziegler Natta after Steam Cracking

- Coke formation | loss of value due to plugged pores
- Reduced Rxn Rate is another

Coke is burned off in the FCC-regenerator to restore catalyst

- More coke, more burn, more heat, leading to reactor heat imbalance

Regen/Reactor heat balance is important to maintain max C3= make

- Regen = $-\Delta H$ React = $+\Delta H$ Loss of rxn rate if imbalanced

Higher N can be diluted with higher CtO ratios

- But higher CtO ratio reacts more severely, again affecting heat balance, ROT

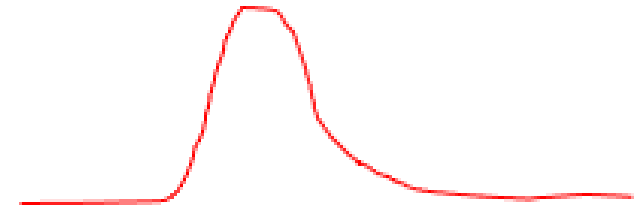
**Catalysts
Killers**

Measurement Principle - Nitrogen

High Temperature Oxidation of Nitrogen Compounds:



NO molecules are converted to excited NO₂* by the addition of Ozone and emitting light (Chemiluminescence) while falling back to a stable state.



A photomultiplier tube measures the emitted light signal.

The response signal is integrated to calculate the area. The concentration is calculated using the linear regression function obtained with standards of a known concentration (area vs concentration).

NSure

NSure: Total Nitrogen & Total Sulfur Analyzer

ONLINE | EASE OF USE | PRECISION | LOW COST OF OWNERSHIP | ROBUST | HIGH UPTIME

Robust 1100°C Furnace

Operate for years at a time until service is needed

Ease of Use

Large touch screen compatible with gloved fingers and no touch pen required



Available as S-only, N-only, or N+S configuration

IECEX, ATEX, NEC certified

Deployable anywhere in the world

Freestanding or Wall-mountable

PAC Antek ElemeNtS

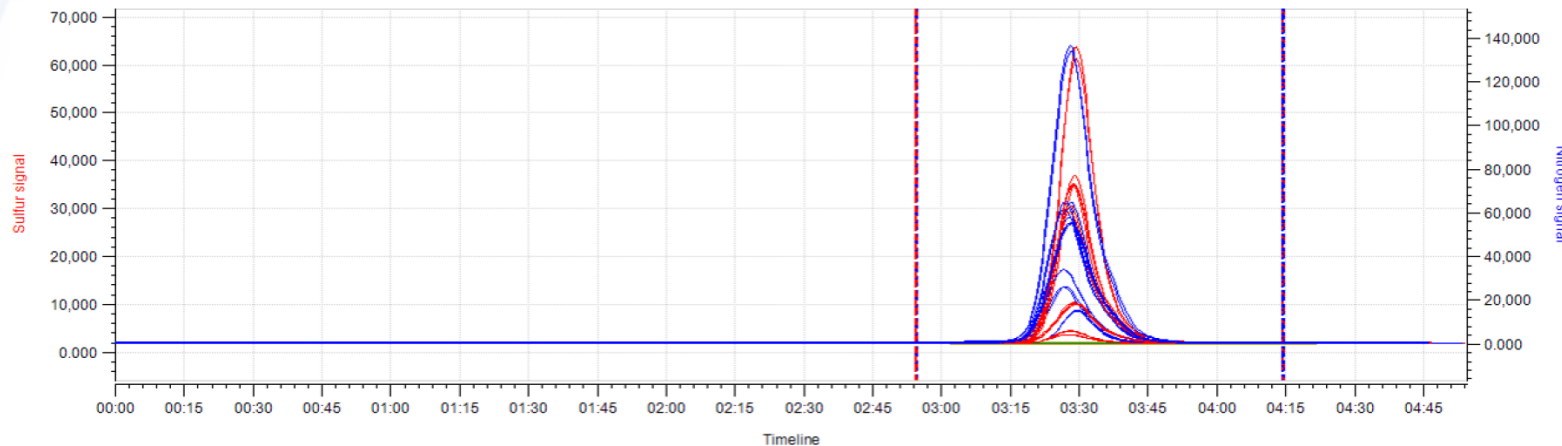
- A combustion analyzer for the simultaneous analysis of Total Sulfur and/or Total Nitrogen in one single run
- Based on
 - UV Fluorescence principle for Sulfur
 - Chemiluminescence principle for Nitrogen
- Complying with global standard methods
- Solution for Solids, Liquids and Gas analysis in one single instrument.
- Available in vertical and horizontal configuration



Total S & N Analysis for WPPO Samples

Sample	S counts	N counts	S-RSD	N-RSD	Conc. S mg/L	Conc. N mg/L	Density (kg/l)	Conc. S (mg/kg)	Conc. N mg/kg
S1	363082	1488718	2.2	1.6	133	1538	0.8024	165	1916
S2	20389	366919	0.9	0.3	7	378	0.7594	9	496
S3	282559	680343	0.9	0.2	103	701	0.7819	132	897
S4	318369	689012	0.5	0.2	116	710	0.7852	148	904
S5	576065	135906	0.5	0.6	211	138	0.7755	271	177
S6	26376	266313	0.4	0.9	9	272	0.7737	12	352
S7	92999	660939	0.8	0.4	34	681	0.7887	43	863

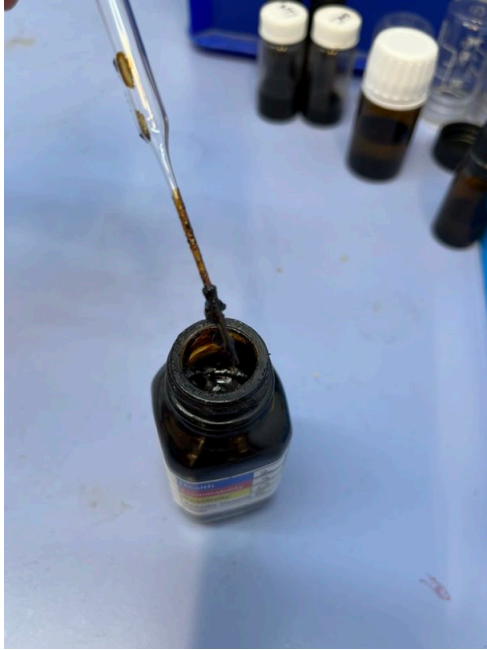
- 7 WPPO samples,
- Each sample measured 3 times
- based on peak shape and baseline; graph indicates a complete combustion,
- S conc: 9 to 271 mg/kg
- N conc: 177 to 1916 mg/kg
- High S & N suggesting a need for further purification steps before their use as a fuel manufacturing or petrochemical feedstock purposes



Bridging the Gap: Increasing Your Profitability

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ppb level analysis of S & N: lab & online
Micro-distillation by 10mL under 10 min

Micro-Distillation of Challenging WPPPO Samples

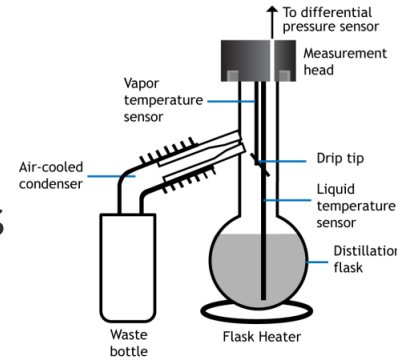


- Collecting necessary amounts of samples at R&D studies
- Performing fast screening studies to bolster process optimization attempts
- Providing uptime without clogging
- Exposure to hazardous emissions
- Easy to use in the midst of changing demographics in the lab
- Lower cost of ownership



OptiPMD for Micro-distillation

- Results in 10 minutes
- 10 mL sample (+/- 0.3 mL)
- Greatly reduced emissions
- 1 button operation
- Previous generation in use since 2005, same analytical engine with modernized interface
- Measurement principle uses data from liquid to vapor evaporation – eliminates condensation from measurement
- Volume not physically measured



OptiPMD

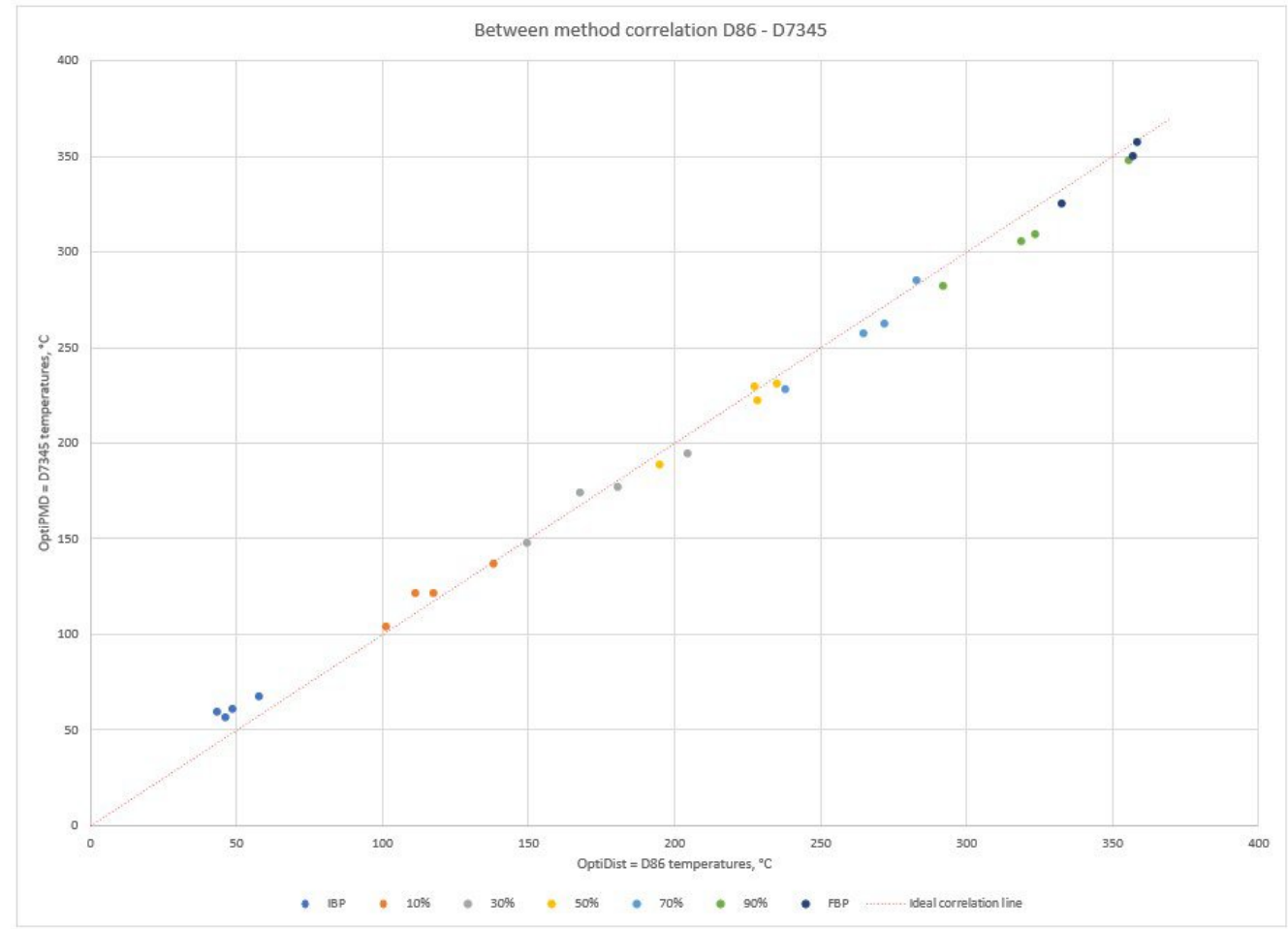
MicroDistillation: 10mL of WPPPO Sample in 10 min

Volume :	Temperature :
IBP	61,4 °C
5 %	103,2 °C
10 %	121,8 °C
20 %	147,5 °C
30 %	177,5 °C
40 %	201,6 °C
50 %	222,3 °C
60 %	242,4 °C
70 %	263,0 °C
80 %	285,6 °C
90 %	309,5 °C
95 %	344,2 °C
FBP	357,5 °C

Volume :	Temperature :
IBP	67,5 °C
5 %	105,0 °C
10 %	121,8 °C
20 %	144,9 °C
30 %	174,8 °C
40 %	202,4 °C
50 %	229,7 °C
60 %	257,3 °C
70 %	284,9 °C
80 %	315,1 °C
90 %	348,0 °C
95 %	392,3 °C
FBP	393,0 °C

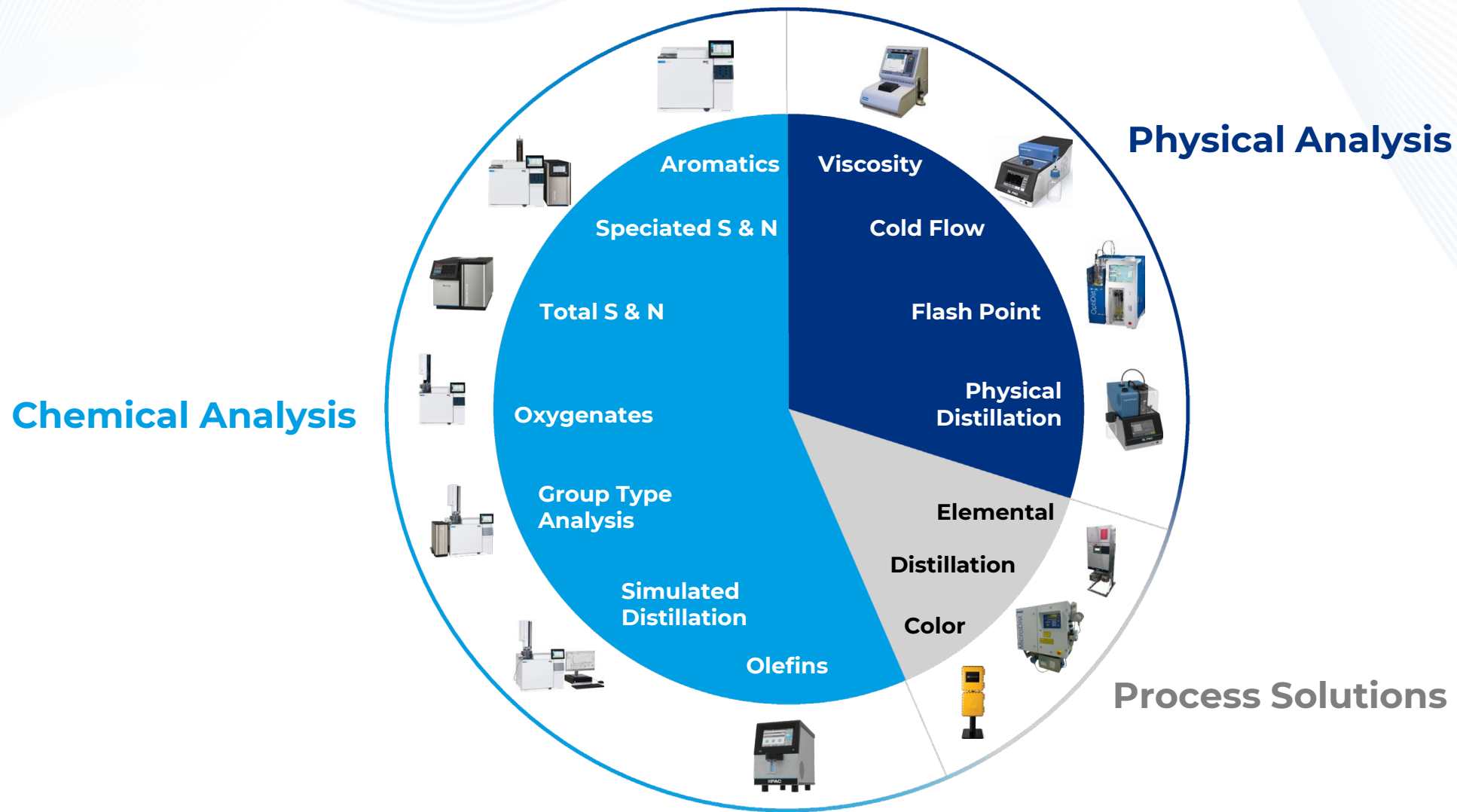
OptiPMD acc to D7345 for WPPPO samples

Suitable even with challenging samples having high paraffinic content and showing huge IBP-FBP variations



R2 value of 0.9973 for D7345 vs D86 correlation by WPPPO samples

PAC Technologies for Growing PetChem Market





PETROCHEMICAL SOLUTIONS

Helping you to **grow**
profitably and transform
towards circular economy
in the petrochemical market

GAS CHROMATOGRAPHY



ELEMENTAL ANALYSIS



DISTILLATION



INTEGRATED
REFINERIES



PLASTIC
CIRCULARITY



**Thank you for
your time!**

We are here to help you
win in the marketplace!