Chemical Market Analytics

BY OPIS, A DOW JONES COMPANY

Propylene

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World Analysis

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Introduction

The World Analysis - Propylene provides a comprehensive analysis and key insights of critical market developments as they shape the future outlook for the global propylene market.

The following reports, data files, analytical tools and visualization modules are available online and can be downloaded from our website:

- Report outlining key strategic insights and the future shape of global and regional markets
- Supply/demand and capacity database access via data browser
- Capacity by company/shareholder, capacity integration, top producer/consumer and surplus/deficit capacity ranking, and ownership/subsidiary information
- Excel data files with standard supply/demand graphics and price forecasts extended to 2050; trade grids with country and regional trade flows
- Data appendix (Excel) with supply/demand, capacity and net equivalent trade tables; and a new dashboard with standard graphs for all countries and regions
- Online dashboard providing visualization of capacity, supply/demand, trade grids, and price, cost and margin forecasts
- Explanatory Notes detailing data sources, methodologies, unit and conversion factors, and World Analysis deliverables
- Energy and Economy assumptions
- Price assessment methodology including price definitions across all regions

In addition to the supply/demand data for the main products, polymer-grade/chemical-grade propylene (PGP/CGP), refinery-grade propylene (RGP) and total propylene, capacity data are also provided for the following products:

- Acrylic Acid (ACA)
- Acrylonitrile (ACN)
- Normal Butanol (NBO)
- Cumene (CUM)
- Epichlorohydrin (EPI)
- 2-Ethylhexanol (2EH)
- Ethylene Propylene Rubber (EPDM)
- Isobutanol (IBO)
- Isopropanol (IPA)

- Polypropylene (PPE)
- Propylene, Polymer-grade/Chemical-grade (PGP/CGP)
- Propylene, Refinery-Grade (RGP)
- Propylene Oligomers (OLI)
- Nonene (Propylene Trimer)
- Dodecene (Propylene Tetramer)
- Propylene Oxide (POX)
- Fluid Catalytic Cracking Units (FCC)

This World Analysis contains detailed information on capacities, production, demand and trade for all significant producing and consuming countries, geographies and regions. Although data gathering is essential for the understanding of history and potential future trends, we believe that the interpretation and analysis of the data is the most valuable part for our clients.

A special thanks to all our clients and friends for sharing their views and expertise. The verification of the data is key to the quality of the analysis, and the input our teams get from direct participants in the global business is most important in arriving at realistic conclusions.

For questions, please contact our regional industry experts listed on the contact page and at the top of the HTML document on our website. General inquiries can be addressed to our Strategic Insights team via StrategicInsights@chemicalmarketanalytics.com.

Executive Overview

- In the years following the outbreak of the COVID-19 pandemic, the global propylene market has been affected in many different ways. During 2022, supply chain disruptions eased off, port congestions were reduced, and the east-west container freight rate returned to pre-pandemic levels, although some other constraints remain. In the second half of the year, destocking activities combined with the shift from consumer spending to service sectors. Mainland China eliminated the zero-COVID restrictions at the end of 2022. Those policies affected production at Chinese factories, as well as demand in that country. The outbreak of Russia-Ukraine war in early 2022 also impacted global supply chains, affecting propylene feedstocks trade, such as naphtha and vacuum gasoil (VGO, a feed for refineries FCC units that produce propylene). Despite these unique challenges, global demand for propylene grew at 4.4% year over year in 2021 but then remained flat in 2022. The shift to a globally aligned and exceptionally weak market that got underway at the end of 2022 was completed in early 2023. The resulting year has been one of sustained low demand, continued capacity growth and inevitably depressed profitability. The outlook for the current base year 2023 was adjusted to less than 2% as consumption growth has been limited by the recession, while overall growth is now expected to be, on average, around 3.2% per year for the next 10 years. Polypropylene (PP) will continue to lead the growth trend, accounting for about 72% of global demand by 2033. However, given the significant amount of PP capacity additions in Asia during the next couple of years and the lingering effects of COVID-19 on the supply chain, PP operating rates will remain at lower levels in the near and medium, the recovery of which will occur midway through the 10-year forecast period. Non-PP assets have not witnessed any such oversupply, but such units are typically not built ahead of demand like PP assets.

- On the supply side, refinery-grade propylene (RGP) grew at about 3.6% year over year in 2021 as refiners increased operating rates in response to the recovery in transport fuel demand. RGP production was bolstered further amid increased severity operation of fluidized catalytic cracking (FCC) units to manage distillate imbalances. Output declined again in 2022 because of weaker demand and the reduction of inventories. Even with oil prices moving up to levels not seen since 2014, propylene from steam cracking grew at a similar rate, driven by the start-up of new steam crackers in Asia. Going forward, three supply dynamics inform the outlook to 2033. First, the drop in transport fuel demand will accelerate incremental shifts in FCC yields to boost olefins supply. Second, the proliferation of lighter feeds into the cracker feedslate will limit propylene coproduction despite continued capacity additions in mainland China. Lastly, the lack of propylene coproduction will remain a pressing concern and on-purpose production will have to fill the gap as these assets will represent more than 50% of the new capacity projected to be added during the 10-year forecast period.

- In 2023, about 70% of global propylene supply were produced as a coproduct from either steam crackers or refineries (not including high-severity FCCs). Propylene production from steam crackers is influenced by the operating rates of crackers as well as the type of feedstock utilized. Regions that mainly utilize naphtha feedstock, such as West Europe and Northeast Asia, generate the greatest amounts of steam cracker coproduct owing to the high propylene yield of naphtha.

- Before the recent preference of ethane-based steam crackers, aggregate propylene production from steam crackers grew at similar rates as ethylene production. However, growth rates for propylene output have fallen behind ethylene owing to the significant ethane-based capacity additions in the Middle East and North America that yield comparatively much lower propylene output, as well as the persistence of cost advantages for natural gas liquids (NGLs) throughout the world that will encourage flexible units to preferentially crack lighter feedstocks.

- Refinery-based propylene assets, including FCC units, are the second-largest source of propylene worldwide, with propylene generated as a by-product of motor gasoline and distillates production. Therefore, propylene sourced from refineries accounts for the largest share in regions with high demand for motor gasoline, such as North America. Worldwide, this refining-based share is projected to account for 24% (not including high-severity FCCs) of the total propylene supply in 2023. This represents a decline during the last couple of years as refineries adjusted operating rates in response to the dramatic fall in transport fuel demand and on-purpose production continued to grow its share of propylene supply. The supply share of refinery-sourced propylene is still expected to drop throughout the 10-year forecast period, but not as much as in previous outlooks, as refineries look to shift FCC yields in response to a more tempered gasoline demand growth environment post-COVID-19 via increased telecommuting, adoption of higher-efficiency engines, and the electrification of transportation vehicles. Global refinery-based propylene production is expected to be slightly lower again in the period 2023-26 but overall expand at an average annual growth rate of 1.9% during the next 10 years, largely from: (1) new FCC projects and expansions in developing countries; (2) higher recovery of propylene from nonchemical (fuel) end uses, such as liquefied petroleum gas (LPG); and (3) the use of higher propylene-yielding catalyst additives in refining processes.

- As a result, propylene from other “on-purpose” sources has become an increasingly important element of the global supply. These commercialized and proven on-purpose technologies include propane dehydrogenation (PDH), metathesis, high-severity fluidized catalytic cracking (HS-FCC), olefin cracking, methanol-to-olefins (MTO), methanol-to-propylene (MTP), coal-to-olefins (CTO), and coal-to-propylene (CTP). The technology of on-purpose plant additions is typically chosen based on the availability of the feedstocks in the respective regions. For example, PDHs became the on-purpose technology of choice where propane is expected to remain accessible, owing to an increase in shale oil and gas production predominantly in North America, but not limited to such region. PDH capacity growth will continue to be seen in other regions; however, the incremental supply of propane to feed this additional PDH capacity is at risk as the reduction of capital spend in the upstream sector still lags the pre-COVID spend, which will likely result in more tempered propane supply growth trajectory than envisioned in previous outlooks (refer to the Strategic Insights section for more details).

- From a supply-share standpoint, the nameplate capacity base is highly fragmented globally, with no producers holding more than 6% except for Sinopec, the national oil company in mainland China. On a shareholder basis, Sinopec remains at the top of the ranking in 2023, with other major global players such as China National Petroleum Corporation (CNPC), Dow, ExxonMobil, LyondellBasell, Saudi Aramco, and Shell all holding smaller shares of about 3–4% each. Enterprise Products Partners has a share of about 2.4% share and only operates production assets in the US.

- Global propylene demand is dominated by PP production for automotive and mechanical parts, containers, fibers, and films. Other important propylene consumption segments include acrylonitrile (used in acrylic fibers and acrylonitrile-butadiene-styrene [ABS] polymers), propylene oxide (used in propylene glycol antifreeze and polyurethanes), oxo alcohols (used in coatings and plasticizers), cumene/phenol (used in polycarbonates and phenolic resins), acrylic acid (used in coatings, adhesives, and super absorbent polymers), and oxo chemicals (used in surface coatings and plasticizers).

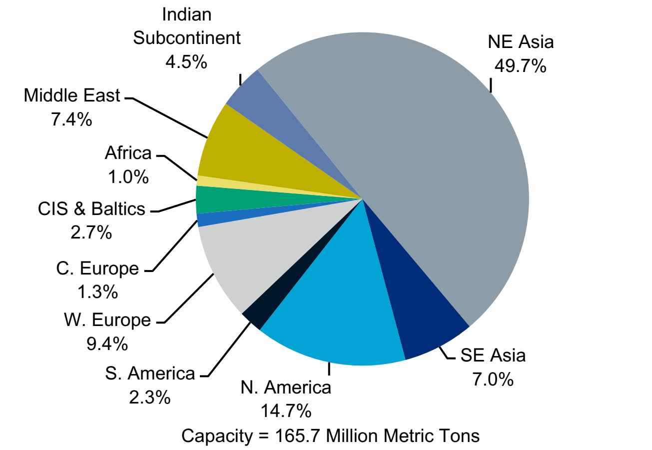
- In the last 40 years, global demand for propylene has only declined twice: once during the 2008/09 financial crisis plus the ensuing recession, and again more recently, in 2020 during the COVID-19 pandemic. However, the year-over-year demand decline was not as severe as the decline observed during the financial crisis because the loss in durable-goods demand was partially offset by the growth in demand from consumables, such as packaging and medical supplies. Prior to the pandemic, propylene demand had grown annually by about 4.4% over the previous 5 years, but future growth rates are expected to be lower than that, on average, with 3.6% projected for the next 5 years and 3.2% over the next 10 years as emerging markets, such as mainland China, which are currently driving demand growth, start to mature. Most of the downstream derivative demand lies in the developing regions increasing their per capita consumption as incomes rise. However, in several cases such as the United States, the demand from more developed regions is due to both inherent regional consumption growth as well as investment to monetize an advantaged position, typically feedstock, to manufacture products for export. Overall PP demand is expected to grow annually by 4.1% during the next five years, driving most of the global growth for propylene. This relatively strong growth rate is due to the competitive cost of PP and its versatility within the thermoplastic resin industry. On the other hand, plastics recycling issues and concerns about waste are now beginning to impact the market, despite the temporary pause given the pandemic and resulting hygiene concerns. Nevertheless, as the recycling trend evolves with governments and companies increasingly inclined to address plastic waste issues, the impact on demand has the potential to become a game changer in the coming years (refer to the Strategic Insights section for more details). While other propylene derivatives, such as acrylonitrile, cumene, and acrylic acid, are expected to register substantial demand growth at rates near or above GDP over the next 10 years, these demand segments will still remain small in comparison to PP.

- International trade of propylene monomer is quite limited because of the expense and limited scale of transporting pressurized or refrigerated liquids. Traded volumes declined further in 2022/23 and only represent about 4% of total supply. Given such additional cost of transport, most of the propylene trade crossing international borders is in the form of easier-to-ship derivative chemicals, such as PP and acrylonitrile, or finished goods containing propylene.

- Owing to the high costs associated with shipping propylene, it is more expensive for a propylene consumer to consistently import propylene rather than produce or buy it in the local merchant market. As a result, most global trade of propylene monomer occurs to cover planned and unplanned production outages. Japan, Taiwan, and South Korea will continue to export the largest quantities of propylene monomer, while mainland China will dominate imports of propylene. Other significant exporting countries are Canada (to the United States), the United States (to Mexico and South America), Saudi Arabia, the Philippines, and Thailand. North America's net export position has sharply increased from 2015 with the expansion of logistics capability. Net exports of propylene from the Middle East are expected to increase owing to capacity additions in the region, although such growth has slowed as investment has cooled from its heated pace during the past five years.

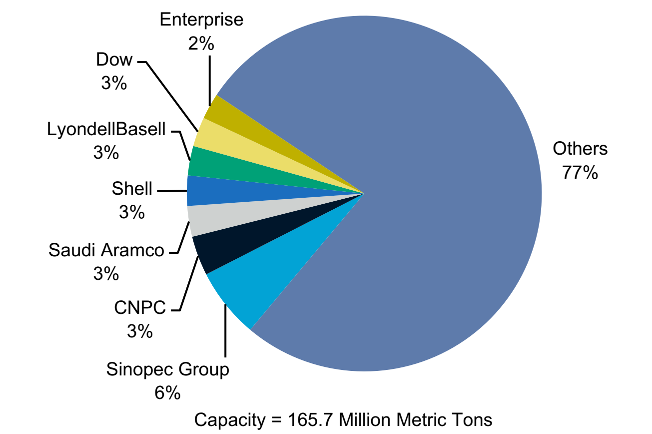
- Given the ample availability of cost-competitive feedstock, the Middle East, Northeast Asia (except for mainland China), and North America have been the leading exporters of propylene monomer and derivatives. However, as new on-purpose propylene and derivative capacity comes online in mainland China, trade flow patterns are likely to change in the longer term.

World: 2023 PG/CG Propylene Capacity by Region



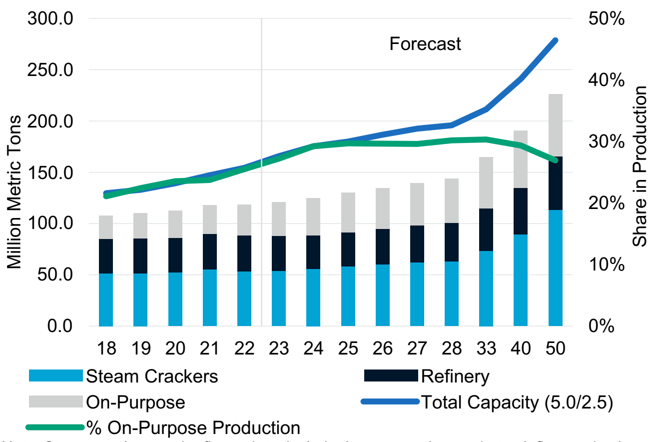
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

World: 2023 PG/CG Propylene Producers by Shareholder



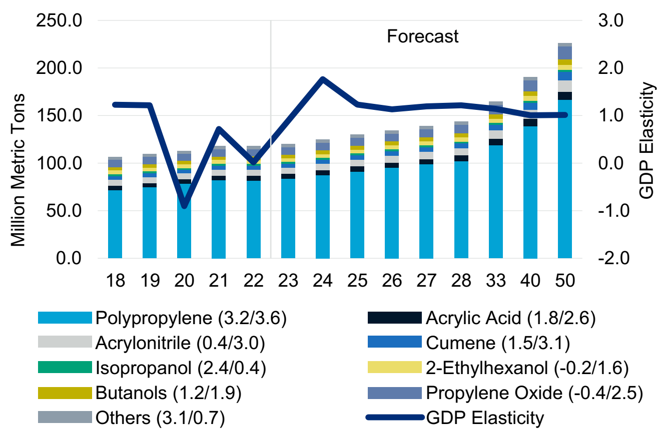
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

World: PG/CG Propylene Production By Source



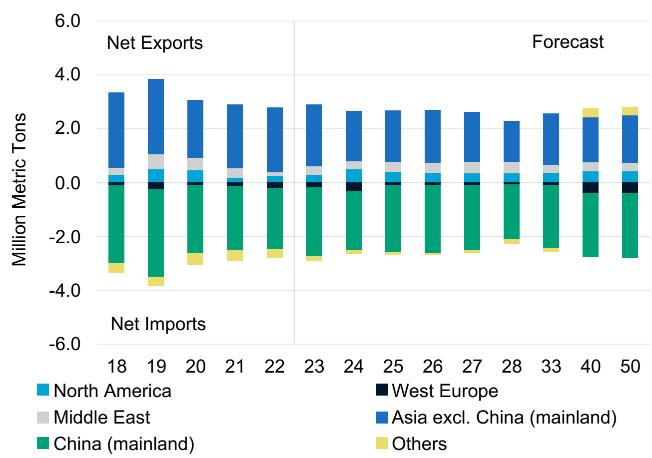
Note: Steam crackers and refinery data include the respecetive crude to olefins production.
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

World: PG/CG Propylene Demand



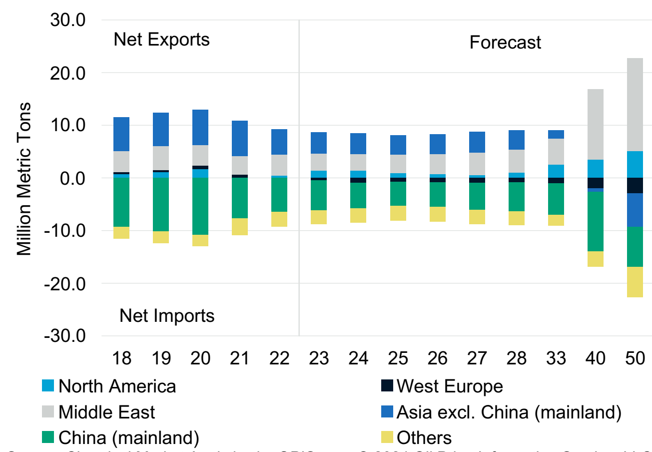
(% AAGR = 18-23/23-33)
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

World: Propylene Net Monomer Trade



Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

World: Propylene Net Equivalent Trade



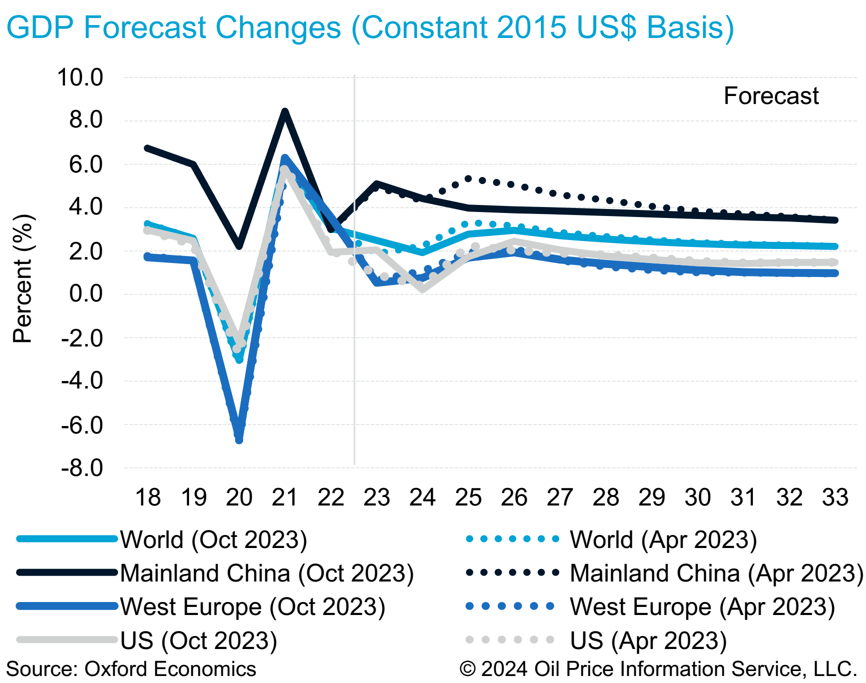
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Strategic Insights

Economic Forecast Update

Since the April 2023 update of the economic outlook that is used as basis for our chemical supply/demand forecasts presented here, economic conditions and the outlook for major countries and regions have changed noticeably. The economies of North America, particularly the US, that produce 27% of global output, have proven more resilient in 2023 than originally anticipated. However, Oxford Economics still expects the US economy to contract starting at the end of 2023 and into 2024 when a combination of high interest rates, tighter lending conditions, a more restrictive fiscal policy and weaker household finances will push the US economy into a sharp slowdown. These factors will cause consumers to cut back on spending and businesses to scale down hiring and investment. Some sectors are already in the depths of a downturn, while others are offsetting these declines at the aggregate level reflecting a "rolling" recession.

Global real GDP growth is projected to slow from 6.2% in 2021 and 3.1% in 2022 to 2.5% this year and 1.9% in 2024. Resilience in the emerging markets of Asia Pacific, the Middle East, and Africa will keep the global economy moving forward through 2023 and 2024. Oxford Economics projects these regions to achieve real GDP gains of over 3.5%. Mainland China's economy is now expected to grow by 5.1% in 2023; following a disappointing 3% GDP growth in 2022. The lifting of the zero-COVID-19 policy in late 2022 has been supporting a resurgence in economic activities, especially in the services sector. Moderate government stimulus measures also have been positively impacting the Chinese economy.



Yet, for the second half of the decade, Chinese GDP growth has been revised lower by 0.8% on average. The two main engines of growth of the past few years – exports and investment – are likely to sputter. Moreover, the ability of demand-side policy measures to boost the economy is limited. The decline in returns on investment - particularly in traditional infrastructure, real estate, and heavy industries with overcapacity - and the retreat in investment growth from the very high levels over the past decade have led to a reduction in the pace of capital accumulation. The trend in China's export growth has also been slowing for years as exports have been losing competitiveness. Moreover, mainland China is moving away from low-cost manufacturing, which is what made it an export juggernaut in the decades following the start of economic liberalization. Add in the escalating trade frictions with the US and the medium-term growth challenge is acute.

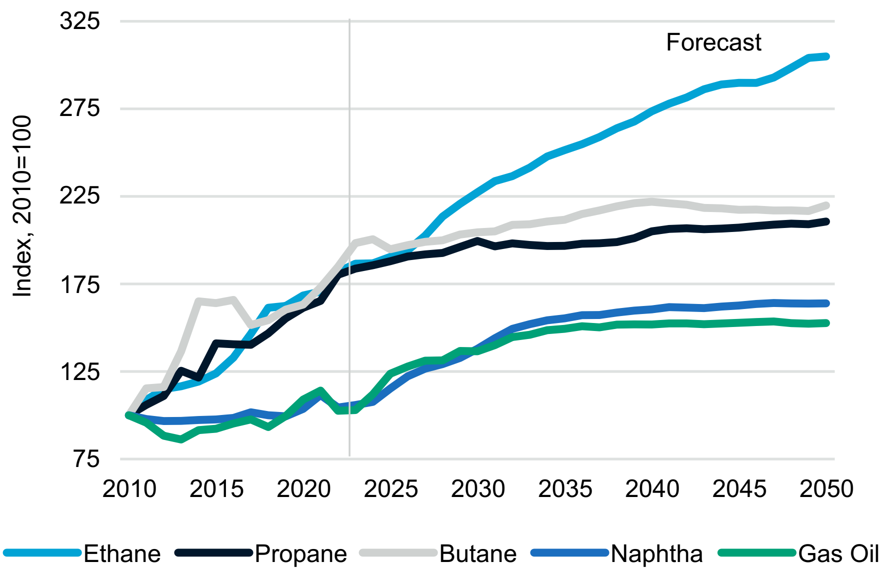
The European economy has stagnated and lacks clear engines of growth, supporting expectations for GDP to expand by only 0.5% in 2023 and 0.8% in 2024. The industrial sector is in the midst of a recession and services activity is not strong enough to offset manufacturing weakness. Monetary tightening is increasingly limiting credit availability and affecting loans, with interest rates on new mortgages remaining on a gradual but steady uptrend. The impact of the energy crisis remains uncertain. As energy prices fall from record highs, the near-term drag on potential output eases. But structurally higher energy prices will have a lasting effect, especially for large industrial economies. The accelerated green transition will boost investment, however, the lift to the capital stock will be offset by lower investment in fossil fuel-based technologies and a higher depreciation rate, as stranded assets are written off and investment shifts towards services.

Energy Transition

Implications for chemical feedstock supply

Energy transition is, in large part, about reducing the use of fossil-fuel based energy sources (natural gas (NG), crude oil, and coal) that emit carbon dioxide (CO_2) when combusted with air and substituting them with renewable, green, or nuclear-based energy supply. These same fossil-fuel based energy sources are also the feedstocks that are used to make based chemicals for plastics and other materials which eventually are converted to consumer products. Ethylene is the largest on-purpose produced base chemical tied directly to these energy sourced feedstocks. As the energy transition occurs, the quantity and mix of these feedstocks will be impacted.

Index of steam cracker feedstock growth



Source: Chemical Marrket Analytics by OPIS © 2024 Oil Price Information Service, LLC.

In the extended forecast period to 2050, the near GDP level growth of petrochemicals is far outpacing the growth of refined products, illustrating the need for more feedstocks. The current outlook assumes that, even with the disparity in growth rates, base chemicals production sourced from oil will basically double its market share over the 30-year period to 2050. This large increase comes in part from petrochemicals growth and in part due to declining fuel demand. Other reported numbers by the International Energy Agency forecast that the chemicals supply from oil will move to 50%, meaning a much larger drop in fuel demand versus chemical growth. The pace at which energy transition occurs is highly debatable and dependent on many factors. Some key factors are the switch to electric vehicles away from the internal combustion engine, government policy, technology advancements, and infrastructure development.

If there is less NG and oil production due to lower demand, there will be less coproduct natural gas liquids (NGL) supply. Chemicals are a swing outlet for NGLs, with economics driving the consumption of this feed source. The four key components of NGL—ethane, propane, butanes, and natural gasoline—all have distinct market dynamics that in the long-run will likely reduce the swing volume to chemicals. This, in turn, would require more naphtha feeds from refining. Furthermore, less NG and oil production may result in coal being used more frequently to make methanol, vinyl-chloride monomer, monoethylene glycol, and vinyl acetate monomer. If emissions from these sources require curtailment and the ethylene contained in these chemicals is still needed, more naphtha feeds could be required from refining.

In the feedstock balancing process for ethylene, all advantaged and/or stranded feeds are exhausted before we move to the last-resort feed. The last-resort feed has been the high cost and marginal route via naphtha steam cracking. Historically, the price differential between naphtha and crude oil has hovered around zero. Naphtha has been a coproduct of refining runs to make higher-valued gasoline, jet fuel, and diesel fuels. The key question is whether a refinery operator spend capex to shift yields, or simply shut down?

In the future, to support the investments to push for more chemicals, we expect naphtha to be an on-purpose product, which means the product will have to cover a larger part of refinery operating costs and sustain maintenance and capital cost upgrades. Therefore, the historical spreads relative to crude will have to increase to justify processing crude oil to make naphtha on-purpose. All else being constant, this will drive up the cost to produce ethylene and ultimately result in higher prices.

Implications for refining operations

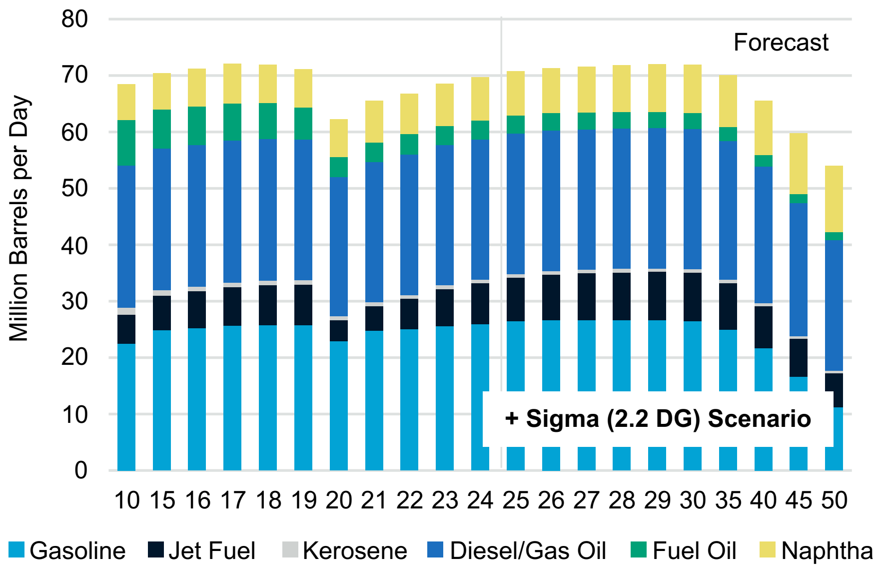
The second-largest source of propylene has been the production from fluidized catalytic cracking (FCC) units and other refinery units (such as cokers), which accounted for a little more than 30% of the total propylene supply in the last 5 years. Based on 2023 estimates, more than 37 million metric tons of refinery-grade propylene (RGP) for the use in chemical applications were produced by refineries globally. Of this amount, 34 million metric tons were upgraded through splitters to chemical-grade propylene and polymer-grade propylene while the remaining 3 million metric tons were directly consumed for production of chemicals such as cumene, isopropanol, and propylene oligomers.

FCC units typically operate at optimum conditions to maximize economics on the refinery complex as a whole and produce gasoline blendstock as their primary product. However, these units also produce C_2–C_4 olefins and alkanes (e.g., propane, butane) as well as distillate blendstock and coke. Operating conditions (high severity or low severity), catalyst type, and other process variables (feed quality, feed rates, recycle rates, etc.) can alter the distribution of products. For example, by adjusting to a higher reaction temperature (high-severity mode), more cracking will occur, generating more propylene and butylene (as well as more light gas and coke) at the expense of gasoline and light cycle oil. Additionally, catalyst suppliers can tailor the formulations to favor more gasoline production or, perhaps, more light olefins (particularly propylene) by adding ZSM-5. Currently, the average global yield of propylene from a barrel of gas-oil feed into FCC reactors is 10% by volume, or approximately 5.5–6% by mass. Catalysts with ZSM-5 additives could ideally increase propylene yields by as much as 20% by volume (approximately 11–12% by mass). However, the decision to add ZSM-5 depends on the objectives and constraints of the FCC unit, such as the throughput capacity of wet gas compressors, fractionation unit capacities, and other downstream units.

Refiners are increasingly investigating ways to meet long-term demand. The global tightness in refined products can be attributed to continuous demand growth, especially in developing economies, associated with lack of investments in capacity and refinery closures or repurposing, especially in developed economies. From 2024 onwards, the start-up of new refining capacities in Africa and Asia should ease the fuels tightness.

In the base case scenario (Mean (1.9 DG) provided by our energy partner, Rystad Energy, global fuels demand is projected to plateau by the mid-2020s and gradually decline from the mid-2030s onward, while their more conservative scenario (+Sigma (2.2 DG)) assumes that peak oil will reached a few years later, in the middle of the next decade. In any case, future refinery operations will likely shift to higher petrochemicals outputs to maintain utilization. Our outlook is driven by petrochemical demand in high-growth economies, as population growth and a rising middle class cause demand for plastics and fibers to soar.

Global Oil Demand by Refined Product



Source: Rystad Energy © 2024 Oil Price Information Service, LLC.

Propylene output from FCC units will still be determined by developments in the gasoline market. Changing fuel-efficiency standards, increases in autonomous transportation, the electrification of vehicles, and competition from other transportation fuels will continue to challenge gasoline demand growth. Additionally, COVID-19 has tempered near- and medium-term demand growth. In the latest base case scenario provided by Rystad Energy, gasoline demand is expected to expand on average by 1% annually before it peaks in the middle of this decade, then decline at an average annual rate of 7% to 2050. In their more conservative scenario, global gasoline demand will only decline at rate of less than 4% in the longer term, which is still a comparably large change compared to the outlook used as basis for the propylene supply/demand balances. As the anticipated demand for gasoline and propylene consumption diverges, more RGP is needed to support such development. Both new refinery builds (including greenfield FCCs or crude oil–to–chemicals configurations) and brownfield investments (FCCs retrofit to handle more olefins output) will favor lower gasoline yields, shifting to higher propylene output. Starting with the 2023 edition of Chemical Market Analytics' propylene supply/demand balances, the hypothetical capacity for RGP has been segregated into three categories to reflect greenfield and brownfield capacity additions. "FCC propylene capacity creep" was added to reflect brownfield investments and changes in FCC operations/catalysts that yield more propylene to chemicals.

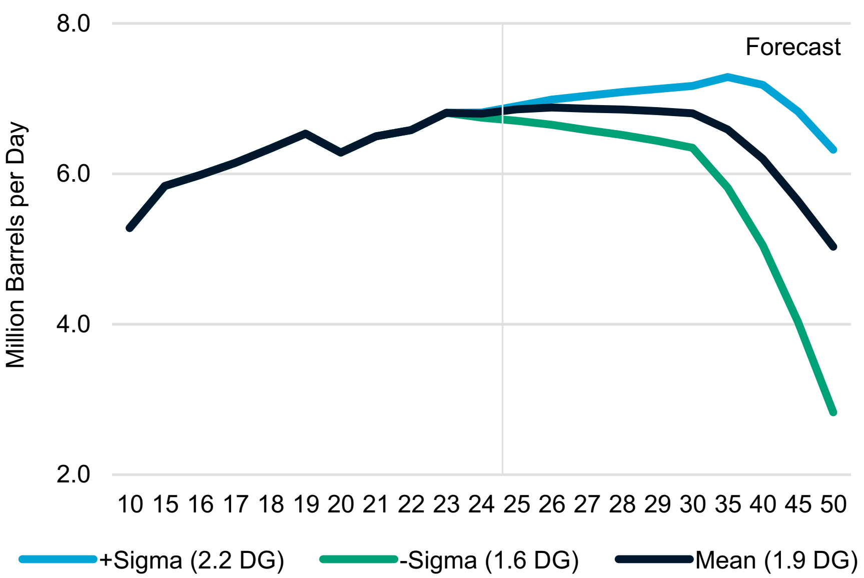
When examining the installed base of FCC units throughout the globe, the collective opportunity for RGP production expansion ranges from nearly 30 million metric tons to a staggering 130 million metric tons. The smaller number is what could happen with minimal investment opportunities and incremental yield shifts, whereas the larger number represents a much more expansive revamp of all FCC units to maximum propylene production modes. However, this theoretical range of opportunity must be tempered with realistic refinery economics. Most refineries around the world do not have the scale to make these investments in units that are essentially gasoline machines, let alone make outsized investments for complete revamps. When rigorously assessing each FCC for its structural advantages (e.g., scale, proximity to logistics/petrochemical infrastructure, relative RGP production to alkylation consumption, etc.), the opportunity set is much more limited and largely focused on three places: the United States, mainland China, and India. The FCC capacity that is likely to upgrade could yield up to 14 million metric tons of additional RGP capacity—below the theoretical range. However, the hypothetical increase in RGP capacity from existing FCC units has been lowered further to roughly 2.5 million metric tons in 2040 and about 3 million metric tons in 2050, mainly driven by a much weaker demand outlook. Nevertheless, peak oil demand, whether it's reached at the end of this decade or in the middle of the next, and robust demand for petrochemical feedstocks signals a shift in refinery operations toward higher petrochemicals integration, which will be needed to close the propylene supply gap.

Propane availability and continued investment in propane dehydrogenation

Gas plant production of propane accounts for nearly three-quarters of total world production, with refineries accounting for the balance. Propane from natural gas has been growing at a higher rate than propane from refineries, owing to increased consumption of natural gas for power generation and strong investment in liquefied natural gas. North America and the Middle East dominate the world supply of propane, accounting for about 40% and 20% of total world production in 2022, respectively.

However, US natural gas liquid (NGL) production was not completely immune to the pandemic's effects. COVID-19 has permanently altered the trajectory of NGL and propane supply growth. Oil prices declined to the point where upstream production economics were marginal at best, and oil production responded accordingly. While the Russia-Ukraine conflict has driven oil prices up to historical levels and established a plausible "super cycle" with record profitability for the upstream industry, the looming energy transition has urged US producers to exercise capital discipline, focus on balance sheet improvements, and invest more strategically. Therefore, a trend with a reduced growth trajectory of US liquids production is now expected to be seen. Moving forward, the upstream development will continue, accompanied by liquids production growth, albeit at a more tempered level.

World: Propane Supply by Scenario

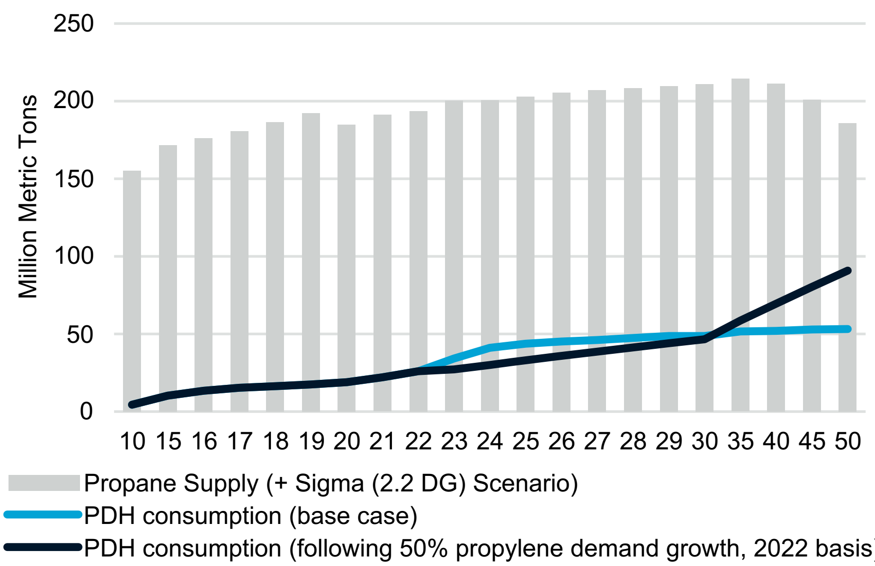


Source: Rystad Energy © 2024 Oil Price Information Service, LLC.

Our energy partner, Rystad Energy, offers three different sustainability scenarios for propane demand going forward, which are differentiated by the level of global temperature rise foreseen. As can be seen in the adjacent chart, the line for the 1.9 DG temperature rise is labelled as the mean scenario, is showing a dramatic decline of gasoline demand towards 2050. In this scenario, which represents Rystad's base case, propane demand reaches a peak level at nearly 7 million barrels per day in two years but eventually drops to about 5 million barrels per day in 2050. In the more conservative 2.2 DG scenario, propane demand is projected to peak at nearly 7.3 million barrels per day right in the middle of the next decade before gradually declining to a level of about 6.3 million barrels per day in 2050. While our current outlook for propylene is based on a lower propane availability than in the previous cycle, translating into less hypothetical capacity to be added via PDH units, the general view for the world remains close to the more conservative 2.2 DG scenario.

On the demand side, the largest end-use segments for propane are the residential, commercial, industrial, and fuel markets. All combined, these markets (which are more premium than the other uses) will likely account for about 55-60% of the total demand by 2028. However, complementary to these segments is propane consumed by petrochemicals, specifically as feedstock for steam crackers and propane dehydrogenation (PDH) units. Over the last decade, there have been symbiotic relationships among US propane supply growth, logistical investment, and PDH/cracker feedstock consumption growth. With high global availability, propane quickly became an advantaged feedstock over naphtha for steam cracking, so operators of these assets quickly captured a lower cost basis by feeding in propane to the technical limits of the assets. This shift occurred in order to mitigate exposure to oil-based naphtha and leverage propane supplies—a perfectly rational response to the rise of cost-competitive ethane cracking. Because the fundamental balances of heavier coproducts are more delicate than the lighter olefins, propane's presence within the liquids feedslate will likely continue to grow. From a PDH perspective, the high selectivity toward propylene and the rising supply of propane made this process the preferred on-purpose vehicle. Given the feedstock attractiveness and the need for on-purpose production to meet propylene demand growth, nearly 22 million metric tons of PDH capacity were added over the last 10 years, and another 15 million metric tons are expected over the next five years. Even with this impressive growth in both PDH and cracker consumption, the chemical demand segment will likely remain in the minority by 2028.

World: Propane Supply vs PDH Demand



Source: Rystad Energy,
Chemical Market Analytics by OPIS

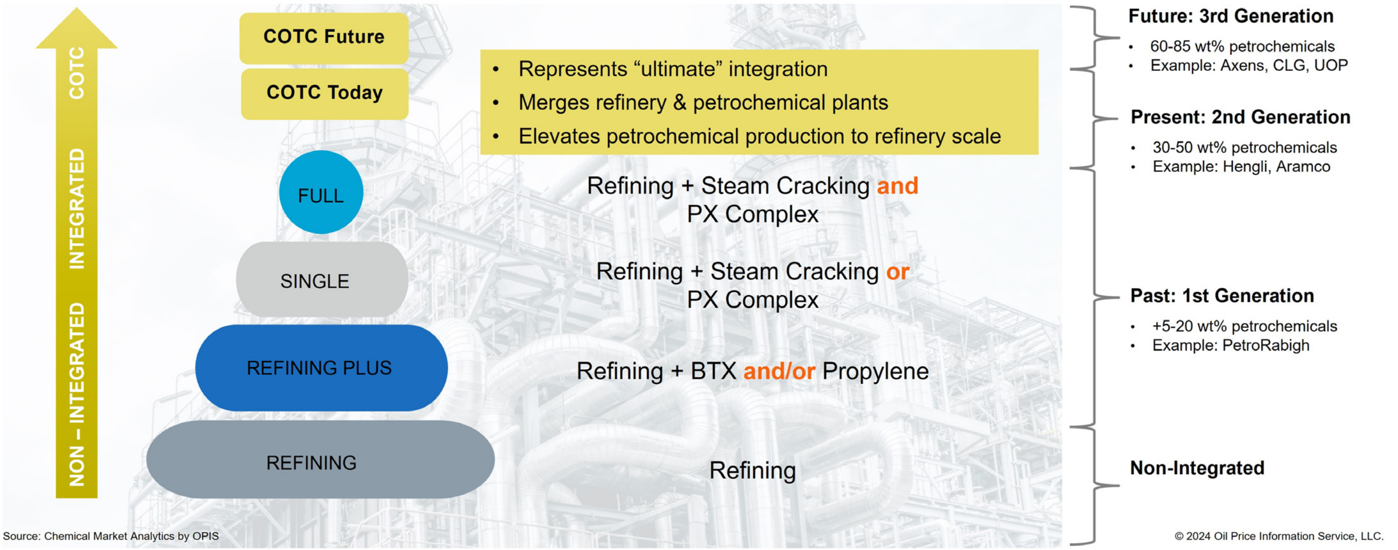
However, these feedstock selections largely hinged on the availability of competitively priced propane. The aggressive pace of PDH additions that will continue over the next five years, combined with the persistent shift toward lighter cracking feeds, means the chemical segment will need to compete with more premium segments, all within a more constrained supply/demand balance. The chemical market's ability to consume propane will eventually exceed the supply's ability to meet such demand. Once this occurs, propane will experience upward price pressure that will economically favor naphtha in steam crackers that have flexibility to swing between the two feeds. The shift from propane to naphtha in steam crackers will increase propylene supply, as the propylene yield from naphtha cracking is typically over 30% higher than propane cracking. However, for PDH units, the biggest threat is the outsized leverage to propane feed; either propylene prices will need to rise so PDH units can compete with premium propane outlets, or cracker consumption will need to drop to increase propane availability, which in turn increases propylene production. For better or for worse, PDH is married to propane.

Crude Oil to Chemicals (COTC)

Crude oil refining has been a source of petrochemical production for many decades, particularly for propylene and aromatics. As a result, this refinery-based production has a direct influence on the fundamental balances for these markets. On propylene specifically, the market influence can be substantial if a region's supply mix is heavily weighted towards the refining segment, which produces propylene as a by-product of gasoline production via fluidized catalytic crackers (FCC) units. In today's environment, as refiners look to incrementally diversify their product slates away from transport fuels, the FCC is a key processing unit that is often investigated for greater petrochemical exposure.

However, as refiners look to deepen their integration into petrochemicals, there are a few key issues that bear consideration. From a strategic standpoint, COTC is multifaceted term and can have different meanings depending on the level of oil conversion to chemicals. COTC can be simple and capital efficient, such as incrementally enhancing propylene production from the FCC, or it can be complex such as a capital-intensive fully integrated refinery site with associated cracking and aromatics complexes. The degree of chemical conversion matters as moving from 5%, up to 40% is a fundamentally different strategic direction versus a conversion as high as 80%; either option will have distinct implications for a refiner such as increasing propylene/aromatics production and shifting the product slate away from traditional fuels to producing additional feedstocks (such as LPG and naphthas) for ultimate disposition through traditional ethylene steam crackers; these are not trivial shifts as the refiner will need to define its level of diversification to chemicals (e.g. incremental propylene/aromatics as a hedge to softer fuels markets or complete transition away from fuels). Lastly, hydrogen and carbon management are critical considerations because a refiner can either inject hydrogen via hydro-processing or reject carbon via FCC's and cokers to meet the necessary ratios of petrochemicals versus fuels products. The graphic below illustrates this evolution.

Refining and petrochemical integration has evolved through several "generations" of integration



Source: Chemical Market Analytics by OPIS

There are many examples of COTC. In mainland China, sites have been built which make a higher yield of aromatics than olefins and yield about 40% petrochemicals per barrel of oil input. The olefin production associated with these sites is via conventional FCC units and conventional steam crackers processing a mix of feeds. In India, Reliance has developed a technology under the name of multi-zone catalytic cracking (MCC) which is like a traditional FCC but allows for more types of feeds injected at different points in the reaction section, which theoretically could run crude oil directly as a feedstock, but no units do so today. Lastly, ExxonMobil and others have developed a heat integrated steam cracker that fractionates light crude and routes the light products to a traditional steam cracker with the heavier products routed back to a refinery.

The journey from the current day technology to the site of the future will be undoubtedly multi-layered and complex, but it will also be encumbered by looming energy transition and the management of carbon dioxide emissions. As refiners adapt to changing world, petrochemicals will play an essential role going forward.

New US Laws that may impact petrochemical industry

The Bipartisan Infrastructure Law and the Inflation Reduction Act (IRA) could both have far-reaching implications for the US industry. The two relatively new laws will add tax relief and subsidies for lowering carbon emissions and emissions of other greenhouse gases. The incentives include relief for new builds and retrofitting of residential and commercial property with the best available technologies to lower energy usage for heating and cooling. It extends to benefits for electric and hybrid vehicles alongside support for battery materials research and development. More broadly, it extends into subsidies for carbon capture, pipeline infrastructure to move carbon dioxide to sequestration locations, and ultimate carbon storage. At the highest level, tax relief and subsidies mitigate investment risk to the industry and rather places that risk on the state and ultimately the tax paying base.

The path that the US has taken on progressing this initiative has drawn criticism from other parts of the world, concerned about a substantial advantage being given to various US industries. In particular, the biggest concern is that these initiatives seem to be against WTO precedence on how these types of incentives can or should be applied nationally. The potential benefit the US petrochemical industry gains from these measures is to make the transition to “green” petrochemical production easier with a considerably lower investment risk. This would give the US industry an unparalleled cost position in the field of “green” chemicals in addition to their already highly competitive position with respect to energy and feedstock costs. It would also leave other regions challenged, particularly those that have adopted an industry-funded model for the development of petrochemicals. Many technology, engineering, procurement, and construction firms alongside the industry itself have aggressively lobbied for this government support, and continue to do so, to generate “green” ESG credits for their US operations. The legislation is expected to support both domestic demand growth as plastics can improve their environmental credentials but also stimulate additional production for exports to support other countries de-carbonization efforts.

Commentary continues to arrive from various stakeholders as the impacts of this legislation has the potential to dramatically impact several industries. The automotive segment is already looking for amendments as certain aspects of battery subsidies could have a detrimental impact on the speed of conversion to hybrid and battery vehicles in the US due to a lack of local battery raw materials. More to come on the topic as the laws are being proposed to study and determine what unforeseen outcomes could result.

Carbon Tax and CBAM

In combination with the localized and global drives to reduce emissions, states are penalizing high emitting assets and industries through implementation of various carbon taxes and emissions trading mechanisms. This has been most rapidly advanced in Europe where a region-wide system, the Emissions Trading Scheme (ETS), has been operational for many years and captured data for most of the petrochemical producing assets since 2021. The impact within the petrochemical sector is most keenly felt on the steam cracker, being the major emitter of carbon dioxide within the industry.

The schemes typically work by defining a group of industries, and therefore assets, and allocating a total level of carbon dioxide (and equivalent) emissions that can be produced in Europe within a certain period such as a calendar year. In the initial phase of the European scheme, the owners of these assets are allocated free credits to reflect the 10th percentile asset, in terms of emissions, amongst their peers and are then required to purchases additional credits or are able to sell credits to match their emissions. This remains the case for the

European ETS though the next stage of scheme is quickly approaching for some industries, if not yet the petrochemical one. Several other regions and countries have also implemented some form of ETS scheme, though typically the costs of these are at a lower level than in Europe.

In addition to this trading scheme, several countries have put in place emission taxes or floor valuations for emissions; in the case when the ETS values fall below these targets, emitters are then taxed. This has resulted in a substantial variation in the cost associated for carbon emissions dependent on location, there has consequently been a cost impact on the industry.

The cost discrepancies on a global basis are quite substantial and so regions that have been implementing carbon taxes and ETS have also been looking for ways to ensure that carbon leakage can be minimized. The process of moving production into low carbon tax locations and then shipping product to high carbon taxation locations is seen as a major risk by those pursuing reduced global carbon production; the solution is to treat importers with the same degree of taxation as seen for local producers. There is, in addition, an underlying drive to pull other countries and regions into operating similar, mirror, ETS schemes and therefore allow for trade free of carbon taxes. The term this import 'taxation' system has been given is Carbon Board Adjustment Mechanism or CBAM.

The implementation of CBAM in Europe is now underway, with the transition phase for cement, iron, steel, aluminum, fertilizers, electricity, and hydrogen in progress. The actual implementation of CBAM will get underway in 2026 after which time importers of a range of products under these categories will be required to disclose certified evidence of their embedded emissions along with the necessary ETS certificates, which will have been purchased for the relevant period. In 2024 and 2025, the reporting of imports and embedded emissions will be required, though the purchase of certificates will not be necessary. The requirements for import certificates will be timed to start with the end of free allocation for local producers, in theory leading to a level playing field within the European market. However, for products exported from Europe, free allocation of credits would continue.

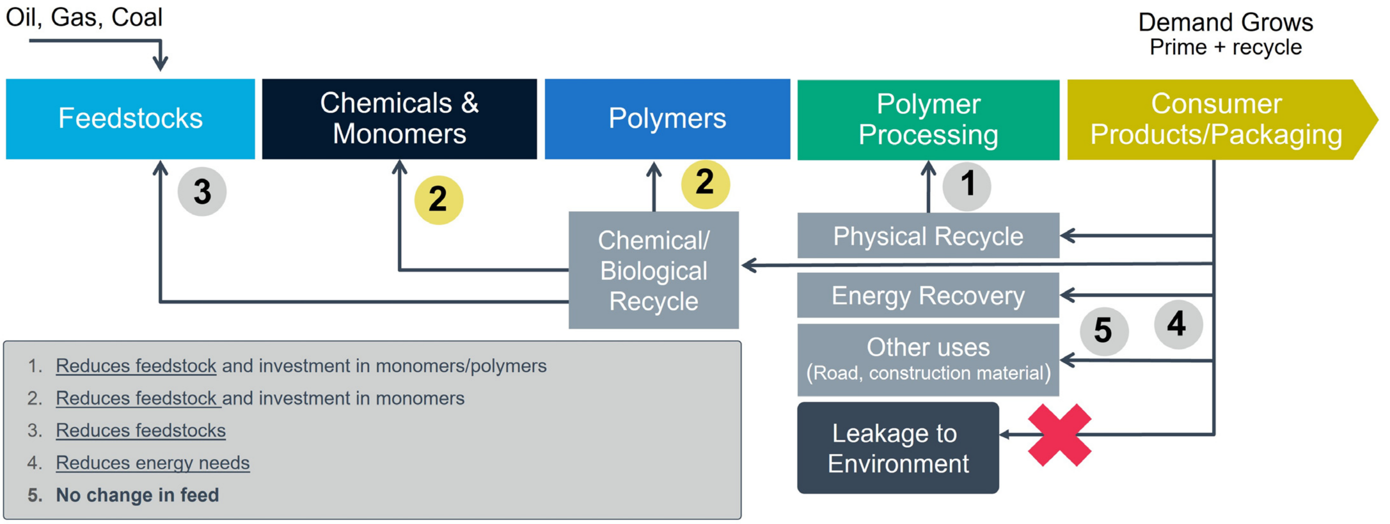
The petrochemical industry presents several challenges for the implementation of CBAM, discussions around this topic continue and no clear decision has yet been made as to its path to adoption. The difficulty for petrochemicals is the vast range of products, and often complex nature of those products, that could potentially be covered by CBAM. The European market imports a large volume of converted goods, several of which have substantial quantities of emissions embedded within them. At some point, the ability to determine that carbon footprint will be unviable, but allowing products to enter without falling under CBAM will put local producers at a cost disadvantage. CBAM may protect the producers in sectors that it covers but it does push the loss of competitive position further downstream.

The range of carbon taxation and emissions trading regimes will make CBAM implementation that much more difficult. It is likely that CBAM will also face challenges from exporting nations through the World Trade Organization and other trading bodies as the mechanism may breach various trading agreements on import taxations. It is unlikely to a smooth ride for CBAM and those exposed to it, with the level of complexity in implementation in the petrochemical industry making it that much more of a challenge.

Plastic Circularity

Plastics have been a major enabler for the development of economies around the globe. Despite numerous societal benefits, the widespread proliferation of plastics has led to the unintended consequence of waste leakage to the environment, which is problematic because virtually all plastic material does not decompose very quickly and creates many negative issues for the environment. The world needs a solution to this leakage that simultaneously protects the environment and maintains the societal benefits that plastics consumption affords. Outright bans on plastics is a solution, but alternatives to plastics are less environmentally friendly. Thus far, the solutions have focused on policies and practices that support collecting and containing waste plastic, then allowing science to create the best solution to close the plastic loop. Each path for closing the loop will have different impacts across the value chain, some are impacting the propylene demand growth.

Sustainability: First Collect, then Contain, then "Smartly" Re-Use



Source: Chemical Market Analytics by OPIS

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As developing populations and economies grow, the consumption per capita of plastics will grow, which will promote the growth of propylene value-chain plastics. The demand growth is also dependent on the 4R's of plastic applications: redesign, reduce, repair, and re-use. In an optimized 4R world, some plastic will continue to be used and a process to close the recycle loop on this remaining plastic will be required. The loop closers will fall into two broad categories of post-consumer waste recycling: mechanical and chemical. Mechanical recycle consists of physically sorting through plastic waste and blending that recovered material with virgin plastic. Chemical recycle consists of returning the plastic to a form that can be injected upstream of polymer processing / blending. This can take the form of depolymerization or conversion back to a feedstock injected into the front of the value chain.

With a defined plastic demand from the drivers above, how much propylene is needed then will be a function of chosen economic path to close the loop. From the chart above, assuming a constant plastic demand, paths 1 and 2 will reduce needs for propylene supply, but paths 3, 4, and 5 will all require more propylene. Where this loop closes becomes a critical assumption for propylene demand growth. In addition, where this loop closes and how much volume of plastic is recycled will also have major implications for the feedstock supply and economics. The more waste plastic that is recycled, the less oil-, natural gas-, and coal-based feeds will be necessary to support the chain, which could lower the investments and operating costs. Moving from mechanical to chemical recycling also comes with some carbon emissions penalties that also will drive the recycling economics in the future. As the world of the recycling evolves, so will its impact on the propylene value chain.

North America

- As of 2023, total supply of propylene (including polymer/chemical-grade propylene and refinery-grade propylene for chemical applications) in North America is estimated at 16.1 million metric tons, which reflects a recovery after dropping to 15.1 million metric tons in 2020 owing to the pandemic effects and rebounding to previous levels in 2021. Despite capacity additions of 2 million metric tons, annual production is, on average, only forecast to grow at a comparably slow pace of 1% in the next five years, mainly driven by a weaker demand outlook and the downcycle in 2023/24. However, when considering the developments over the next 10 years, production levels are expected to improve and grow at a rate of 1.8% annually, with an additional 2.5 million metric tons of hypothetical capacity included in the outlook for the period 2028-33.

- North America supply growth during the next 10 years is mainly driven by investment in on-purpose production. Supply growth from steam cracking is limited as low-propylene-yielding ethane remains the preferred feedstock throughout the forecast period, although cracker operators may move liquefied petroleum gas (LPG) into the feedslate in the short window when the economics are favorable. Supply growth from steam crackers, which accounted for about 27% of the regional output at roughly 4.4 million metric tons in 2023, will continue to follow a downward trajectory over the next 10 years as new capacity built to meet the regional ethylene demand will continue to favor advantaged ethane feedstock.

- In response to the pandemic-induced reduction in fuel demand, the production of refinery-grade propylene (RGP) for the chemicals market slumped to 8.2 million metric tons in 2020, but then rebounded to about 9.0 million metric tons in 2021. The subsequent two years saw slightly lower output again on the back of weakening demand and global oversupply. From a longer-term perspective, the lingering behavioral changes in the aftermath of the COVID-19 pandemic will continue placing downward pressure on gasoline demand and margins. Such trend changes will encourage refiners to optimize their refining configuration and produce higher-valued petrochemicals amid steadily rising chemical demand; a few refiners are considering this or have already moved in this direction. Therefore, RGP production is forecast to grow and reach a volume of about 9.3 million metric tons by the end of the 10-year forecast period to 2033 and about 11.5 million metric tons by 2050, with most of that growth expected to be seen in the United States. Canada produced around 550,000 metric tons of RGP for chemicals in 2021 and while the volumes for 2022-23 were assessed at levels above 600,000 metrics tons, the output is projected to trend lower again in the longer term. Even though the Mexican government has laid out plans to improve operations and even build a new refinery, these initiatives can be difficult to accomplish, at least during the 10-year forecast period. The current outlook includes some hypothetical RGP and FCC splitter capacity for 2023 onward.

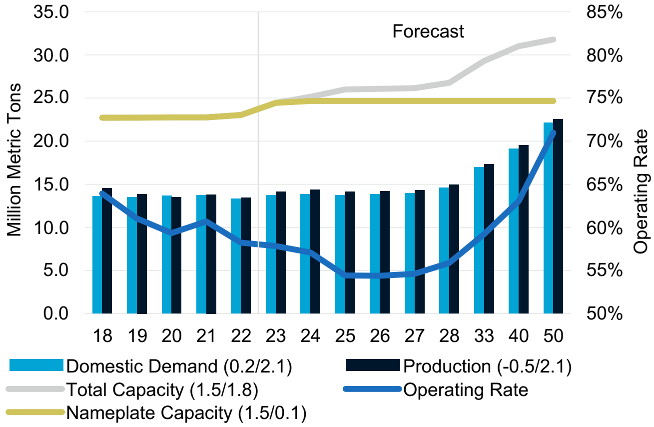
- From an on-purpose standpoint, North America's propylene production from propane dehydrogenation (PDH) facilities and metathesis units is estimated at about 16% and 5%, respectively, in 2023. Several new PDH units are either already onstream or planned to be added in the next couple of years. In 2022, Inter Pipeline commenced operations of their 525,000 metric ton per year PP-integrated unit in Alberta, Canada. In the US, Dow has completed the set-up of a pilot plant which applies the company's fluidized catalytic dehydrogenation (FCDh) technology in one of their mixed-feed crackers in Plaquemine, Louisiana to produce 150,000 metric tons per year of on-purpose propylene. Enterprise's second PDH unit at Mont Belvieu, Texas with a PGP capacity of 750,000 metric tons per year commenced operations in the second quarter of 2023. The FID for Canada Kuwait Petrochemical Corporation's (CKPC's) 550,000 metric ton per year PDH project in Alberta was made in February 2019, and the unit was originally forecast to come online by 2024. Due the frozen capital spending on this integrated PDH/polypropylene (PP) plant, the timeline for this still hypothetical capacity was pushed back to 2028 and more recent information indicates that the project was scrapped. Formosa Plastics Group's 600,000 metric ton per year unit in Point Comfort, Texas was expected to come online by 2025, but the company has not provided any official decision on the project. Meanwhile, Formosa's Sunshine project (two phases) in St. James Parish, Louisiana, which would include a PDH unit and started preconstruction activities in 2020, remains on hold due to unresolved environmental issues related to the site.

- The region's domestic demand is not expected to reach its 2007 peak level of nearly 15 million metric tons (polymer-grade propylene [PGP] and chemical-grade propylene [CGP]) until 2023, after several new derivatives units that will have been added (Braskem's polypropylene (PP) unit started in the second half 2020, Inter Pipeline's PP unit in mid-2022, LyondellBasell's propylene oxide/tert-butyl alcohol (PO/TBA) plant in mid-2023, and ExxonMobil's PP and Vistamaxx units, in 2022 and 2023, respectively). The pandemic-induced global recession in 2020 wiped out a year of demand growth, but combined demand for PGP and CGP bounced back to pre-pandemic levels quicker than originally anticipated in 2021 and is estimated at around 13.7 million metric tons in 2023. Domestic demand for propylene is expected to increase annually by 1.2% through 2028 and 2.1% through 2033. With the addition of new derivative units, regional demand is set to increase by about 3.2 million metric tons in the next 10 years, reaching a volume of almost 17.0 million metric tons in 2033.

- North American propylene demand sees a higher distribution to non-PP derivatives than the other key regions, which typically have 65–80% demand share for PP. Based on total propylene demand, the region only has around 52% PP share in 2023. The shift in propylene derivative manufacturing away from commodity resins, such as PP, toward other derivatives, such as PO, was driven by differences in the degree of competition in the global markets. While the Middle East and Southeast Asia have focused on the PP market with supplies from substantial capacity additions, only a limited number of other propylene derivative projects were previously seen in these two regions. Therefore, the high margins that are associated with these non-PP derivatives are attracting investment in new plants. However, demand for PP is still projected to increase faster than the other derivatives in the region and will likely account for a sizable 88% share of the nearly 3.3 million metric tons total propylene domestic demand growth occurring over the next 10 years, with the PP demand share reaching about 58% by 2033 and 64% by 2050. As the market accommodates the new supply, future investments in propylene production are likely to be made concurrently with downstream propylene derivative investments as well.

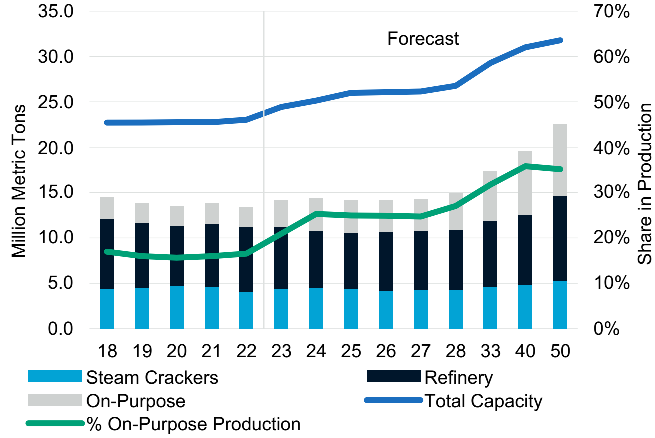
- On a net equivalent basis considering both propylene monomer (PGP and CGP only) and propylene contained in its derivatives, North America has been a moderate net exporter with an average annual volume of about 1.2 million metric tons seen in the period from 2017 to 2020. Shortages in supply combined with increasing demand, especially for PP, has moved to region close to balance in 2021 but this trend has already been reverted again in 2022North America's net export position is expected to strengthen further over the 10-year forecast period to 2033 and beyond as both propylene and propylene derivative assets are added at a faster pace than domestic demand growth. On a country basis, the US is a large net equivalent exporter, with an annual volume of 2-3 million metric tons registered in the last 5 years, while Canada and Mexico were both net importers in the past. Mexico's net import requirement, which has been around 1.5 million metric tons in the last three years, is forecast to continually grow which will mainly be driven by the increasing demand for PP. Following the start-up of new PDH and PP producing capacities in 2022, Canada's requirement for propylene equivalents has declined significantly in 2023, moving the country to a balanced or even small net export position in the next couple of years. Longer term, Canada is projected to become a net exporter of about 1 million metric tons of propylene equivalents, with PP accounting for the largest portion.

North America: PG/CG Propylene Supply & Demand



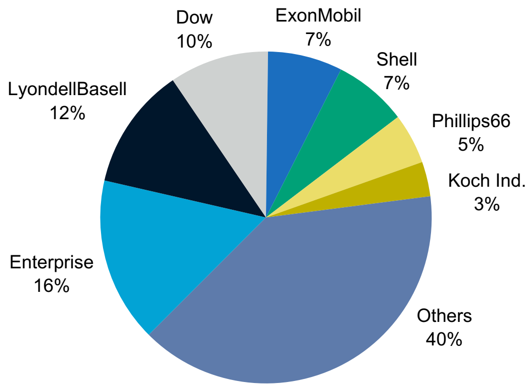
(% AAGR = 18-23/23-33)
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

North America: PG/CG Propylene Production by Source



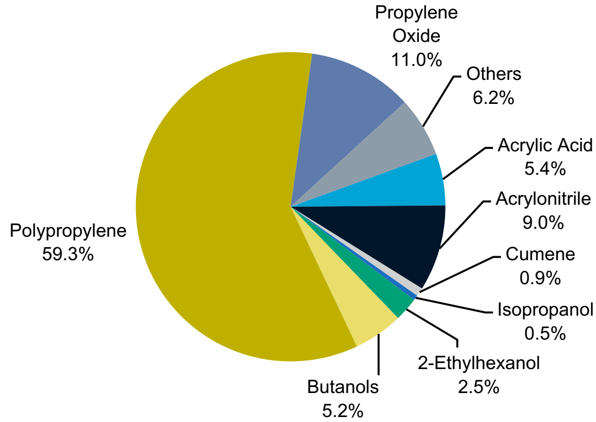
Note: Steam crackers and refinery data include the respecetive crude to olefins production.
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

North America: 2023 PG/CG Propylene Producers by Shareholder



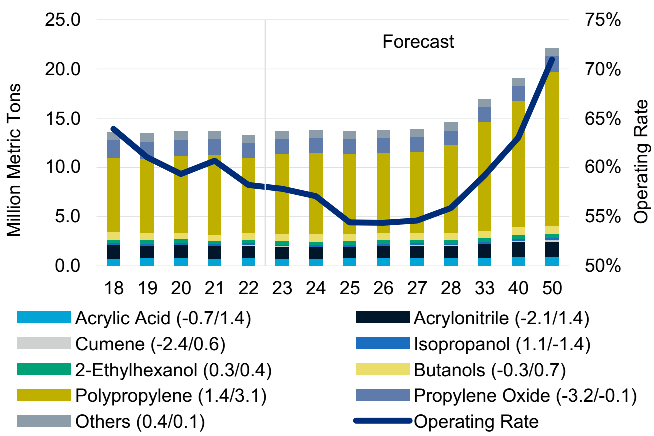
Capacity = 24.4 Million Metric Tons
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

North America: 2023 PG/CG Propylene Demand by End Use



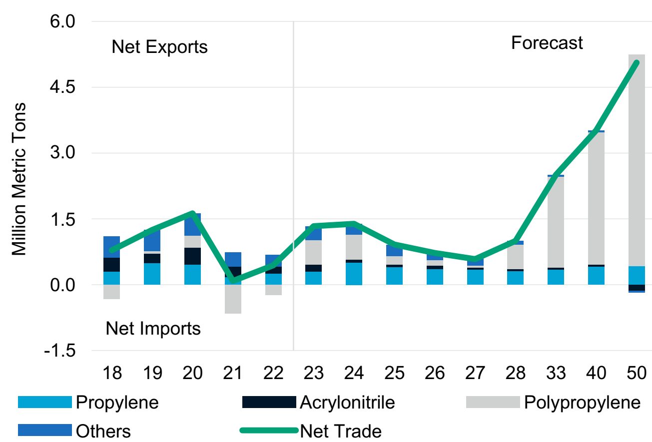
Domestic Demand = 14.6 Million Metric Tons
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

North America: PG/CG Propylene Demand



(% AAGR = 18-23/23-33)
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

North America: Propylene Net Equivalent Trade



Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

South America

- South America still only accounts for a little more than 2% of the global polymer-grade/chemical-grade propylene production and demand in 2023 despite being home to nearly 7% of the world's population. Within the region, Brazil remains the largest producing and consuming country, accounting for more than 80% of the region's supply and roughly 70% of demand. Given the strong presence of the oil industry in the region, refinery-based propylene production plays an important role. Over the past five years, fluidized catalytic cracking (FCC) splitters contributed nearly half of the total propylene supply, with the remainder coming from steam cracking.

- Future supply growth via both crackers and refining is not enough to meet the region's growing demand for propylene-based goods, and supply will have to come either through increasing imports or the development of on-purpose assets. The most feasible on-purpose propylene project is a metathesis unit supplied by increasing ethylene production in the region, leveraging the abundant natural gas (with associated NGL's) from the Vaca Muerta shale gas field in Argentina and the offshore "pre-salt" fields in Brazil. The shale fields of Argentina could provide propane to feed a potential propane dehydrogenation (PDH) unit. However, the current outlook doesn't include any on-purpose production capacities in the extended forecast period to 2050 but assumes that longer term, about 180,000 metric tons of co-product propylene could potentially be added via new naphtha-based steam cracker capacity in Brazil.

- More than 80% of South America's propylene demand comes from polypropylene (PP), which has driven monomer capacity increases in the past. Demand growth in the region is likely to continue as the region's population moves up the income curve. It is notable that investment in new capacity is somewhat constrained by the proximity of the region to the new low-cost capacity existing and planned in North America, which can leverage advantaged feedstock supply and low freight rates to South America. This situation is evidenced by the fact that Braskem preferentially invested in expanding PP capacity in the US rather than Brazil. Apart from BASF's new acrylic acid plant in Brazil, which came online in 2015, no other major propylene derivative plant has been added in the past 10 years.

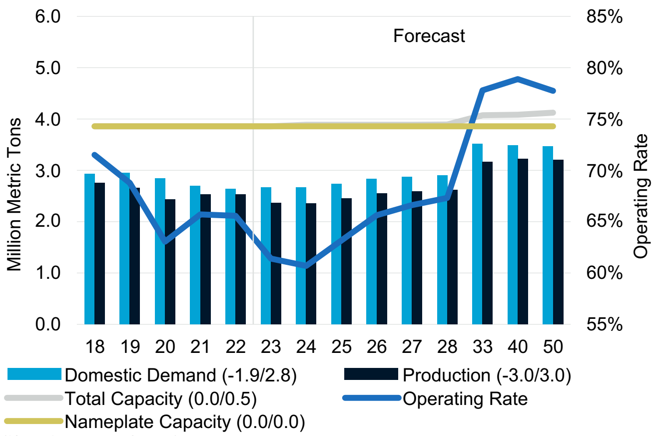
- The COVID-19 pandemic had a significant impact on propylene demand in South America, with a 13% demand decline registered for the period from 2019 through 2021. Overall propylene demand has not rebounded in the period 2022-23 and will likely remain weak in 2024. Therefore, it is not expected that pre-pandemic levels will be reached again before the end of the decade. Longer term, domestic demand in South America is forecast to increase slightly as new capacities for polypropylene, acrylic acid and 2-ethylhexanol are added a and then remain stable around a level of 3.5 million metric tons.

- Notably, any future derivative capacity additions are contingent on improving economic conditions in the region, particularly within Brazil, as well as adoption of pro-business policies that ensure secure investments in the petrochemical space. Until such time, overall regional demand growth for propylene derivatives will be met by increased imports of the derivatives themselves, semifinished goods, and finished goods.

- South America has historically been a comparably small net importer of propylene and propylene equivalents contained in derivative trade. Amid increasing consumer demand, the region's net equivalent import position was still below 600,000 metric tons in 2020 and reached a new high level of about 1.2 million metric tons 2021, with a similar volume estimated for 2023. This is not expected to change much in the next 5-10 years, as any propylene and propylene derivative capacity added in the region falls short of demand. The region's net equivalent import position is expected to move up slightly to an average level of nearly 1.4 million metric tons during the 10-year forecast period to 2033. The later years of the current decade could see net equivalent trade volumes increase to almost 1.6 million metric tons until the potential new PP capacities in Brazil will help to reduce the dependence on imports, at least temporarily.

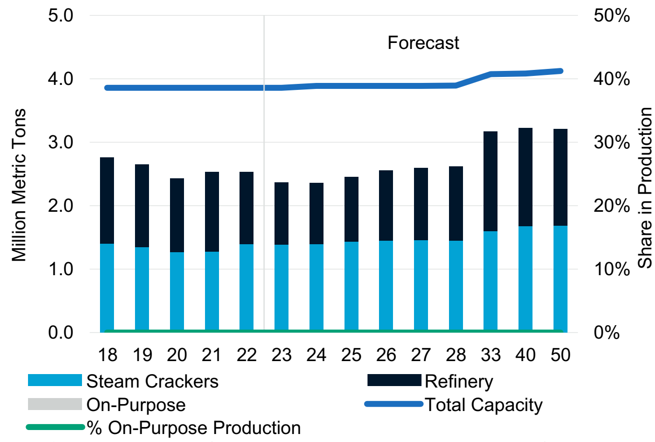
- PP will continue to be the driving force for increased propylene net equivalent trade volumes moving into the region. North America, Northeast Asia (particularly South Korea), and the Middle East will remain key PP suppliers to the region, with imports increasingly coming from North America in the forecast years through new PP capacities coming online in the US and Canada. In the later part of the extended forecast period to 2050, South America's net imports are projected to reach a volume of 3 million metric tons, more than 80% of this will be PP.

South America: PG/CG Propylene Supply & Demand



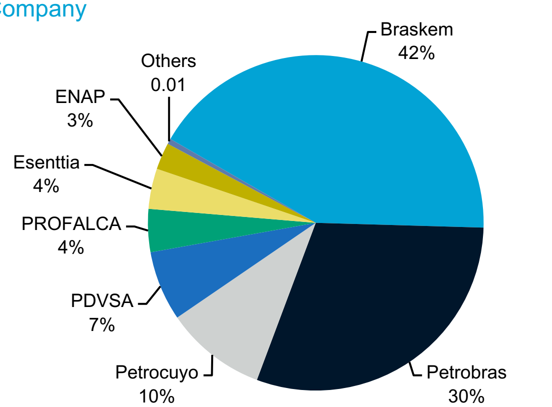
(% AAGR = 18-23/23-33)
Source: Chemical Market Analytics by OPIS

South America: PG/CG Propylene Production by Source



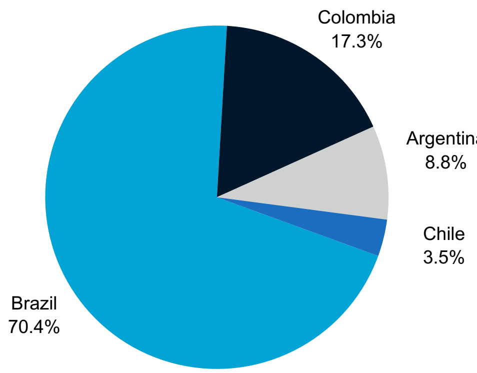
Note: Steam crackers and refinery data include the respecetive crude to olefins production.
Source: Chemical Market Analytics by OPIS

South America: 2023 PG/CG Propylene Producers by Company



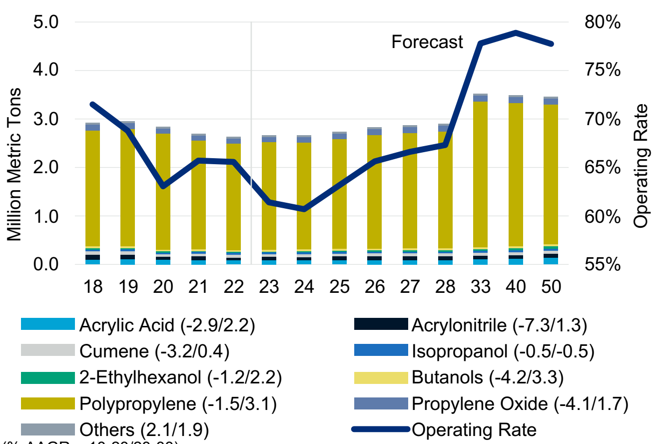
Capacity = 3.9 Million Metric Tons
Source: Chemical Market Analytics by OPIS

South America: 2023 PG/CG Propylene Demand by Geography



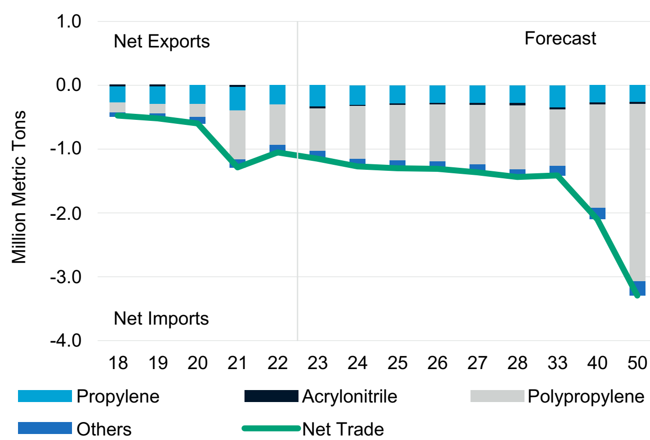
Domestic Demand = 2.7 Million Metric Tons
Source: Chemical Market Analytics by OPIS

South America: PG/CG Propylene Demand



(% AAGR = 18-23/23-33)
Source: Chemical Market Analytics by OPIS

South America: Propylene Net Equivalent Trade



Source: Chemical Market Analytics by OPIS

West Europe

- In the last decade, the closures of steam crackers in Italy, and France, as well as refinery shutdowns in France, Germany, and the UK, have resulted in a net reduction of the nameplate propylene capacity in West Europe. Furthermore, the years before the pandemic saw a large swing in feedstock usage, with considerably increased use of ethane and continued ingress of propane and butane into what have traditionally been naphtha crackers. This shift has resulted in a large decline in the volume of propylene that is being produced as a coproduct in steam crackers and there have been some adjustments to compensate for this large loss of supply. The additional ethane used in European steam crackers is being sourced from the US, with a combined loss of propylene supply from the various deals to import ethane assessed to be 400,000–500,000 metric tons. Alongside the infrastructure to use US ethane, smaller-scale investments have been underway to optimize the usage of refinery sources of fluidized catalytic cracker (FCC) off-gas as well as utilize the European-sourced ethane that has been backed out of others' systems by the imports. After two years of unattractive LPG cracking economics, 2022 and 2023 saw a dramatic shift with propane favored consistently throughout the period whilst butane has also been in use for most of the time. However, the various ethane importers have been heavily impacted by unplanned and long-term planned outages over this period. The result has been a reduced level of propylene output in 2022 and 2023, in addition to the relatively low utilization rates on steam cracker operations.

- Regional supply reached a peak level of more than 14 million metric tons in 2016, but it has been in decline since then. The year 2023 saw the lowest level of propylene supply from steam crackers in over 30 years, 2022 production levels were similarly depressed. Given the lull in consumption levels of lighter steam cracker feedstocks during the pandemic, there was slight recovery after the trough in 2019, but propylene production has since declined. About 70% of the total propylene supply is currently sourced from steam crackers and 24% comes from FCC splitters, whereas on-purpose production via propane dehydrogenation (PDH) and metathesis still only makes up for 5% and 2%, respectively.

- The historical losses in propylene supply from steam crackers were seeing the additional pressure from refinery supply as refineries come under increasing pressure to reduce capacity in a shrinking fuels market. Traditionally, FCCs have been a steady source of income for refineries and the flexibility to generally ensure a high output of propylene even with lower FCC throughput has kept supply steady. The pressure on fuels demand during 2020 and 2021 accelerated the urge for refinery operators to act with the closure of the Total (now TotalEnergies) refinery in Grandpuits, France, and PetroINEOS' FCC unit in Grangemouth, UK, in 2021. In 2022, the invasion of Ukraine by Russia forces and resulting wave of sanctions and restrictions on Russian trade served as catalyst for a sharp reversal of fortune for European refineries. The large loss of supply of refined products from Russia pushed European refineries to run at high rates and profitability for these units increased sharply. While propylene output was supported by these changes, rebounding after the collapse during the pandemic, the long-term risk of further refinery closures remains. However, the shift in focus for many refinery operators to increase the proportion of chemicals produced, including propylene, will bring some additional supply to compensate, at least in part, for those losses. There may be other opportunities for refineries that survive the coming years to increase their yields, although it is more likely that closures will outpace expansions and refinery output will not recover enough to reach the levels seen 4-5 years ago.

- With the structural loss of output already seen and the persisting risk of further reductions, Europe has had to consider options to fill the gap in propylene supply so as to ensure continued operations on derivative plants; the alternatives would be derivative capacity closures to structurally reduce demand. Long-term solutions have been under study for some time, with on-purpose sources of propylene being considered. The next increase was set to be the Borealis dehydrogenation unit, which is now likely to commence operations in 2025 given the delays seen because of COVID-19 restrictions and contractors challenges. This unit will have a capacity of 750,000 metric tons and be the second dehydrogenation plant located at the Kallo site near Antwerp, Belgium. Associated with the unit, Borealis plans to lift polypropylene capacity, although the scale of these plans has been much reduced, leaving the majority of this capacity set to decrease their purchase requirement. The second project proposed is by INEOS, which has considered to add 750,000 metric tons of capacity in Antwerp with a dehydrogenation investment. Progress on the plan has slowed dramatically as all focus has shifted to the associated ethane cracker. The project made it into the engineering stage, but it will likely be some time before further progress is made. However, should downstream assets return to more normalized rates and the derivative industries do not see widespread closures, the large shortage of propylene in the INEOS system, and the structural shortage that would then be seen in Europe would support such a stand-alone investment.

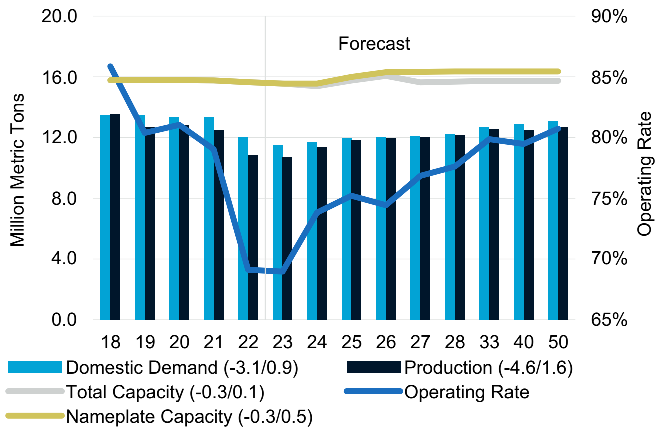
- Closures of steam cracker capacity in 2022 impacted propylene supply, with the closure of the Versalis cracker (490,000 metric tons ethylene capacity) in Porto Marghera, Italy, in May 2022 tightening the Mediterranean balance significantly. Further closures are also expected in the coming years. The pressure on propylene sourced from steam crackers may escalate with building of an ethane cracker in Antwerp. The INEOS Project One cracker, part of the same investment as the dehydrogenation project, is based on imported US ethane and will displace a significant volume of purchased ethylene. This will in turn put pressure on other European crackers and likely lead to closures, the consequence of which would be a reduction of propylene supply.

- Overall, propylene demand had been stable in West Europe for several years, reflecting both stable end-use markets but also limitations on supply. The modest declines of consumption levels seen in 2017 and 2018 were compensated by a large increase in net equivalent imports, demonstrating the higher domestic derivative demand, with reductions in domestic supply offset by imports of derivatives. In 2022, the impact of the war in Ukraine and resulting escalation in energy costs left European derivatives with a highly uncompetitive cost position that caused dramatic reductions in production. The concern over European economic growth given the energy crisis has only further depressed demand. A forecast return to higher demand will require increased imports of propylene derivatives to meet domestic demand growth in the long term. However, in the short term, with new PDH capacity onstream, the region is expected to see trade flows stabilize with a high level of imports. Demand growth for derivatives will align with economic growth, which, although at a low level, will be sufficient to ensure the new capacity is fully absorbed during the 10-year forecast period to 2033.

- West Europe has historically been a net exporter of propylene derivatives, which was primarily attributed to the large volume of polypropylene (PP) exports. However, the gradual and ongoing loss of PP export markets to competitive Middle Eastern producers has not only resulted in a significant decline of net exports, sitting with a net import position in the future. When the combined trade for both propylene monomer and equivalents (propylene traded in the form of its derivatives) is considered, the transition from a net exporter to a net importer, which was originally anticipated to occur in 2019, actually happened in 2022, West Europe will remain a net importer in the future.

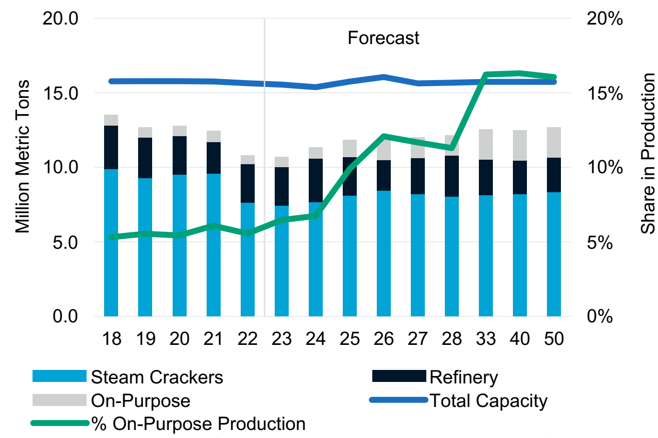
- Despite the forecast for the propylene market, West Europe will likely continue to look for imports of propylene monomer from Central Europe, though the historical supply from Russia came to an end in 2022 and is not expected to return. Therefore, Europe will be left to rely on other sources such as the US, Middle East, and Asia. This will prove increasingly difficult as regional balances in the US and Middle East are shifting tighter whilst Asian exports of derivatives may well prove to be a better option than shipping monomer. West Europe will continue to be a net importer of propylene monomer. However, from 2025 onward, monomer import requirements will decline as local supply increases.

West Europe: PG/CG Propylene Supply & Demand



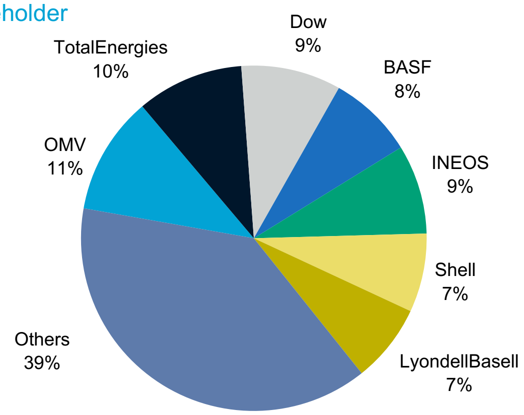
(% AAGR = 18-23/23-33)
Source: Chemical Market Analytics by OPIS

West Europe: PG/CG Propylene Production by Source



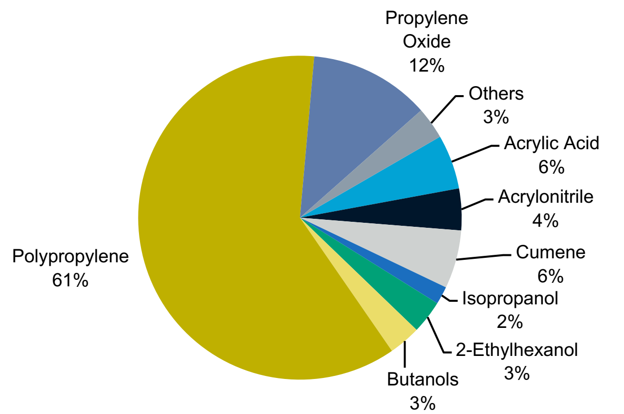
Note: Steam crackers and refinery data include the respective crude to olefins production.
Source: Chemical Market Analytics by OPIS

West Europe: 2023 PG/CG Propylene Producers by Shareholder



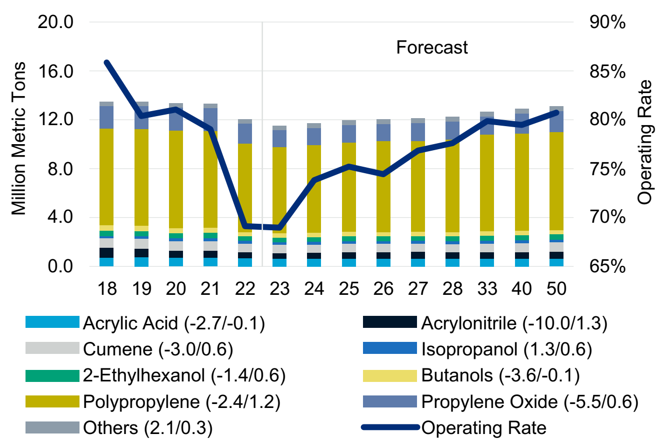
Capacity = 15.6 Million Metric Tons
Source: Chemical Market Analytics by OPIS

West Europe: 2023 PG/CG Propylene Demand by End Use



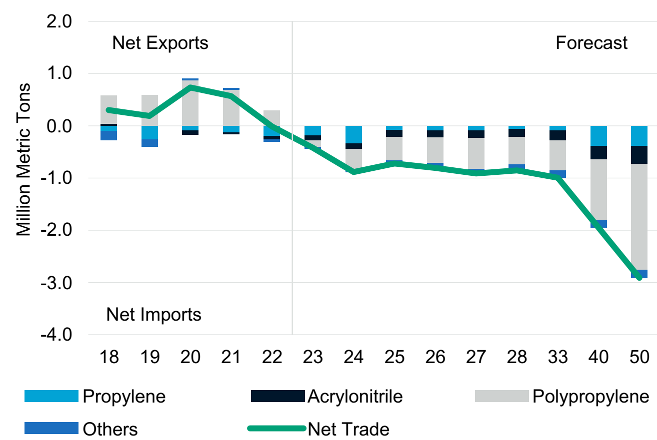
Domestic Demand = 11.5 Million Metric Tons
Source: Chemical Market Analytics by OPIS

West Europe: PG/CG Propylene Demand



(% AAGR = 18-23/23-33)
Source: Chemical Market Analytics by OPIS

West Europe: Propylene Net Equivalent Trade



Source: Chemical Market Analytics by OPIS

Central Europe

- Central Europe is a comparably small propylene-producing region, accounting for 1.3% of global capacity. Regional propylene supply has been limited over the last 10–15 years because steam crackers and refinery capacities were uneconomical compared with the new, more efficient units that started up globally. Thus, steam cracker utilization was placed under pressure from growing imports.

- The invasion of Ukraine by Russia forces in February 2022 has had a major impact on the outlook for petrochemical operations in Central Europe. The industry has been almost entirely reliant on the supply of feedstock from refineries utilizing Russia crude oil, supplied through the Druzhba pipeline. The pipeline runs from Russia through Belarus and into Poland or via Ukraine into Hungary. The imposition of western sanctions and self-sanctioning by western companies has reduced access to Russia oil and pushed many operators to shift to alternative supply sources, not a straightforward, and somewhat costly, transition. When combined with the increase in natural gas costs, the result has been a notable increase in cost position for producers. The allowance under EU sanctions for continued supply of pipeline crude oil into 2023 has brought some relief and for those willing to trade with Russia as well as time for those needing to optimize alternative supply sources.

- Based on 2023 data, the total nameplate capacity for polymer-grade propylene (PGP) and chemical-grade propylene (CGP) in Central Europe amounts to a little more than 2 million metric tons, which is slightly above the historical high of 1.9 million metric tons. The lower capacities seen in the years following 2008–09's global recession were caused by a wave of closures and rationalization. The rebound can mainly be attributed to additional refinery-based production in Bulgaria, Croatia, and Romania, as well as the start-up of a new on-purpose production plant in Poland. In early 2018, Polish producer Orlen (formerly PKN Orlen) completed the construction of a metathesis unit at their Płock production site. The new plant became fully operational in 2019 and has a capacity of 100,000 metric tons, increasing Poland's total nameplate PGP capacity to 585,000 metric tons per year. The planned start-up of additional on-purpose capacity in the form of the Grupa Azoty PDH plant in Police, Poland has been pushed back from the original date in 2023 and now shows an effective capacity increase in 2024.

- Even though some additional capacity became available from refineries in 2005–06 and, most recently, from a new metathesis unit in Poland, propylene production is still mostly associated with steam crackers. So far, only one new steam cracker project has been announced for the forecast period to 2033. Orlen's Olefins Complex III, planned to be built at the Płock site in Poland, will replace one of the older crackers and add, on net basis, 400,000 metric tons of ethylene and about 205,000 metric tons of propylene. The new capacity was assumed in the forecast to become available in 2025, though labor issues are now pushing the start-up date further back. Given the lack of advantaged feedstock in the region, any further increase in the regional nameplate capacity will likely be limited to the expansion of existing crackers, cracker integration with refining assets or the construction of another metathesis or propane dehydrogenation (PDH) unit later in the forecast period.

- The Grupa Azoty project made steady progress to mechanical completion; the PDH unit in Police, Poland, has completed construction though has faced some challenges in the commissioning phase delaying start-up by several months. The plant with a capacity of 430,000 metric tons will be integrated with a polypropylene (PP) unit. The start-up was originally planned for 2022, but has been delayed, despite swift progress in 2021, and assumed to be operational in late-2023, though this has not been achieved. Additionally, MOL is arranging for a metathesis plant at the refining and steam cracker complex in Tiszaujvaros, Hungary in order to supplement other propylene optimizations in their system and supply a new propylene oxide and polyols plant that is already under construction. The propylene project is planned to be onstream in 2024, a year after the derivatives.

- Similar to ethylene, regional production volumes for propylene decreased from 2007's peak (albeit to a slightly lesser extent) because of a larger-than-usual portion of refinery-based propylene that has been partly compensating for the losses from steam crackers. However, the large drop in supply seen in 2016 was mainly caused by the temporary shutdown of the Orlen Unipetrol cracker in Litvinov, Czechia. The unit went offline after an accident in August 2015 and restarted in October 2016 after extensive repairs. Since then, propylene production volumes have recovered and are estimated to have reached an annual level of over 1.6 million metric tons in 2023. Between sluggishly improving demand and an increase in the total nameplate capacity base, production levels are forecast to increase further to a volume of nearly 2.3 million metric tons in the forecast period to 2033 and beyond.

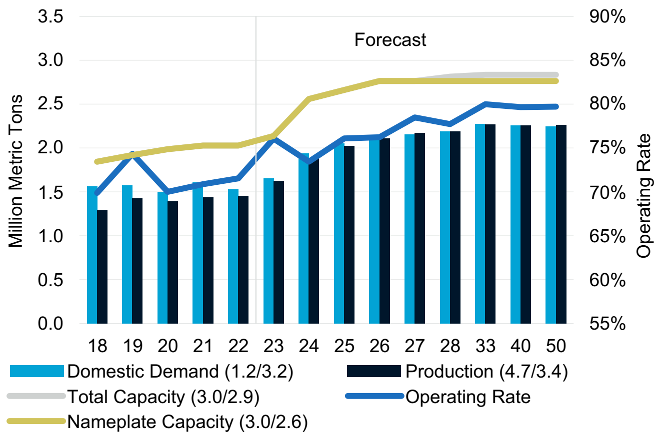
- Based on 2023 estimates, about 58% of the total regional supply of PGP and CGP is sourced from steam crackers, while fluidized catalytic cracking (FCC) splitters account for 30% and projection for in-purpose supply making up the balance, though this is likely to be lower given delays in the Grupa Azoty start-up. Driven by the addition of new capacities, the share of on-purpose production is projected to increase to about 25% by 2032, which will likely reduce the supply share from steam crackers and FCC splitters to 52% and 23%, respectively.

- On a company basis, Orlen (formerly PKN Orlen), MOL Petrolkémia (formerly TVK), Orlen Unipetrol (formerly Unipetrol RPA), and Slovnaft were the four largest producers of propylene in the region in 2023. The Slovakia-based Slovnaft benefits from additional refinery-based production that accounts for half of their propylene capacity. Orlen and Orlen Unipetrol are both wholly owned subsidiaries of the Orlen Group, while MOL Group is the major shareholder of both MOL Petrolkémia and Slovnaft. On a shareholder basis, Orlen and MOL will likely remain the two largest regional players in the next 5–10 years, though their share of the market will be reduced somewhat by the entrance of Grupa Azoty.

- In Central Europe, propylene is mainly consumed by PP production, which accounted for about 78% of domestic demand in 2023. This is slightly higher than the mid-70% levels seen over the past 5 years. The percentage share in demand is not expected to change much in the next 10 years, with additional polypropylene demand being meet both domestically and through imports whilst growth in production of other derivatives will maintain the balance. As a result of the increase in propylene oxide capacity in Hungary, the segment is projected to exhibit double-digit growth on a percentage basis in the next 5 years. Most of the other propylene derivatives are not likely to drastically change their percentage share of the total consumption during the 10-year forecast period, with scope of increase domestic supply given the comparatively low current rates of utilization.

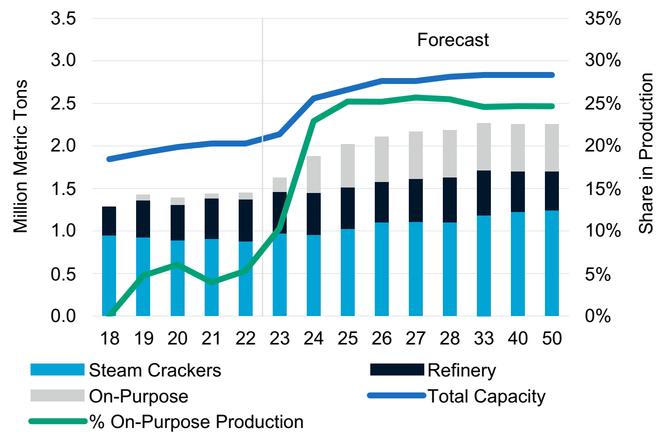
- Central Europe has been a net importer of propylene monomer, with an average annual requirement of about 130,000 metric tons seen in the last 5 years. Major propylene exports typically originate from Hungary, Romania, and Serbia, with material mainly being moved between countries within Central Europe and sometimes to Western Europe. Supported by the start-up of new capacities, most notably in Poland, propylene monomer imports are projected to decline in the next couple of years, eventually moving the region to a small net exporting position by 2026. While the total net equivalent trade volume increased steadily up to 2021, economics headwinds have stifled demand growth and trade balances have swung into reverse, firmer refinery operations also supporting local supply. Moving forward the lower level of net equivalent imports—mainly PP— is expected to be stable as local supply meets growing demand expectations. It is projected to increase further to reach volumes of more than 1.5 million metric tons by the end of the 10-year forecast period in 2033.

Central Europe: PG/CG Propylene Supply & Demand



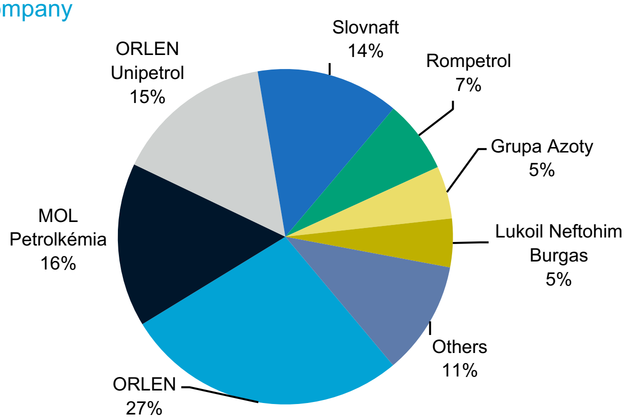
(% AAGR = 18-23/23-33)
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Central Europe: PG/CG Propylene Production by Source



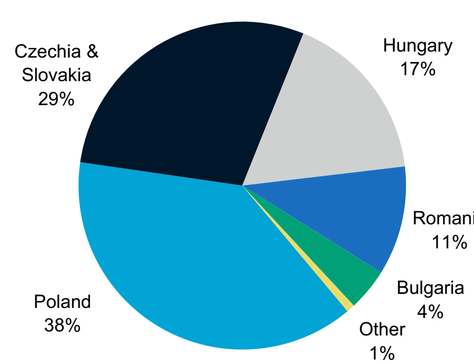
Note: Steam crackers and refinery data include the respecetive crude to olefins production.
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Central Europe: 2023 PG/CG Propylene Producers by Company



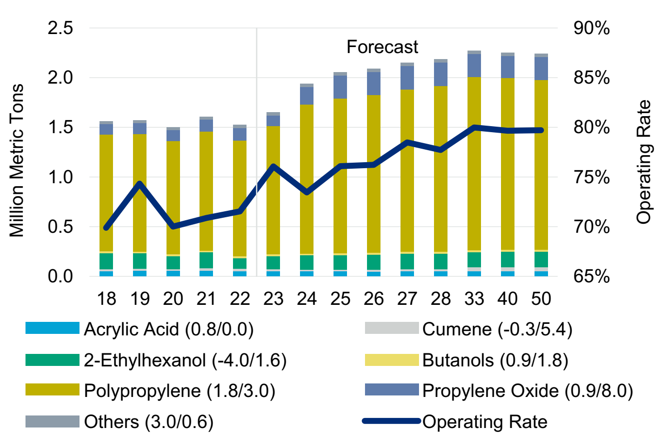
Capacity = 2.1 Million Metric Tons
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Central Europe: 2023 PG/CG Propylene Demand by Geography



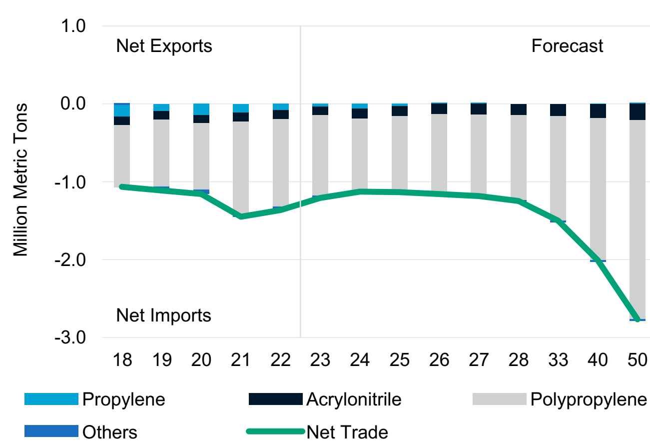
Domestic Demand = 1.7 Million Metric Tons
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Central Europe: PG/CG Propylene Demand



(% AAGR = 18-23/23-33)
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Central Europe: Propylene Net Equivalent Trade



Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

CIS & Baltic States

- CIS and Baltic States refers to the region comprising the Commonwealth of Independent States (for the most part the countries of the former Soviet Union: Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan) as well as the three Baltic States of Lithuania, Estonia, and Latvia. Despite its large territory, the region still only accounts for less than 3% of the global polymer-grade/chemical-grade propylene capacity and demand. About 72% of the total nameplate capacity is located in Russia.

- Strategically positioned at the crossroads between Europe, Asia, and the Middle East, Russia has a great deal of influence concerning developments in the rest of the CIS region. With its petrochemical industry growth, Russia has potentially enhanced the development of the whole region, as it is rich in raw materials and interested in investments aimed at development and modernization of its industrial base. However, the current realization of its potential has been impeded by existing political and socioeconomic circumstances, which include a sharp drop of crude oil prices in late 2014 and a subsequent recession in an economy that is highly dependent on the export of raw materials. This situation led to a devaluation of the ruble in 2014–15, which presented difficulties in financing planned projects in the petrochemical industry, in addition to the political risks and economic measures taken by Western countries and the US in response to the Russia–Ukraine military conflict. The scenario was repeated in 2020, with a reduction in oil processing and the political developments in the region being criticized and penalized by Western democracies.

- The developments of 2022 have the potential to not just change the outlook for the region but also the entire map of the region. The emergence of a new divide in eastern Europe has become a reality in 2022. The full-scale invasion of Ukraine by Russia in February of 2022 has quickly changed the political environment, not just of the region, but of the world. The invasion and occupation of the Crimean Peninsula in 2014 catalyzed almost no reaction from western states, in part due to the large majority of pro-Russian citizens of Crimea. However, the attack on Ukraine and tactics of suppression and destruction has drawn widespread condemnation and brought significant support from western states, with supply of weapons, intelligence, and aid. There is no going back for Russia or Ukraine and the impact on the petrochemical industry in the region will likely be profound.

- As of 2023, the average annual nameplate capacity of polymer- and chemical-grade propylene in the CIS and Baltic States region amounts to almost 4.5 million metric tons. This represents an increase of over 1 million metric tons from the 2018 level, with 500,000 metric tons alone attributed to the start-up of the ZabSibNeftekhim cracker in Tobolsk, Russia. The most recent capacity expansion is associated with a new 500,000 metric tons propane dehydrogenation (PDH) unit in Atyrau, Kazakhstan which successfully commenced operations in late 2022. The plant is operated by Kazakhstan Petrochemical Industries (KPI) and supplies feedstock to an integrated polypropylene unit.

- Supported by new capacities, propylene production volumes increased substantially over the last 5 years and reached a new high level of over 3.5 million metric tons in 2021, with slightly lower levels estimated for 2022 and 2023 due to the ongoing conflict in the region. In 2023, 58% of regional propylene supply is sourced from steam crackers, with refineries still accounting for 20% while on-purpose production has increased its share in total production to about 22%.

- Looking at the medium- and long-term developments in the region, there are several projects planned to be realized in the next 5–10 years and beyond, most of which will be located in Russia. If all of the current expansion plans are realized without massive delays, the total propylene capacity in the CIS and Baltic States region will increase by roughly 1.8 million metric tons in the 10-year forecast period to 2033 and close to double in size by 2050.

- The region under scrutiny is characterized by close ties between petrochemical producers and the major regional oil and gas companies as well as the authorities. The situation had been gradually changing, giving space to more businesses to keep stakes in the industry. However, the merger of Sibur and TAIF Group (including two of the largest regional producers, NKNK and Kazanorgsintez), which was completed in September 2021, has resulted in a dominate player within the CIS and Baltic States region. On a shareholder basis, SIBUR remains by far the largest shareholder of capacities in 2023, followed with some distance by Lukoil, Rosneft, and Gazprom.

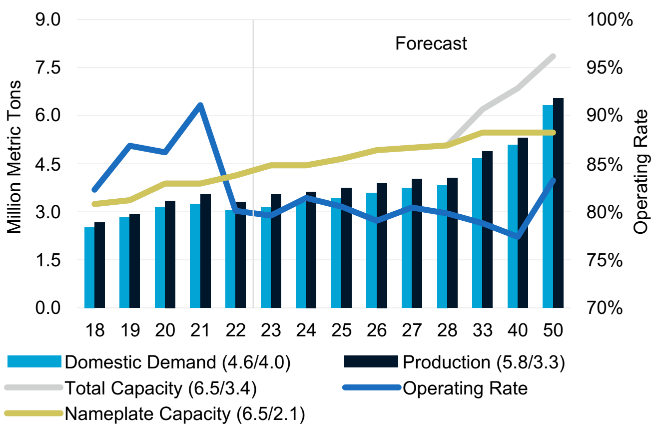
- Domestic demand for polymer- and chemical-grade propylene in the CIS and Baltic States region increased at a comparably healthy rate of 4.6% annually, on average, in the last 5 years and while it has reached a new high of about 3.2 million metric tons in 2021, demand growth has been impacted by the Ukraine-Russia conflict and slightly lower levels are assumed for the period 2022-24. Russia currently accounts for 82% of the region's total demand, compared with 87% in 2018. This reflects the increasing number of new investments made in other markets within the region, including Uzbekistan, Turkmenistan, and Kazakhstan.

- While the regional demand profile for propylene is a little more diverse than that of ethylene, it is also strongly dominated by polyolefins production, in this case polypropylene (PP), which still accounts for about 76% of regional propylene consumption in 2023. With a share of a little more than 6%, the combined oxo alcohols production is the next-largest propylene consuming sector in the CIS and Baltic States region, followed closely by acrylonitrile, which makes up for a little less than 6%. All other derivatives only account for 4% or less of the total consumption.

- In the next 10 years, domestic demand for polymer-grade/chemical-grade propylene is forecast to grow, on average, at a healthy rate of about 4.0% annually and increase to a level of roughly 4.7 million metric tons by the end of 2033. This will mainly be driven by continued growth projected to be seen in the already large PP segment, which will increase its share of propylene consumption to about 78% in 2033 and 83% in 2050. Most of the other propylene derivatives are forecast to expand at a slower pace and, thus, remain considerably smaller end-use segments. The largest growth rates are expected to be seen for propylene oxide, with double-digit growth projected for the period 2023-33, but in terms of volume, its share in propylene demand will likely not exceed a range of 2%.

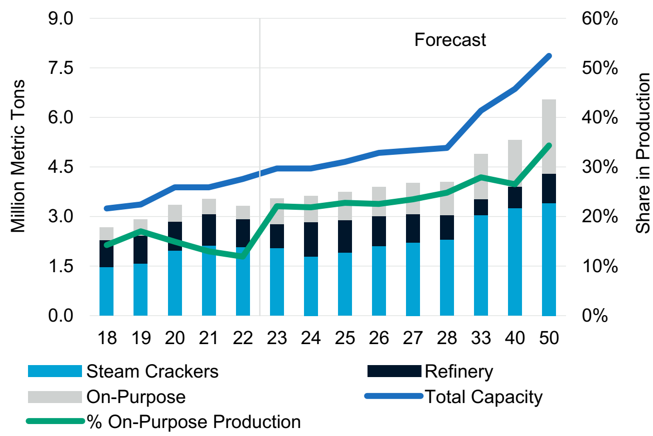
- The region is currently a net exporter of propylene monomer and derivatives. Net exports of propylene monomer exceeded the 300,000 metric tons in 2021 and are expected to remain at high levels in the forecast period. Overall, the regional net equivalent export position is projected to strengthen further during the extended forecast period, with the total volume forecast to reach a volume of about 1.8 million metric tons by 2033 and increase further to a level of almost 2.8 million metric tons by 2050. This will mainly be driven by new PP investments, given the right political and economic conditions and implementation of the full scope of the projects planned in the region. However, the CIS and the Baltic States comprise an exceptionally large territory, which means that logistics costs play an important part in the final destination of exports. New derivative producers in Uzbekistan, Kazakhstan, and Turkmenistan will therefore likely focus on markets in the Middle East, Africa, Central Europe, and Asia.

CIS & Baltic States: PG/CG Propylene Supply & Demand



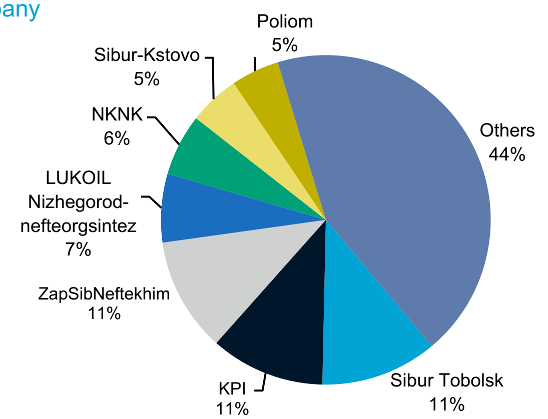
(% AAGR = 18-23/23-33)
Source: Chemical Market Analytics by OPIS

CIS & Baltic States: PG/CG Propylene Production by Source



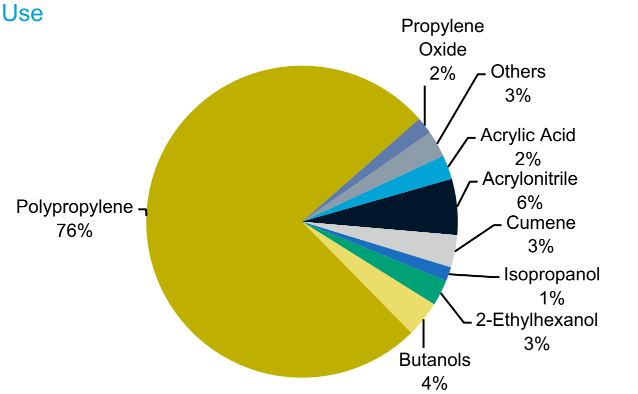
Note: Steam crackers and refinery data include the respective crude to olefins production.
Source: Chemical Market Analytics by OPIS

CIS & Baltic States: 2023 PG/CG Propylene Producers by Company



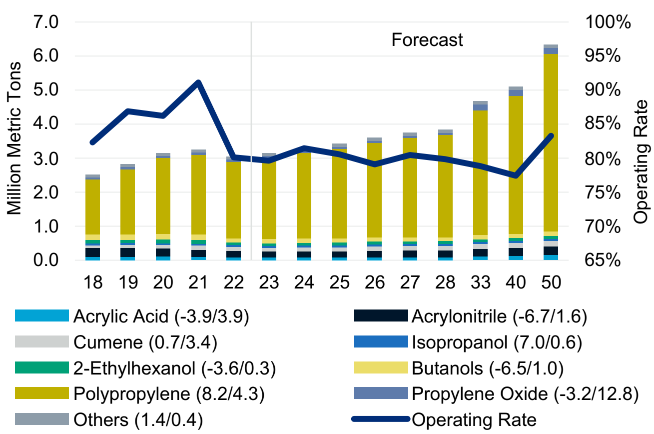
Capacity = 4.5 Million Metric Tons
Source: Chemical Market Analytics by OPIS

CIS & Baltic States: 2023 PG/CG Propylene Demand by End Use



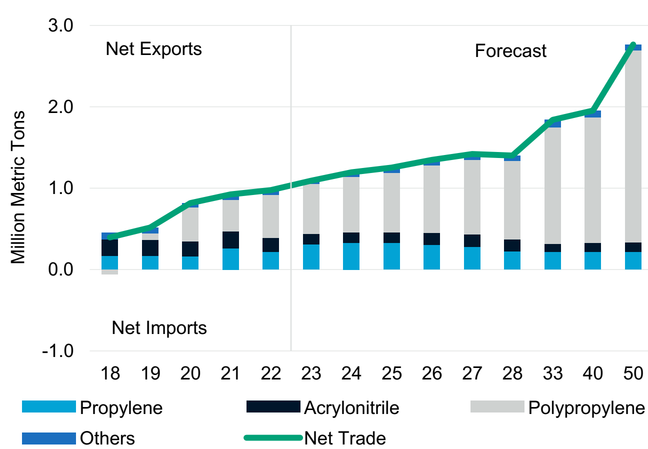
Domestic Demand = 3.2 Million Metric Tons
Source: Chemical Market Analytics by OPIS

CIS & Baltic States: PG/CG Propylene Demand



(% AAGR = 18-23/23-33)
Source: Chemical Market Analytics by OPIS

CIS & Baltic States: Propylene Net Equivalent Trade



Source: Chemical Market Analytics by OPIS

Africa

- As of 2023, Africa remains one of the smallest propylene producing and consuming regions, accounting for less than 1% of global capacity and demand. Most of the regional polymer-grade/chemical-grade propylene is produced in South Africa, where Sasol operates a large coal gasification plant as well as a Superflex olefin cracking unit. Egypt is the second-largest producing country in the region, with the Egyptian Propylene & Polypropylene Company (EPPC) operating a 400,000 metric ton propane dehydrogenation (PDH) unit that was brought onstream in 2010. Nigeria is the third-largest propylene producing country where the combined output of one steam cracker (Eleme PC) and two refinery-based units (Eleme PC and Warri Refinery) almost makes up for the volume previously produced at the single steam cracker in Libya, which was idled in 2011.

- Egypt is utilizing its natural gas reserves with some of the associated propane used in the integrated PDH–polypropylene (PP) unit. The unit was operational late in 2010. However, owing to a lengthy start-up and commissioning phase, achieving full commercial production took a number of years. While additional ethylene capacity was brought onstream with the commissioning of the 460,000 metric ton ETHYDCO Egyptian cracker in the middle of 2016, this has only resulted in a very small increase in coproduct propylene output as the unit is mainly using ethane feedstock.

- Regional propylene production is estimated to reach a volume approaching 1.2 million metric tons in 2023 which is comparable to levels seen for the previous 10 years. On a company basis, EPPC remains the second-largest regional producer, accounting for almost 25% of the total capacity, behind Sasol in South Africa which makes up for roughly 61%. Supply sources of propylene are forecast to be fairly stable in the next decade. With the presence of Sasol's Superflex unit in South Africa and EPPC's PDH unit in Egypt, a comparably large portion of the region's propylene supply is already sourced from on-purpose units. As Algeria is a large exporter of liquefied petroleum gas (LPG), the construction of a PDH unit is moving closer though facing many obstacles; the target start-up date is 2027 though delays look likely.

- In addition, the current outlook assumes that another steam cracker will be built near Ain Sokhna, on the Egyptian coast of the Red Sea, and come onstream by 2029. The plant with an ethylene capacity of 1.4 million metric tons will utilize naphtha as a feedstock and produce up to 800,000 metric tons of polymer-grade propylene. Other olefin developments are under consideration but currently not expected to be realized before the middle of the next decade. Although a PDH–polypropylene investment is being considered by a joint venture between Sonatrach and TotalEnergies in Algeria, previous plans for a new cracker did not materialize and it is assumed no new cracker capacity will come onstream until 2039/40. Nigeria is also considering investment in steam cracker capacity, although given the political environment, the probability of this moving forward, given the political environment, is comparatively low.

- After being static for the past five years, regional propylene production is projected to grow again in the second half of the current decade and reach a level of more nearly 2.9 million metric tons by 2033. No restart of the Libyan cracker was assumed in the analysis used as basis of this report though recent changes to that system make some output from the unit a distinct possibility in the forecast period. The political situation in Libya makes the operation of the cracker in the country very challenging and the historical exports of monomer will be difficult to place in a long market. Egyptian demand to supply a PP unit is now being met with some imports from the Middle East and though reliability of supply is becoming more difficult again given capacity expansion there.

- PP is the major propylene derivative produced in Africa, accounting for about 89% of domestic demand in 2023. Propylene consumption for other derivatives remains limited to butanols (8%) and acrylic acid (3%), with all production capacities located in South Africa. While this is not expected to change much in the next decade, the share of PP will increase further to 95% as new capacities come onstream in the region.

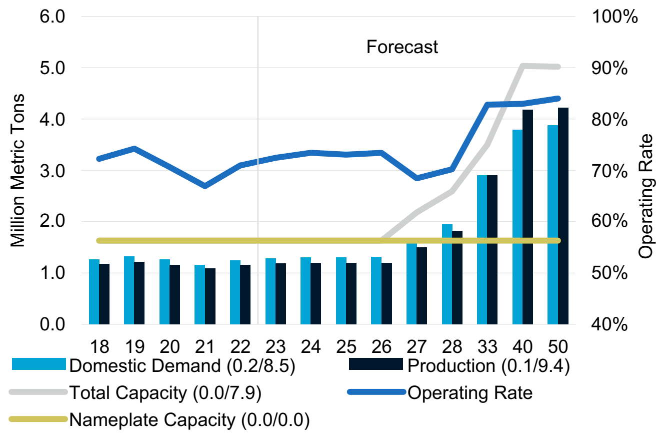
- In the long term, propylene consumption will continue to expand by almost 9% annually, on average, mainly driven by future additions in polypropylene capacity. The additional derivative capacity from EPPC in Egypt, which came onstream at the end of 2010, has gradually been able to move to higher utilization rates after prolonged start-up issues. Political tensions within Egypt have done little to support demand in that country. The smaller PP unit in Egypt operates based on imports of propylene from the Middle East though supply may need to be found from elsewhere given tightening monomer balances in the neighboring region. The plans for a new naphtha cracker to be built in Egypt would eliminate supply issues for this unit and while this was originally forecast to be the case by the end of the 10-year forecast period to 2033, further delays still remain a possibility.

- While Africa has historically been a net exporter of propylene monomer, this is not the case today. Libya dominated propylene monomer exports until the conflict in 2011, which resulted in the cracker being idled. South Africa has exported small quantities in the past, but there are difficulties in using the Richard's Bay terminal for propylene exports.

- As of 2023, Egypt is the only importer of propylene monomer in Africa; the imported material is used to feed OPC's PP unit. This unit had been idled given the loss of supply from Libya and the start-up of the EPPC PDH unit. However, OPC's PP unit has since resumed operations, with relatively attractive economics in 2016-17. Its long-term future depends on the progress of the naphtha cracker project that is being developed by the Red Sea Refining and Petrochemical Company (RSRPC). Imports are not forecast to continue structurally in the long term, but if they do continue, it will be at relatively low levels and limited to the next 10-15 years. EPPC's PDH unit is fully integrated with its own PP unit and there are no provisions to allow for either propylene imports or exports. If all announced projects are realized as assumed in the current outlook, the region as a whole could move to a net importing position for propylene monomer by 2035, with the annual average volume estimated to be around 200,000 metric tons.

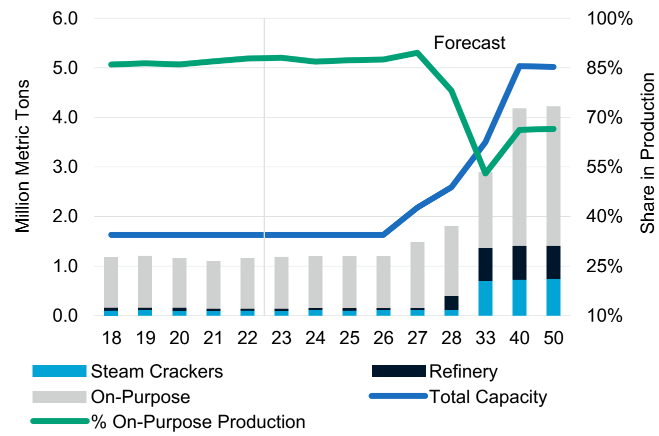
- Looking at propylene contained in derivative trade, Africa's net import requirement for PP has been steadily increasing over the last decade though saw a dip in 2022. This increase has been seen despite growth in local supply. The ongoing demand growth in the region and lack of additional supply will require an increasing supply from other regions, until additional capacity comes onstream in the second half of this decade. Propylene net equivalent imports, which include propylene trade as monomer and in form of its derivative, reached a peak level of nearly 1.4 million metric tons in 2021, more than 90% of this can be attributed to PP, before dropping slightly in 2022. The current outlook is for the region remain a large net importer and reach a new high peak in total net equivalent imports in 2026. Additional capacity will then allow import levels to ease considerably, though the continent will remain heavily reliant on imports.

Africa: PG/CG Propylene Supply & Demand



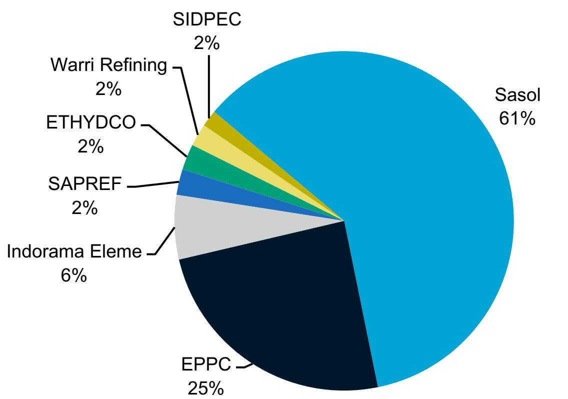
(% AAGR = 18-23/23-33)
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Africa: PG/CG Propylene Production by Source



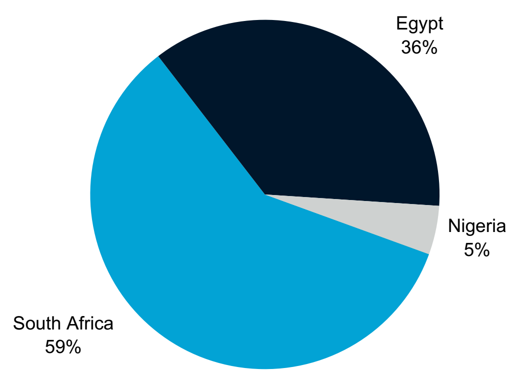
Note: Steam crackers and refinery data include the respecetive crude to olefins production.
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Africa: 2023 PG/CG Propylene Producers by Company



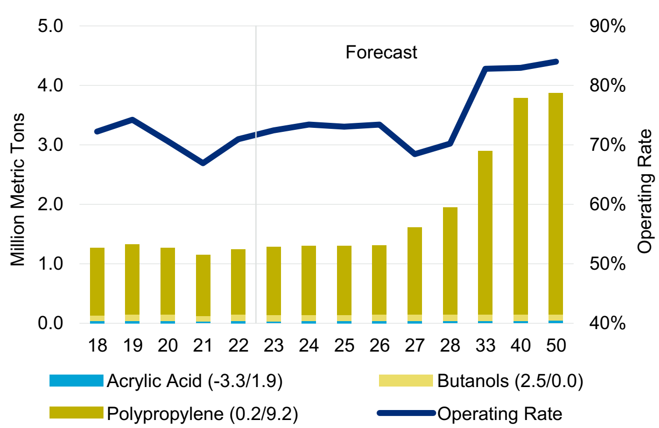
Capacity = 1.6 Million Metric Tons
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Africa: 2023 PG/CG Propylene Demand by Geography



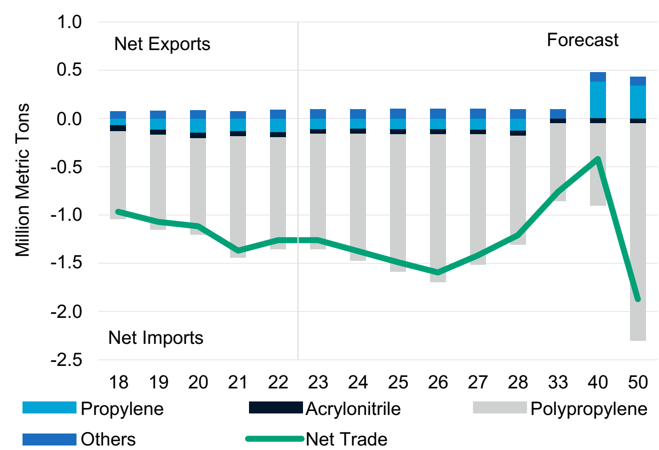
Domestic Demand = 1.3 Million Metric Tons
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Africa: PG/CG Propylene Demand



(% AAGR = 18-23/23-33)
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Africa: Propylene Net Equivalent Trade



Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Middle East

- The development of the Middle East's propylene and derivatives industry had lagged behind its rapidly growing ethylene product chain for many years. The pace of expansion was hindered by limited propylene supplies from mostly ethane-based steam crackers that generated little propylene coproduct. Additionally, the Middle East faced limited access to technologies for manufacturing propylene derivatives such as propylene oxide. Over the past 15 years, rapidly increasing propylene production, with a gradual move to heavier steam cracker feedslates and on-purpose production, has eliminated most of these supply constraints. However, that trend has started to reverse as additional sources of ethane become available. The last few years has seen crude oil production cuts cause pressure on overall feedstock supply and resulted in reduced output. In 2020 and 2021 the effect of the pandemic on demand forced heavy reductions whilst in 2022 and 2023 cuts have also been seen as global supply elsewhere has moved ahead demand growth. One example is the Sadara cracker in Saudi Arabia, which started up in 2016. Based on a 50% naphtha feed, the cracker has added a significant amount of new propylene supply, but the allocation of discounted condensate and additional ethane has now lessened its propylene output.

- Conventional refinery-grade propylene supply increased in 2016 after the fluidized catalytic cracking (FCC) unit in the United Arab Emirates increased operating rates the year prior. Following a fire at this unit in early 2017, propylene production stopped and did not restart until early 2019. Despite the large refining industry in the region, there have been limited opportunities to economically access the propylene from FCC units. In Saudi Arabia, Petro Rabigh runs a high-severity FCC unit with a nameplate propylene capacity of 800,000 metric tons. The Borouge 3 complex in the United Arab Emirates involves polypropylene (PP) investments that are substantially based on refinery-sourced propylene from the adjacent Takreer refinery.

- Alternate propylene production technologies account for a significant portion of the Middle East's total propylene supply. Most propane dehydrogenation (PDH) units are located in Saudi Arabia, feeding associated PP assets. Much of Saudi Arabia's propylene production comes from steam crackers running on discounted liquefied petroleum gas or condensate feedstocks, as well as PDH units using discounted propane. In late December 2015, the pricing mechanism changed substantially, shifting from a naphtha-related formula to a propane-based one. For PDH operators, the pricing mechanism ensures a fixed discount on export values and, therefore, a steady cost advantage.

- The actual production level rose sharply with the 2019 restart of the Takreer FCC and metathesis units, which had been offline after a fire in 2017. The restart added over 1 million metric tons of combined propylene capacity. In 2021, additional capacity was brought onstream by OQ in Oman with a new steam cracker, supply propylene. The unit only really achieved stable operations during 2022 supporting production levels. However, broader pressure on production levels due to pure economics have countered this increase.

- Polymer-grade and chemical-grade propylene supply in the Middle East is likely to grow slowly in the next five years; beyond that, a faster growth rate is once again expected. Increases in supply from steam cracking primarily come from crackers running propane and heavier feedstocks in the Saudi Arabian industry. Later in the forecast period, investments in other countries will also see these heavier feedstocks increasing the propylene supply, although at a relatively modest level. The current outlook assumes that the projects under consideration in the region may add about 3-3.5 million metric tons of polymer-grade/chemical-grade propylene capacity by 2033.

- The last five years have seen no change in the use of propylene into non-PP applications at a stable 13-14%. The start-up of an acrylic acid plant and an n-butanol unit in Saudi Arabia follow the addition of propylene oxide and cumene assets over the past 10 years and are signs of shifting emphasis within the region. In the past, lower logistics costs, readily available technology licenses, and sales portfolio considerations (complementing polyethylene) made PP the propylene derivative of choice. As regional producers continue to move toward the production of more advanced specialty products, the propylene derivative slate is becoming more diverse. Acrylic acid, cumene, propylene oxide, and butanol are now produced in Saudi Arabia, acrylonitrile in Turkey, and small volumes of oxo-alcohols in Iran. A more diversified derivative slate is also being considered elsewhere in the region.

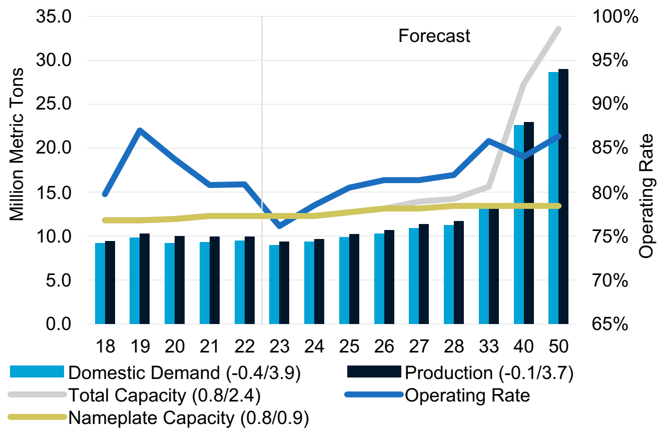
- However, the majority of the Middle East's propylene production goes into PP, which accounted for 86% of the total demand in 2023 and will continue to drive regional consumption at high annual growth rates in the longer term. Consumption into other derivatives is also expected to advance at healthy rates, albeit from a smaller base. Driven by the start-up of new capacity in Saudi Arabia later in the current decade, the largest growth on a percentage base is projected to be seen in the acrylonitrile segment. As the regional derivative slate becomes more varied over the next few years, it will provide a balance to the fast-expanding PP segment. Nonetheless, PP is currently projected to consume, on average, still 84% of all regional propylene supplies by the end of the 10-year forecast period to 2033 though drifting above 90% in the longer term.

- Propylene demand will essentially grow with supply, as most of the new derivative capacity is tied to upstream propylene production. While nearly all of the new propylene production will be exported in the form of PP, other derivatives will also see export growth in the forecast period, and the region is projected to move to briefly become a net exporter of acrylonitrile in 2033-34.

- The Middle East has historically been a net importer of propylene derivatives, principally because of Turkey's high import requirement for PP. Saudi Arabia, Kuwait, and Oman have been PP exporters for several years, but it was only in 2009 that the whole region became a net exporter of propylene derivatives. By 2028, the Middle East is expected to be a net exporter of almost 3.75 million metric tons of propylene equivalents, meaning propylene traded as monomer and in the form of its derivatives. By 2033, the region should approach a total net export volume of 5 million metric tons.

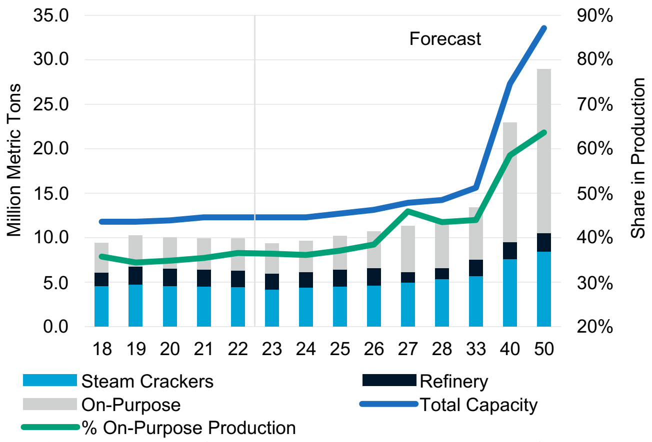
- Propylene monomer exports are also being seen, although in smaller volumes relative to the large derivative trade, mainly because of the much higher cost of transportation. Initially, these came from Jubail Chevron Phillips, which has no associated propylene derivative capacity. However, the sharply increasing derivative requirements have constrained export volumes from Saudi Arabia. The start-up of a metathesis unit in Rabigh (as part of Petro Rabigh's second phase) has occasionally allowed the producer to export its propylene surplus; the scale of the unit is a little larger than needed for the associated cumene unit. Occasional exports have been seen for a number of years. In the United Arab Emirates, the refinery/cracker complex in Ruwais moved to a longer position on propylene in 2015 after the refinery and metathesis start-ups—although the complex was seeking to move into structural exports of propylene, supply was unreliable and modest. Exports stabilized in 2016, but a fire at the Ruwais FCC unit in early 2017 limited production the following year and stopped further exports. However, after a PDH start-up in 2018 and the restart of the refinery and metathesis unit in 2019, the United Arab Emirates exported regularly from 2019-2021. This export flow continues, though at reduced rates after the new PP unit started up earlier in 2022.

Middle East: PG/CG Propylene Supply & Demand



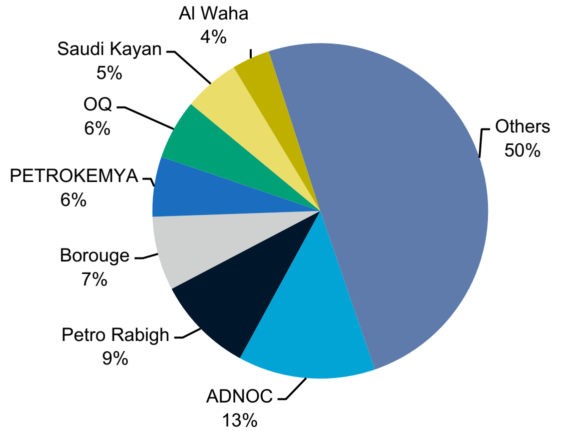
(% AAGR = 18-23/23-33)
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Middle East: PG/CG Propylene Production by Source



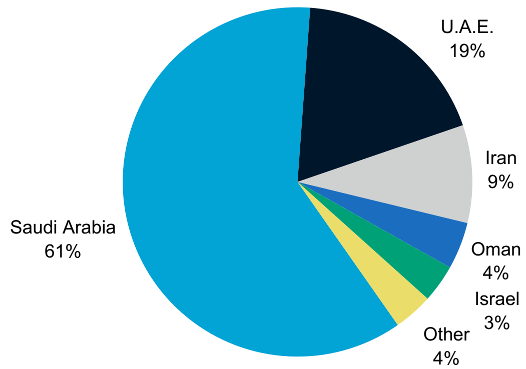
Note: Steam crackers and refinery data include the respective crude to olefins production.
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Middle East: 2023 PG/CG Propylene Producers by Company



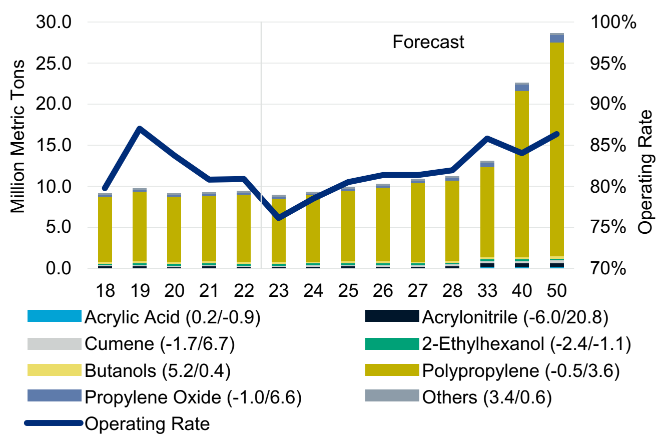
Capacity = 12.3 Million Metric Tons
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Middle East: 2023 PG/CG Propylene Demand by Geography



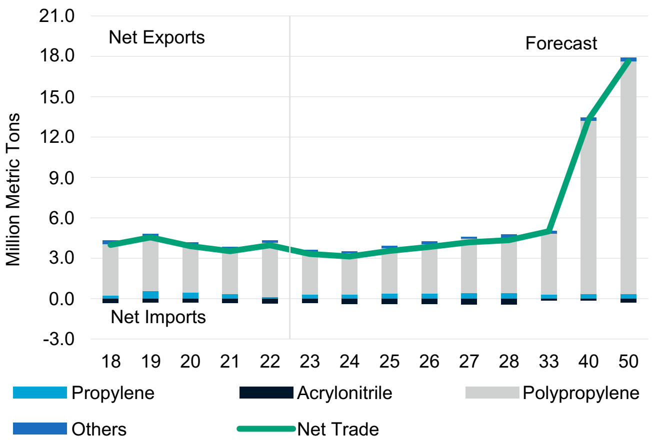
Domestic Demand = 9.0 Million Metric Tons
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Middle East: PG/CG Propylene Demand



(% AAGR = 18-23/23-33)
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Middle East: Propylene Net Equivalent Trade



Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Indian Subcontinent

- As of 2023, the Indian Subcontinent still only accounts for about 4.5% of global polymer-grade/chemical-grade propylene capacity, with all regional production facilities located in India. Historically, propylene supply growth from steam crackers has been limited by slow ethylene capacity growth, but this changed after the start-up of two large naphtha crackers by Indian Oil Corporation (IOC) in 2010 and ONGC Petro Additions Limited (OPaL) in 2017. More recently, HPCL Mittal Energy Ltd. (HMEL) completed the construction of a 1.2-million-metric-ton-per-year ethane, propane, and butane/naphtha cracker that is integrated with the Guru Gobind Singh refinery in Bathinda, India. The plant has a propylene capacity of 500,000 metric tons per year. It was originally expected to come on-line in late 2021 but has been delayed due to the COVID-19 pandemic and only started operations in mid-2023. Looking ahead, additional propylene capacity from steam crackers could be added in India at the beginning of the next decade. Pakistan has contemplated building a cracker with integrated derivatives facilities for a while, but such an expensive investment has been considered highly unlikely given the country's volatile currency and political instability. The current outlook assumes that the Pakistan project could be realized by mid-2031.

- In 2023, propylene produced from steam crackers is estimated to make up for almost 35% of total propylene production in this region. Historically, most propylene has been supplied from refinery fluidized catalytic cracking (FCC) units. In 2020, various Indian refineries reduced their run rates in the second quarter amid COVID-19 containment measures but soon picked up in the second half of the year as lockdowns eased. Nonetheless, a more contagious COVID-19 variant swept the region during the second quarter of 2021, severely hindering gasoline demand recovery and thus weakening refinery-based propylene output. However, the economy grew persistently in the second half of 2021, causing refining runs to ramp up and return to the five-year range by the end of the year.

- Roughly 54% of propylene produced in the Indian Subcontinent comes from FCC units with the remaining supply coming from high-severity FCC (HS-FCC) units. Within the region, the most competitive propylene source is one of the world's largest FCC units, which is owned by Reliance Industries and located in Jamnagar. Reliance built another HS-FCC unit in Jamnagar in 2008 that can produce up to 900,000 metric tons of propylene per year. To adapt to the energy transition, Reliance revealed plans to revamp their two existing FCC units to HS-FCC units in order to maximize petrochemical yields (of propylene, in particular), while also applying its proprietary multizone catalytic cracking (MCC) for high olefin conversions in the same complex. This new MCC process targets a wide range of feedstocks, from FCC and coker naphtha to vacuum gas oil and even crude oil. Other "mega-complexes" that will include additional refineries and naphtha crackers are under consideration; however, these projects will most likely not start up in the next five years. Also in 2023, Bharat Petroleum Corporation Limited (BPCL) completed the expansion of their Kochi FCC unit which increased the propylene output by 250,000 metric tons. The start-up of Nayar Energy's new residue FCC unit added another 550,000 metric tons of propylene capacity. Refinery projects that are expected to be realized in India by 2028 include two new residue FCC units that are planned to be brought onstream by Indian Oil (2025 and 2026) as well as two new FCC units associated with the HPCL Barmer Refinery & Petrochemical Complex (2026) and Indian Oil's Panipat refinery (2027).

- To date, there are no propylene on-purpose units installed in the region, but in late 2021, India's state-owned petrochemical producer, Gail, announced that it would build the first propane dehydrogenation (PDH) plant in Maharashtra, India. The plant will have a nameplate propylene capacity of 500,000 metric tons per year and will be integrated with a grassroots polypropylene (PP) facility of the same capacity. In May 2021, Pakistan's Engro Corporation unveiled plans for a PDH-PP integration complex with a nameplate capacity of 750,000 metric tons per year. While both facilities were originally announced to come onstream by 2024/25, the current outlook only includes nameplate PDH-based capacities that will be added in India by 2027.

Longer term supply growth in the region will likely be dominated by crude-oil-to-chemical (COTC) developments, also considered to be on-purpose production, which could potentially add another 16 million metric tons of propylene capacity by 2050.

- In 2023, Reliance had a 40% share in the regional propylene capacity on a shareholder basis, so the company clearly dominates the regional market. By 2028, the Reliance's share of the market is expected to fall to less than 28% as other Indian producers, like HPCL, Bharat Petroleum (BPCL) and Indian Oil, continue to increase their propylene production capacities.

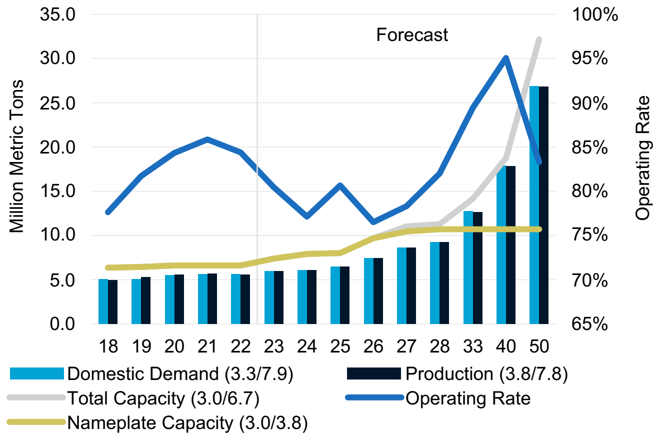
- Overall domestic demand for propylene is estimated to have increased by about 6% year-on-year to a volume of more than 5.9 million metric tons in 2023, all concentrated in India. The higher propylene monomer demand is due to increasing PP production, which accounted for 95% of the total propylene consumption in 2023. Furthermore, new production plants for various other propylene derivatives—including 2-ethylhexanol, n-butanol, acrylic acid, butyl acrylates, and 2-ethylhexyl acrylates—were commissioned in the period 2021-23. Looking ahead, domestic demand for propylene in the Indian Subcontinent is forecast to grow at an average annual rate of more than 9% over 2023–28 and will continue to increase at a fast average annual growth rate of almost 7% over 2028–33.

- Propylene demand from key derivatives like PP, acrylic acid, and the combined oxo-alcohols increased further in 2023 on the back of new capacities in the region. Most of the new propylene monomer demand and capacity in India is intended as feedstock to supply new PP units because production of this derivative is likely to maintain its strong growth over the next decade. India's large population of nearly 1.4 billion people is driving PP growth, and the country's per capita consumption of PP is very low at just 4.7 kilograms, compared with the global average of about 10.5 kilograms. The regional per capita PP consumption is even smaller at 4.2 kilograms. Therefore, there is still room for strong growth, and over the next 10 years, PP production levels are forecast to expand at an average annual rate of about 7%. Over the 10-year forecast period, PP will remain the dominant consumer of propylene monomer in the Indian Subcontinent, with a 91% share of demand in 2033. Investments in acrylic acid, oxo-alcohols, and propylene oxide production will modestly increase demand originating from other propylene derivatives in India. Future projects involving isopropanol could occur in the next decade, but this is still uncertain.

- The Indian Subcontinent only occasionally trades small volumes of propylene monomer. India has historically been a net exporter of PP, but since PP demand is expected to grow at a faster pace than new supply additions, the country will become a larger net importer of up to 9 million metric tons PP during the extended forecast period to 2050. A few projects for other propylene derivatives, such as cumene/phenol, acrylic acid, and acrylonitrile, are under consideration in India, but most of these projects have yet to start construction, and the ongoing pandemic has made their outcomes more uncertain. Therefore, the region will remain a significant net importer of acrylonitrile and other propylene derivatives during the forecast period.

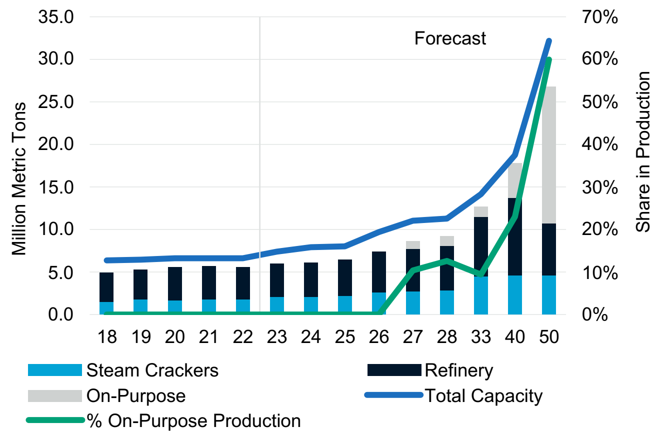
- The Indian Subcontinent as a whole is typically a net importer of propylene equivalents, with the region's total net requirement is expected to reach around 4 million metric tons in 2028 and more than nearly 6 million metric tons by 2033 driven by the surging demand growth. In addition, given the low acrylonitrile and phenol capacity in the region, import volumes are comparatively high for these products and will likely remain strong during the 10-year forecast period until new projects are built domestically. Moving forward, some exports of propylene derivatives headed to mainland China may be directed to the Indian Subcontinent because of mainland China's increasing self-sufficiency. Imports of PP are expected to jump from 1.6 million metric tons in 2023 to around 4.3 million metric tons in 2033, with further increases projected to be seen in the later part of the extended forecast to 2050.

Indian Subcontinent: PG/CG Propylene Supply & Demand



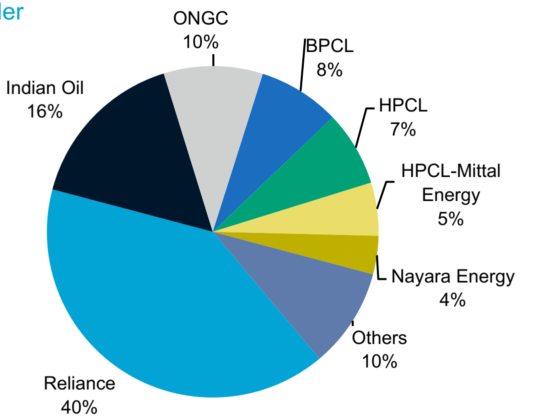
(% AAGR = 18-23/23-33)
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Indian Subcontinent: PG/CG Propylene Production by Source



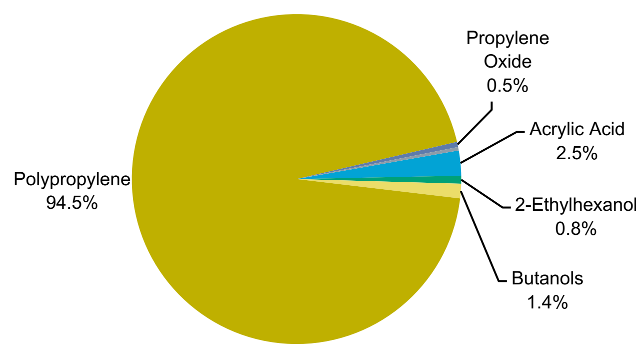
Note: Steam crackers and refinery data include the respective crude to olefins production.
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Indian Subcontinent: 2023 PG/CG Propylene Producers by Shareholder



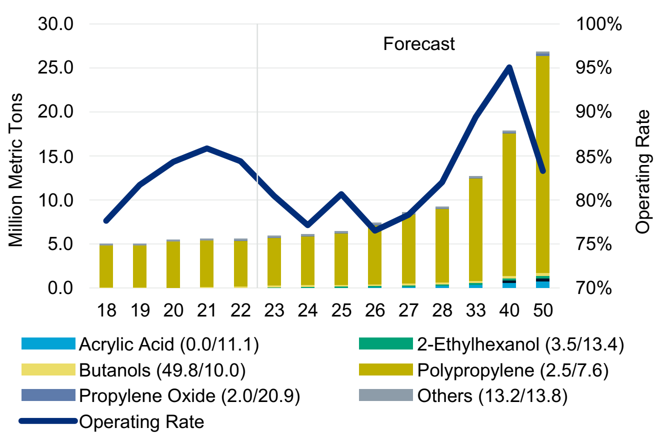
Capacity = 7.4 Million Metric Tons
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Indian Subcontinent: 2023 PG/CG Propylene Demand by End Use



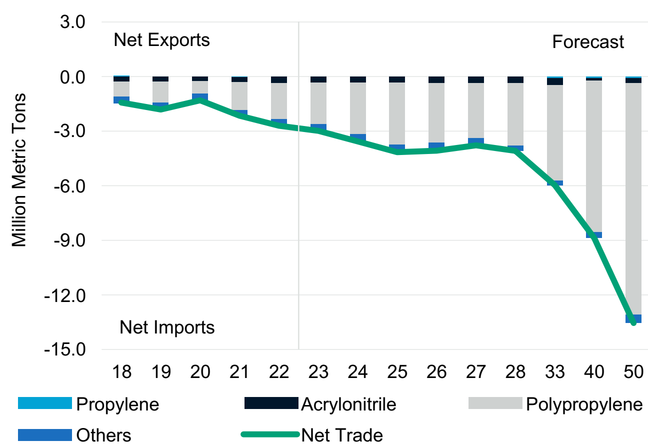
Domestic Demand = 5.9 Million Metric Tons
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Indian Subcontinent: PG/CG Propylene Demand



(% AAGR = 18-23/23-33)
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Indian Subcontinent: Propylene Net Equivalent Trade



Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Mainland China

- In 2023, mainland China remained one of largest propylene producers and consumers, representing almost 35% of global capacity and 38% of global demand. The Chinese market accounts for around 78% of propylene demand in broader Northeast Asia, so it is discussed separately from the other regional markets because of its large size and more dynamic growth profile.

- Driven by the fast demand growth for propylene, mainland China has been aggressively building new capacities based on both conventional and unconventional processes. By 2023, the total nameplate capacity for propylene (combined polymer-grade and chemical-grade) reached about 62 million metric tons which means that the capacity base has expanded, on average, by more than 10% annually during the period 2018-23. While investments in alternative sources of propylene continue to become more widespread in mainland China, most of the capacity continues to be linked to steam crackers using liquid feeds such as naphtha, condensates, gas oil, and liquefied petroleum gas. Some of the new units are pure ethane crackers that will not yield much, if any, propylene. Other projects have been switched to using a mixed feed that includes LPG in addition to ethane. Nevertheless, coproduct output from ethylene production will remain the leading source of propylene in mainland China, increasing from around 34% in 2023 to about 36% in 2033.

- In the period 2020-23, 24 new steam crackers with a combined ethylene capacity of nearly 22 million metric tons have been brought onstream in mainland China. Another six are still in the implementation stage and expected to start-up in the next 2 years, adding about 6.5 million metric tons of capacity. Going forward, ethylene crackers appear to be the most attractive projects for investors in mainland China and a second wave of steam crackers is already on the horizon. As of early 2024, another 20 steam crackers with a combined ethylene capacity of almost 23 million metric tons are planned to come onstream in mainland China by the end of 2028. Several of the new steam crackers are planned to be built by state-owned enterprises (SOEs) which are keen to increase the chemical yields from their existing integrated refinery-cracker complexes.

- Oil refining coproduction of propylene, not including output from HS FCC units, is the second-most popular propylene source in mainland China, accounting for about 18% of the propylene output in 2023. The production share is forecast to drop to 13%, on average, by 2028, in large part because of differences in refining utilization. Operators who have priority for getting crude oils are able to run at high rates, but refiners who are short of feedstock have to run at low rates. Obviously, the state-owned enterprises Sinopec and PetroChina (CNPC) have more crude oil sourcing both from the domestic market and imports. Meanwhile, the transition to green energy and its impacts on fuels' demand and refining runs will have negative implications for propylene coproduct production. Therefore, the current outlook assumes that some rationalization will be seen not only for steam crackers but also for refinery assets.

- Several projects currently under construction will utilize on-purpose processes, such as the olefins conversion technology (metathesis), methanol-to-olefins (MTO) and coal-to-olefins (CTO), and propane dehydrogenation (PDH). Unlike state-owned enterprises (SOEs) and multinational companies (MNCs), many private players are in favor of the crude oil–to–chemicals (COTC) route and keen to fix the feedstock shortage to improve their competitiveness. Higher chemical feedstock output from refineries will result in higher chemical production. Hypothetical capacities for COTC are included in the current outlook for 2032 onward.

- With healthy margins seen in recent years, PDH has become one of the most attractive on-purpose propylene production routes for investors in the region. The total propylene capacity from PDH has increased to a volume of almost 18 million metric tons in 2023, with another 7 million metric tons expected to come onstream by the end of 2025. Most of the propane requirements for these PDH projects will be imported, mainly from the Middle East or as North American shale gas.

- The high oil prices in 2010–14 resulted in tremendous domestic interest in further developing and utilizing the vast deposits of bituminous coal in the Inner Mongolia and Northern Shaanxi provinces. This led to increased development of CTO units. Although the investment involved is often massive (three times the investment cost of a steam cracker), the coal feedstock costs of the CTO units were low, and they were competitive with domestic naphtha-based steam cracker complexes, as well as most olefin derivatives imports. When oil prices declined again in 2015-21, environmental concerns about emissions and water access added to this propylene source's operating viability. Nevertheless, new investments for this route are still being seen.

- With respect to MTO operations, producers located in the coastal areas are key players in both the spot methanol and olefin markets in Asia. Although many MTO plants theoretically have negative cash margins from an olefins-and-methanol perspective, some are still able to run. The key reason for this is that MTO plants in the coastal areas have diversified olefin derivatives. Some even trade all of their olefin monomers. In addition, more and more MTO plants have improved their flexibility and can purchase or sell olefin monomers according to olefin and derivative economics. Considering the combined output from both CTO and MTO, these production routes only account for about 13% of mainland China's propylene supply; this is not expected to change in the next 10 years.

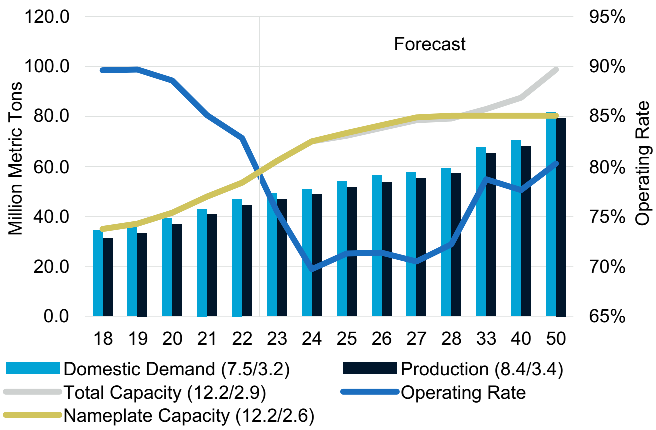
- In the next 5 years, propylene capacity from steam crackers and on-purpose production plants is expected to increase by more than 17 million metric tons which will more than offset the anticipated capacity decrease caused by steam cracker and refinery rationalizations via Beijing environmental initiatives. The additional capacity will also ensure sufficient propylene supply in the short term when low operating rates at steam crackers and the switch to more gas-based cracking may constrain propylene coproduct production. In the longer term (2028-50), propylene production in mainland China is expected to grow more or less in line with domestic demand at an average rate of 1.5% annually.

- With a 17% share in the total nameplate capacity base, Sinopec is by far the largest propylene producer in mainland China on a shareholder basis, followed by CNPC at 9%. Similar to ethylene investments, Sinopec remains the largest single investor in propylene production capacity. As future capacity additions will focus not only on traditional steam cracker coproduction and refining but also on on-purpose production, the investment mix for all players in the space is expected to widen.

- Rapid economic growth, a large population, low capital cost structure, and low labor costs all drive continued propylene demand growth in mainland China. In 2023, propylene demand is estimated to have amounted to about 49 million metric tons, which is even larger than ethylene demand. Consumption growth has been and continues to be driven by the developments in the polypropylene industry, which accounts for about 70% of mainland China's propylene requirement in 2023. The next-largest end uses with a share of about 6-7% each are acrylonitrile, oxo-alcohols, and propylene oxide. This is not expected to change much in the next decade and beyond.

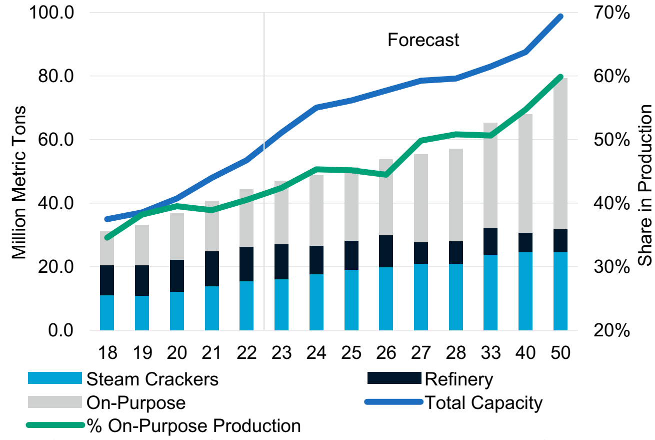
- Mainland China continues to be the key export market for Japan and South Korea because of its geographic proximity and their small domestic markets, but it also receives product flows from Southeast Asia and, to a lesser extent, the rest of the world. The ongoing investment in new production capacities to increase self-sufficiency has resulted in net equivalent imports of propylene and propylene derivatives to drop below 6 million metric tons in 2023, with further declines to about 4.6 million metric tons expected to be seen in 2025/26. Net propylene equivalents traded in the form of the monomer and its major derivatives will likely not reach 2020's peak level of about 11 million metric tons again until the end of the next decade. From a monomer perspective, net imports have also declined compared to historical levels and are forecast to remain, on average, at a level of about 2.2 million metric tons per year until 2033.

China (mainland): PG/CG Propylene Supply & Demand



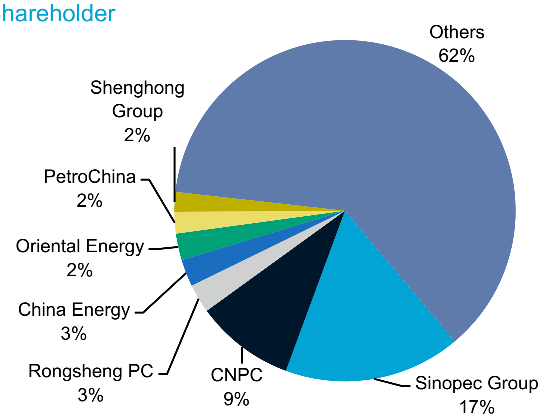
(% AAGR = 18-23/23-33)
Source: Chemical Market Analytics by OPIS

China (mainland): PG/CG Propylene Production by Source



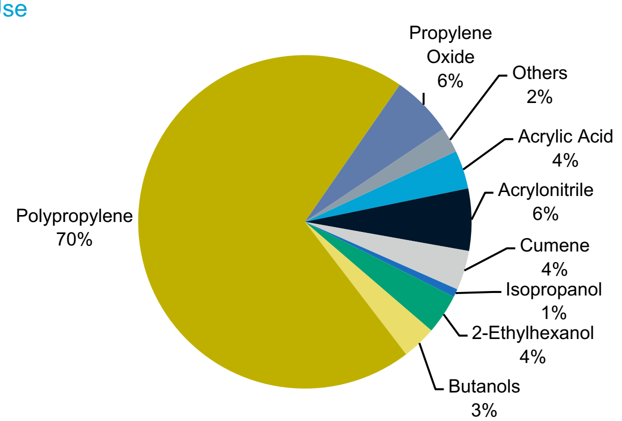
Note: Steam crackers and refinery data include the respecetive crude to olefins production.
Source: Chemical Market Analytics by OPIS

China (mainland): 2023 PG/CG Propylene Producers by Shareholder



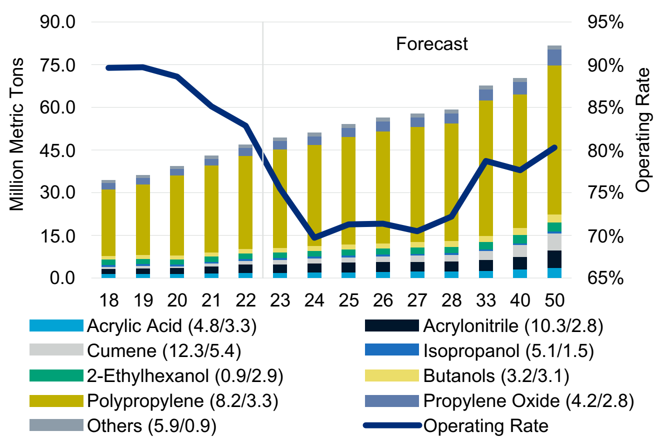
Capacity = 62.2 Million Metric Tons
Source: Chemical Market Analytics by OPIS

China (mainland): 2023 PG/CG Propylene Demand by End Use



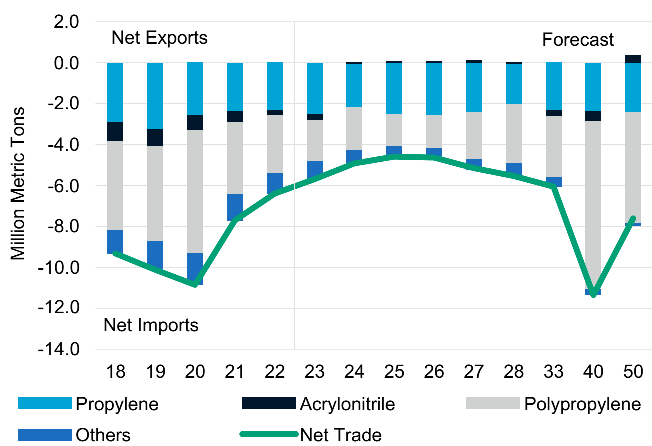
Domestic Demand = 49.3 Million Metric Tons
Source: Chemical Market Analytics by OPIS

China (mainland): PG/CG Propylene Demand



(% AAGR = 18-23/23-33)
Source: Chemical Market Analytics by OPIS

China (mainland): Propylene Net Equivalent Trade



Source: Chemical Market Analytics by OPIS

Other Northeast Asia

- Northeast Asia consists of several distinct petrochemical markets that are at various stages of development: Mainland China and Japan, both with very large markets, are opposites in terms of market maturity. While Japan's olefins and derivative industries are facing weak domestic demand growth, which is typical of a very mature market, mainland China's industry remains unable to meet the rapidly growing consumption requirements of its large domestic market. In contrast, South Korea and Taiwan, China both have considerably smaller domestic markets, and their olefins and derivative industries rely mainly on exports for growth. Therefore, the discussion of the propylene market and forecast for mainland China has been broken out and moved to a separate section.

- Nameplate capacities for polymer-grade/chemical-grade propylene (PGP/CGP) in the remain stable at about 20.2 million metric tons as the capacity growth seen in recent years has been more or less offset by rationalization. The most recent capacity additions can be attributed to the new steam crackers brought onstream by Hyundai Chemical, LG Chemical, and Gs Caltex in 2021-22. With a 52% share in the total propylene producing capacity, South Korea is the largest producer within the Other Northeast Asia group as of 2023, followed by Japan (30%) and Taiwan (18%). Even though a small amount of propylene is potentially available from a small steam cracker in North Korea, there is no information available about either production or consumption of propylene in this country.

- The majority of the existing propylene capacity is based on cracking liquid feeds (naphtha, condensates, gasoil, and liquefied petroleum gas [LPG]); steam crackers and refinery FCC units make up for about 71% of the total nameplate capacity in 2023. This compares to a share of 75% seen a decade ago and shows that investments in alternative sources of propylene such as olefins conversion technology (metathesis), high-severity catalytic cracking, and propane dehydrogenation (PDH) are still becoming more widespread.

- In the forecast period to 2033, the region is forecast to see lackluster capacity additions as the key export market mainland China builds up its nameplate capacity base to increase its self-sufficiency. All new projects under development in Other Northeast Asia will likely be located in South Korea. The new steam cracker planned by S-Oil Corporation at Ulsan will add another 1.8 million metric tons of ethylene and 800,000 metric tons of CGP capacity in mid-2026. Furthermore, the current outlook assumes that a small increase of refinery-sourced propylene in South Korea and further rationalization of steam cracker capacity in Japan could be seen in the second half of the 10-year forecast period.

- With healthy margins in the past 5-10 years, PDH has been the most attractive on-purpose propylene production route for investors in Northeast Asia. South Korea continues to assess new PDH plants, importing propane mainly from the Middle East and the US. Healthy margins will continue to support PDH capacity growth but triggering project approval appears more challenging. Therefore, the current outlook does not include the potential start-up of a 600,000 metric tons PDH unit in South Korea by 2026 but instead the addition of new HS-FCC capacity with the same size and timing and another similar project in the later part of the extended forecast period.

- As of 2023, the Taiwanese Formosa Plastics Corporation and South Korea's LG Group are the largest producers of PGP/CGP on a shareholder basis, accounting for about 9% and 8% of the total capacity in Other Northeast Asia, respectively. Given the limited amount of new capacities planned to come onstream in the next decade, the ranking of top producers is not expected to change much until the start-up of the S-Oil cracker in 2026. Based in South Koreas, S-Oil is majority-owned by Saudi Aramco since 2015.

- In the last two years, propylene demand in the Other Northeast Asia region has declined significantly from record high of 2021 and is estimated at a level of 14 million metric tons for 2023. Domestic demand is expected to recover in the next 5 years and remain subdued in the longer term. Consequently, the region will continue to fully depend on export flows of propylene and its derivatives to close the balances. Similar to other parts of the world, propylene demand growth has been and continues to be driven by the developments in the polypropylene (PP) industry, which currently accounts for about 55% of the region's total propylene consumption. The mix of other derivatives all make up a much smaller part of the propylene consumption. With a share of almost 11%, acrylonitrile is the second-largest derivative segment, followed by cumene and the combined oxo alcohols (2-ethylhexanol and butanols), which account for about 10% and 7% of the total demand in 2023, respectively.

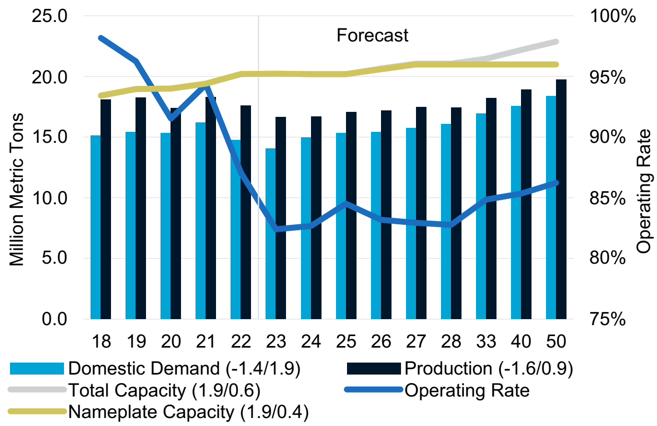
- Given the surplus of propylene and propylene derivatives, the Other Northeast Asia region continues to look to the growing mainland China market as the primary outlet for its excess production. Net exports of propylene equivalents (propylene traded as monomer and in the form of its derivatives) recovered in 2021 from the small dip in 2020 but trended downward again in 2022 and 2023 driven by weaker domestic demand. The total volume of net equivalent exports is expected to remain on average around 7.4 million metric tons in the period 2023–25 and increase to about 8 million metric tons in the later years of the extended forecast period to 2050, driven by bearish PP and acrylonitrile exports.

- While South Korea has been a net exporter of propylene monomer and derivatives since the early 1990s, its net export position has grown significantly in the last 15 years owing to propylene capacity increasing faster than domestic demand, which ultimately led to increased volumes available for export. The overall net equivalent export position of South Korea is projected to increase further in the future as new propylene derivative capacity is commissioned during the 10-year forecast period to 2033 and beyond.

- Japan has been a large net exporter of propylene monomer and derivatives for many years, with exports estimated to account for more than 10% of its total production in 2023. Capacity additions scheduled to come onstream in mainland China and South Korea through the forecast period will add pressure to Japanese propylene exports. Over the next five years, Japan is expected to see its net exports of propylene derivatives shrink gradually, owing to a continued loss of competitiveness, while net exports of propylene monomer are projected to remain stable at a level of 450,000 metric tons.

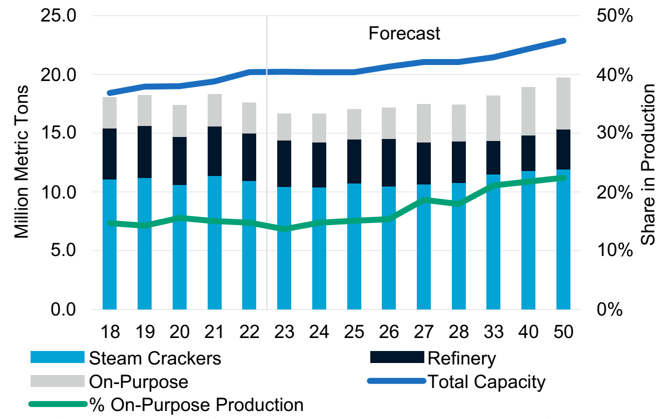
- As of 2023, Taiwan, China also remains a significant net exporter of propylene monomer and derivatives. Some of the export volumes have been linked to internal product transfers at Formosa (between Taiwan, China and mainland China). However, the start-up of Formosa's new PDH unit at Ningbo in early 2024 will reduce export volumes from Taiwan, China to mainland China going forward.

Other Northeast Asia: PG/CG Propylene Supply & Demand



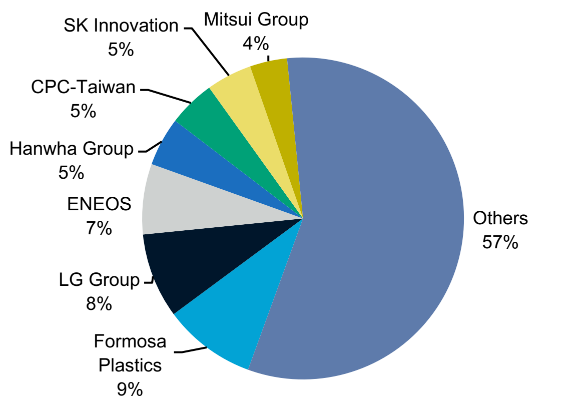
(% AAGR = 18-23/23-33)
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Other Northeast Asia: PG/CG Propylene Production by Source



Note: Steam crackers and refinery data include the respective crude to olefins production.
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

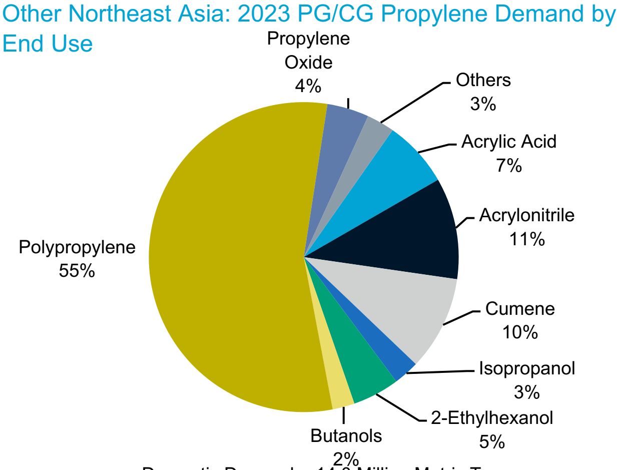
Other Northeast Asia: 2023 PG/CG Propylene Producers by Shareholder



Capacity = 19.2 Million Metric Tons

Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

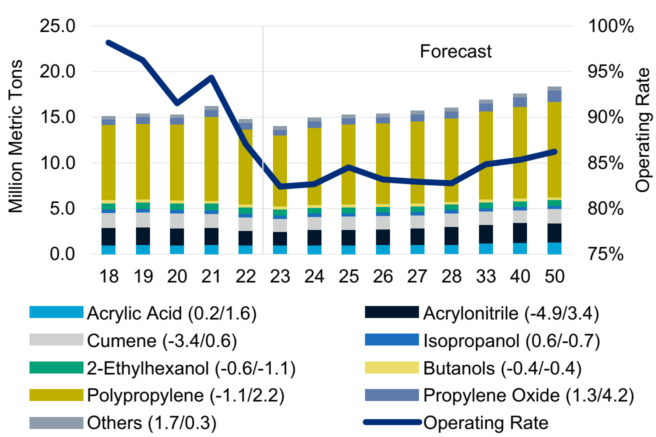
Other Northeast Asia: 2023 PG/CG Propylene Demand by End Use



Domestic Demand = 14.0 Million Metric Tons

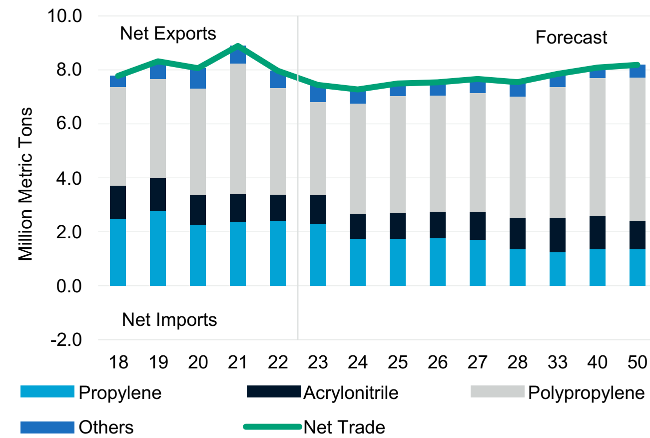
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Other Northeast Asia: PG/CG Propylene Demand



(% AAGR = 18-23/23-33)
Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Other Northeast Asia: Propylene Net Equivalent Trade



Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Southeast Asia

- As of 2023, Southeast Asia accounts for 7% of global propylene (polymer grade and chemical grade) capacity and 6.6% of the global demand. There has been great progress over the past decade in the Southeast Asian petrochemical industry. Several world-scale olefins and derivatives complexes, fluidized catalytic crackers (FCCs), and on-purpose propylene units were built to take advantage of the growing regional demand for propylene and derivatives, as well as the geographic proximity to the huge Chinese market. Thus, the nameplate capacity base of the region has expanded by about 60% in the last 10 years.

- The healthy margins during the tight ethylene market over the last five years have spurred active cracker expansions and contributed to more propylene capacities in the region. Saudi Aramco and PETRONAS have formed joint ventures (JVs) to further their equal ownership and participation in the Refinery and Petrochemical Integrated Development project in the Pengerang Integrated Complex, Johor, Malaysia. The new cracker and FCC units started operations in the fourth quarter of 2019 but ran at a reduced capacity because of a lack of feed from its upstream refinery. However, the whole integrated complex was shut down in mid-March 2020 after an explosion at the refinery. The start-up of the refinery and cracker, along with downstream derivatives plants, has been delayed several times, and the complex and has only been restarted at the end of 2022. Notably, this integrated complex will add 1.2 million metric tons of propylene supply when both the new FCC and cracker run at nameplate capacities. In Vietnam, the Long Son cracker project commenced operations in early 2024. In Indonesia, Chandra Asri expanded their cracker capacity in late 2015 and late 2019. PT Lotte Chemical Indonesia broke ground in December 2018 for their new naphtha cracker, which will have a capacity of 1 million metric tons of ethylene and 0.5 million metric tons of propylene per year. The plant is expected to come onstream in mid-2025. Additionally, there are several projects under the study phase in Southeast Asia, including the Hengyi refinery-cracker complex in Brunei, Chandra Asri's new cracker project in Indonesia, and several JV projects by Pertamina with partners such as CPC Corp, Rosneft, and ADNOC, also in Indonesia.

- On-purpose propylene supply has also increased with the presence of metathesis units in Singapore (PCS), Malaysia (Lotte Chemical Titan), Thailand (MOC, IRPC), and Indonesia (Pertamina), as well as propane dehydrogenation (PDH) capacities in Thailand (HMC Polymer, PTTGC), Malaysia (PETRONAS), and Vietnam (Hyosung). About 1.7 million metric tons of new propylene capacities are expected to be added in Southeast Asia by 2028, with another 2.3 million metric tons projected to be onstream by the end of the 10-year forecast period in 2033.

- The Southeast Asian market used to suffer from insufficient propylene supplies, but with the start-up of the aforementioned projects, the region's supply and demand are trending toward a more balanced, or even long, position. While investments and expansions have targeted growth in the region's emerging economies, some restructuring and consolidations have taken place in other parts of Southeast Asia, owing to fierce competition from larger, more modern, and more efficient refinery complexes within Asia. The pandemic contributed to fears of fuel demand collapse, which only accelerated the shift.

- As of 2023, the Siam Cement Group (SCG is the largest propylene producer in Southeast Asia on a shareholder basis, followed closely by PETRONAS and ExxonMobil. The regional ranking of the top producers is expected to change somewhat by 2028, with Siam Cement increasing their market share to nearly 12%.

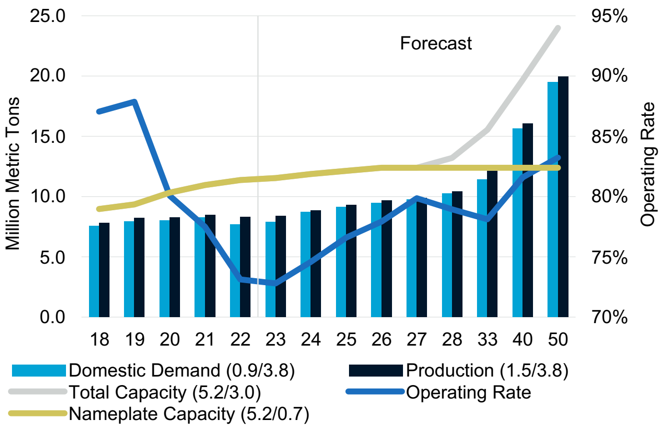
- COVID-19 weighed heavily on regional demand for propylene derivatives over the past two years. Most Southeast Asian countries applied strict nationwide containment measures and gradually eased them as the situation improved, although some countries and cities had to reapply lockdowns because of resurging COVID-19 cases in late 2021. Propylene derivatives demand related to construction, automobiles, and durable goods were all negatively impacted in 2020, while polypropylene (PP) demand in Southeast Asia remained healthy, mainly because of increasing exports to the key mainland China market. PP demand for the packaging, medical, and hygiene sectors continued to be supported by increased regional demand, as well as exports to other regions. Consequently, year-on-year propylene demand growth in Southeast Asia increased slightly by 1.1% in 2020 and improved further by 3% in 2021 but then declined by about 7% in 2022 on the back of weaker demand for PP. Following the recovery seen in 2023, strong, growing momentum will continue in the next five years, reflected by an average annual growth rate of more than 5%.

- Over the 10-year forecast period to 2033, propylene demand is expected to expand by almost 4% annually, predominantly driven by PP. Overall, demand from PP in Southeast Asia is projected to increase by 55%, or about 3.2 million metric tons, in the next 10 years. Malaysia, Vietnam, and Indonesia will likely be the main contributors to the increase in PP production. PP will continue to be the largest propylene derivative in Southeast Asia, increasing its share of regional demand from 75% in 2023 to 80% by 2033.

- Southeast Asia was a net importer of propylene monomer in 2015–16, owing to a series of unexpected cracker outages and shutdowns in the region. It became a net exporter of propylene monomer during 2017–19 after regional capacities were added and exports to Northeast Asia (including mainland China, Taiwan, and South Korea) increased. In the meantime, Vietnam's propylene monomer imports remarkably increased in 2020 thanks to the start-up of a PP unit ahead of the upstream propylene capacity (the associated PDH unit commenced operations in the third quarter of 2021). Thus, Southeast Asia turned to a more-or-less balanced trade position for propylene monomer in 2021-2023. Going forward, Southeast Asia is expected to be a small net exporter of about 130,000 metric tons, on average, until the end of this decade, with the average volume increasing to nearly 500,000 metric tons in the longer term.

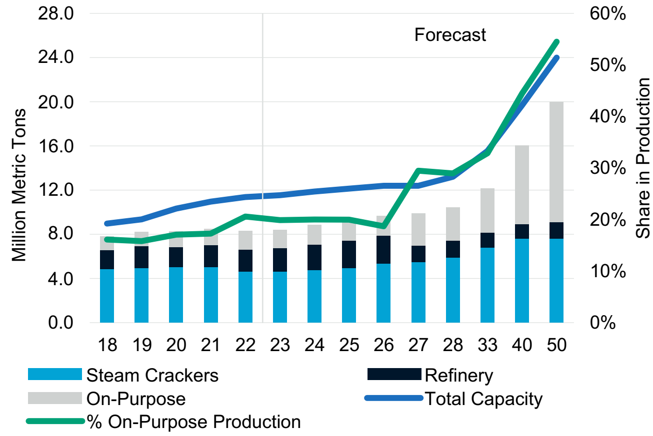
- Mainland China is the largest and most important export market for most Southeast Asian propylene derivative producers. They placed a stronger focus on exports to the Chinese market in 2020 because of weak regional demand and mainland China's faster recovery of derivatives demand due to its successful control of COVID-19. During the current economic recovery phase, mainland China will likely maintain its crucial role as a target market for propylene derivatives producers in Southeast Asia. However, mainland China is rapidly expanding its capacity of integrated propylene-to-derivatives units, which will be a key challenge for producers in Southeast Asia over the next couple of years. In addition, new propylene and propylene derivative capacities in the Middle East and India will mainly export to Asia, including Southeast Asia. Although the price advantage of Middle Eastern producers is less pronounced for propylene and propylene derivatives than ethylene derivatives, pressures in the international market will intensify, particularly during the recovery phase from the global recession and still worsening global oversupply situation, mainly for PP.

Southeast Asia: PG/CG Propylene Supply & Demand



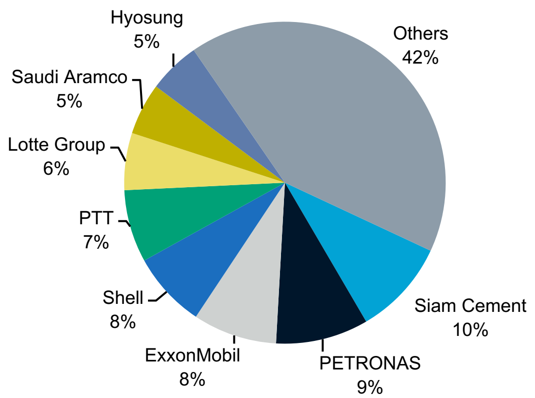
(% AAGR = 18-23/23-33)
Source: Chemical Market Analytics by OPIS

Southeast Asia: PG/CG Propylene Production by Source



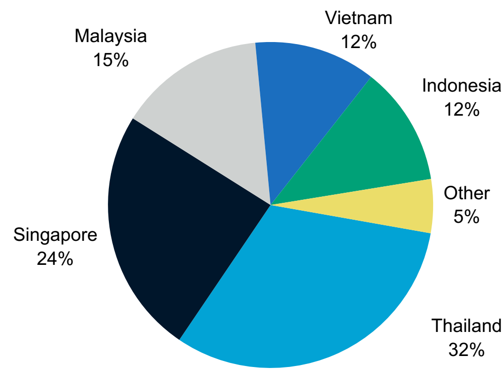
Note: Steam crackers and refinery data include the respecetive crude to olefins production.
Source: Chemical Market Analytics by OPIS

Southeast Asia: 2023 PG/CG Propylene Producers by Shareholder



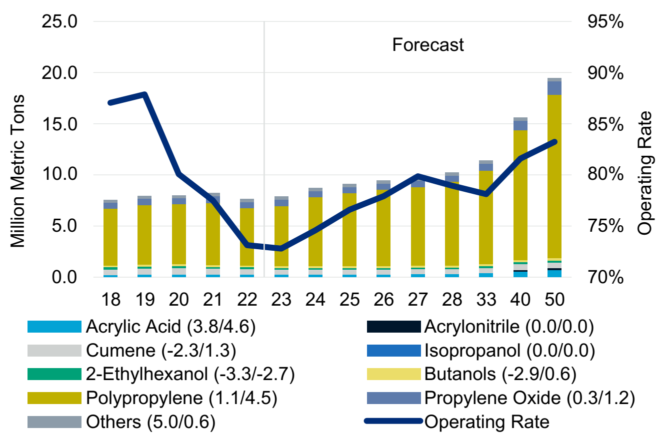
Capacity = 11.5 Million Metric Tons
Source: Chemical Market Analytics by OPIS

Southeast Asia: 2023 PG/CG Propylene Demand by Geography



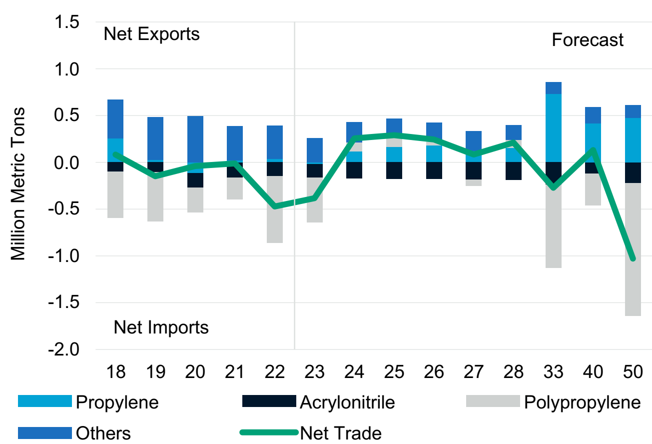
Domestic Demand = 7.9 Million Metric Tons
Source: Chemical Market Analytics by OPIS

Southeast Asia: PG/CG Propylene Demand



(% AAGR = 18-23/23-33)
Source: Chemical Market Analytics by OPIS

Southeast Asia: Propylene Net Equivalent Trade



Source: Chemical Market Analytics by OPIS

Production Process Overview

Introduction

The World Analysis - Propylene is a study of worldwide markets for propylene and propylene derivatives. The following chapter serves as a background to the study by providing an overview of the technology for the production of propylene and selected derivatives. This review of technology has been developed from published information and discussions with producers.

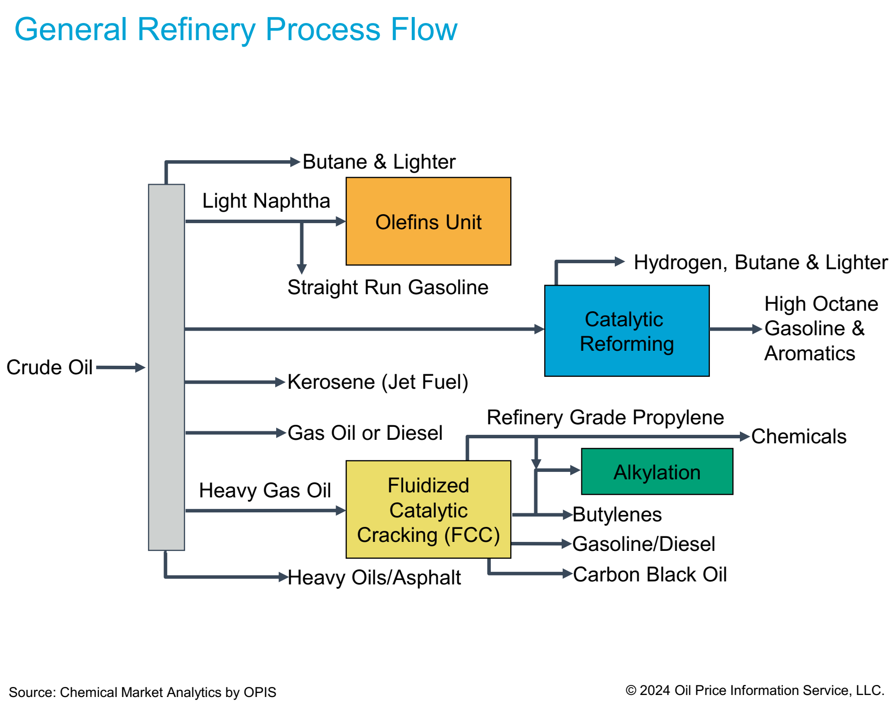
Propylene is second only to ethylene by volume as a structural material platform for producing other organic chemicals and, like ethylene, it has virtually no use in consumer markets without being processing into some derivative product. Downstream it is polymerized (as in the production of polypropylene) or reacted with other chemicals (as in the production of acrylonitrile, propylene oxide, and oxo alcohols) to produce a large variety of industrial products. Propylene is commercially generated as a coproduct, either in an olefins plant or in the fluidized catalytic cracking (FCC) unit of a crude oil refinery, but it can also be produced on-purpose in propane dehydrogenation, metathesis, or methanol-to-olefins plants.

After ethylene, the second-largest volume product from a steam cracker is typically propylene. In fact, the production of propylene from such a plant is so important that the name “olefins plant” is often applied to this kind of manufacturing facility. Except where ethane is used as the feedstock, propylene is typically produced at levels ranging from 40% to 60% of the ethylene produced dependent on feedslate used. In an olefins plant, propylene is generated by the same pyrolysis and purification processes as ethylene. It is recovered as either chemical grade (92 to 96% purity) or polymer grade (99.5% purity) and must be essentially free of diolefins, acetylenes, and other olefins.

Propylene production in refineries

In a crude oil refinery, propylene is a coproduct of fluidized catalytic cracking (FCC) units producing useful, lighter products from atmospheric and vacuum gas oils. An FCC unit converts these heavy oils into motor gasoline, fuel oils, and significant quantities of olefins, especially butylenes and propylene. In areas where the refinery olefins supply is plentiful and there is a need for a higher-octane motor gasoline blend stock, the propylene and butylenes are often used to manufacture motor gasoline alkylate.

The main purpose of a refinery is to produce motor gasoline and various grades of fuel oils by separating crude oil into useful, high-value fractions and converting the other fractions into high-value components by various specialized processes. In a typical refinery, the first step is to remove salt and various contaminants from crude oil, using a desalter. The crude oil is then sent to two main distillation columns, an atmospheric column and a vacuum column, that separate the oil into many different fractions. The lightest fractions are natural gas liquids containing methane, ethane, propane, butanes, and natural gasolines. These components are further separated for sale as fuel products or sent either to other conversion units to make gasoline-blending components or to an olefins plant as feedstock. The next lightest fractions are naphthas and the petrochemical products benzene, toluene, and xylene. These are either hydrotreated and blended directly into gasoline or further processed by hydrotreatment and catalytic reforming to make higher-value gasoline-blending components. The next fractionation cut are distillates that are separated and hydrotreated in order to form various fuel oils such as kerosene, diesel, and jet fuel. Still heavier are gas oils that are either sent to a catalytic cracker to make gasoline, fuel oils, and other coproducts, such as butylenes and propylene, or processed in a hydrocracker. The residue from the atmospheric distillation column is sent to vacuum distillation to further recover gas oil. The heaviest fractions from the vacuum distillation column are considered residue products and are typically converted into a solid coke or asphalt product.



The gas oil cuts from the main distillation columns in a refinery are sent to an FCC unit for the primary purpose of upgrading the gas oils to a higher-value product, typically motor gasoline. The feed to the FCC unit is preheated in a heat exchanger or furnace, mixed with small catalyst particles, and then introduced into a riser, which is a large vertical pipe that sends the mixture of feed and catalyst into the reaction chamber. Upon contact with the catalyst, the reaction begins immediately and proceeds until the product vapors separate from the catalyst, or the catalyst is "deactivated" by coking, i.e., carbon deposition on the particles. Then, the hydrocarbon vapors are transferred to a distillation section, where gases and liquids are separated into fractions. The largest volume products coming from the FCC unit are gasoline blending components, but smaller volumes of fuel oils, butylenes, and propylene are also produced. The propylene yield from feed to an FCC unit is in the range of 5–15% (by volume), depending on the operating conditions and catalyst type.

However, technologies have been developed for maximizing the propylene yield (approaching 25% yield) from catalytic cracking units. Examples of these include Honeywell UOP's PetroFCC™ process, which maximizes propylene yields from heavy feeds. Sinopec Research Institute of Petroleum Processing (RIPP) of China developed and commercialized deep catalytic cracking (DCC), which promotes a more even distribution of products among gasoline and fuel oils, and there is a much higher propylene yield. More recently, SINOPEC RIPP developed a high-severity catalytic pyrolysis process (CPP) that maximizes production of both ethylene and propylene from heavy, low-value feedstocks. Shaw is the licensor of both the DCC and CPP processes outside of mainland China. Lummus Technology offers the I-FCC™ process that combines their FCC process with a proprietary Indmax catalyst formulation developed by Indian Oil Corporation. KBR, Inc., in alliance with ExxonMobil, offers the MAXOFIN™ process, which provides ability to adjust propylene yield as market conditions demand. In the balances provided in this analysis, Chemical Market Analytics shows production of propylene from these, and other, enhanced FCC process technologies, such as high-severity FCC (HS FCC).

Propylene generated by catalytic cracking generally has a purity of 65–80%, depending upon operating conditions of the unit. Refinery-grade propylene has several potential consumption options: acid alkylation; dimersol and polymer gasoline; propane blending; direct consumption into chemicals, such as cumene, isopropanol, and oligomers; and purification to polymer-grade propylene (PGP) or chemical-grade propylene (CGP). FCC units designed for enhanced propylene production typically include purification to PGP or CGP.

Fuel applications for propylene

Most refinery-grade propylene (RGP) consumed within oil refineries is for acid alkylation. When propylene is reacted with isobutane, the resulting C_7 iso-hydrocarbon is referred to as propylene alkylate. This material has a clear octane value of about 89.5. In the past, when tetraethyl lead was being added to gasoline, propylene alkylate was a preferred blend stock, because it had a good lead response (i.e., the lead gave the propylene alkylate a solid octane boost). However, in an unleaded gasoline pool, propylene alkylate contributes little octane enhancement, particularly to unleaded premium. Yet, for many years, alkylation has been the refiner's easiest outlet for large volumes of propylene. Even in today's industry, when crude C_3 and C_4 streams are not separated in the refinery and isobutane is readily available, the refiner frequently converts the C_3 and C_4 olefins into alkylate, despite the knowledge that alkylate usually offers poor value for the propylene, particularly when the isobutane price is relatively high, that is, close to the price of gasoline.

Just as alkylation provides an outlet for refinery-generated propylene, some refiners (and even a few olefins plant operators) have installed dimersol and polymer gasoline units to convert propylene to hexene (dimate). In the dimate process, two molecules of propylene are combined to form a C_6 dimer that can be used as a gasoline blending component similar to alkylate. Since propylene dimate and alkylate are close in their vapor pressure and octane values, either can be used in gasoline with nearly equal value, but dimate has a slightly lower clear octane value. The significant difference between dimate and alkylate is that the economics of alkylate depend heavily upon the price spread between gasoline and isobutane, whereas the economics of dimate are more directly related to the value of gasoline.

Under scenarios of high propane pricing, refiners can blend propylene into their propane sales streams, limited by the quality requirements of their customers. HD-5 specification propane requires less than 5% propylene in the US, although higher levels of propylene may be acceptable for certain industrial uses.

Chemical applications of propylene

The double bond in propylene lends itself to multiple paths for further processing into valuable products for consumers. The largest of these applications is polypropylene (PP), which is a highly favored resin used for its rigidity and heat resistance for many applications. For this process, propylene must be purified to 99.5% purity, appropriately named polymer-grade propylene (PGP). Another significant application is reacting propylene with oxygen to form propylene oxide, which serves as the primary chemical for polyurethane uses such as foam cushioning and rigid foam board insulation. Other major derivatives of propylene are acrylonitrile (used in acrylic fibers) and oxo alcohols (used as solvents and also reacted to produce acrylates, acetyls, vinyl plasticizers and other specialized derivatives). In such processes, PGP or chemical-grade propylene (CGP), with a purity level between 92% and 96% is typically used.

Without purification, refinery-grade propylene (RGP), which is propylene with a purity level less than 92%, has limited direct use in chemical processes. Only three major chemical conversion processes can directly consume the low-purity RGP: cumene, isopropanol, and oligomers. Cumene is manufactured from propylene and benzene with an acidic catalyst and used in the production of phenol and acetone. Isopropanol can be produced by treating propylene with sulfuric acid and subsequent hydrolization. It is mainly used as a solvent but also serves as the main ingredient used in high quality hand sanitizers. Finally, oligomers are formed by combining several propylene molecules into trimers (nonene) or tetramers (dodecene). Oligomers are used in the production of polymers, detergents, and gasoline.

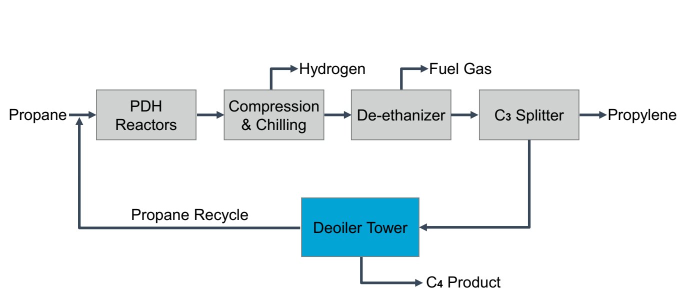
The most significant market for RGP is when it is upgraded to PGP or CGP. Refiners may choose to either sell the refinery propylene, as most do, or upgrade it themselves into chemical or polymer grade to enhance its value. To be utilized in other processes besides those producing cumene, isopropanol, and oligomers, RGP must be purified to either CGP or PGP, which is usually accomplished in a propylene purification splitter that is essentially a large distillation column that separates propylene from propane. RGP often contains traces of components such as sulfur, arsenic, and water that are harmful to some derivative processes and must be removed by catalytic or adsorption processes. Economic calculations detailing propylene purification splitter operations are presented in the **Production economics** section. The economics of splitter operations are notable because they provide the link between the RGP markets and the PGP and CGP markets.

On-purpose propylene production

Although the propylene yielded from olefins plants and fluidized catalytic cracking (FCC) units is typically considered a coproduct in the process to produce the more important primary products, ethylene and motor gasoline, propylene is also increasingly commercially produced on purpose. In some areas, there has been a shift to lighter steam cracker feedstocks with much lower propylene yields. This shift has created an imbalance of supply and demand for propylene, thus creating a need for on-purpose propylene generation. Propylene demand worldwide is forecast to grow more quickly than ethylene demand, resulting in a greater need for propylene beyond its availability as a coproduct. Maximizing production and recovery of propylene from FCC units through high-severity (HS) FCC has become one major source of on-purpose propylene. The three other most common methods that are, or will be, employed to address the imbalance are propane dehydrogenation, metathesis, and methanol-based processes.

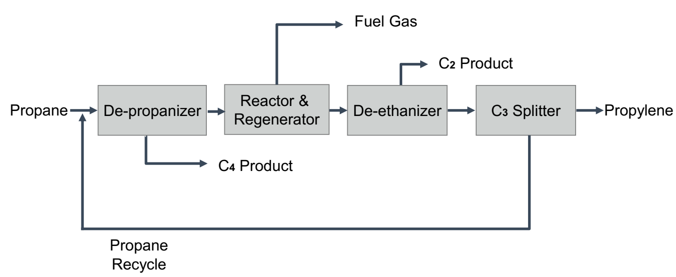
Propane dehydrogenation (PDH) is a catalytic process that converts propane into propylene and hydrogen (by-product). The reaction is endothermic and is carried out in the presence of a noble- or heavy-metal catalyst such as platinum or chromium. The yield of propylene from propane is about 85 weight percent. The reaction by-products (mainly hydrogen) are usually used as fuel for the propane dehydrogenation reaction. As a result, propylene tends to be the only product, unless local demand exists for the hydrogen by-product. UOP Oleflex™ and Lummus Catofin are the two most widely licensed processes. PDH technologies are also offered by Uhde (STAR process), Linde/BASF, Snamprogetti/Yarsintez, and Dow (FCDh process). Notably, the emerging Dow fluidized catalytic dehydrogenation (FCDh) process is based on a circulating fluidized-bed concept, which is widely used in FCC units in petroleum refining.

Propylene via Propane Dehydrogenation



Source: Chemical Market Analytics by OPIS

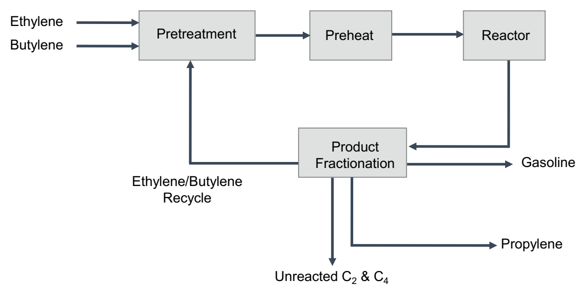
Dow FCDh Process Flow



Source: Chemical Market Analytics by OPIS

Metathesis, also known as disproportionation, is a reversible olefin conversion reaction between ethylene and butenes in which double bonds are broken and then reformed to synthesize propylene. Propylene yields of more than 90 weight percent are achieved. This option may also be used when there is no butene feedstock available. In this case, part of the ethylene feeds an ethylene dimerization unit that converts ethylene into butenes, which maintains the process using the remainder of the ethylene. The Lummus olefins conversion technology (OCT) is the predominant technology employed for metathesis. Axens is developing the Meta-4 process, which was originally jointly developed by IFP and the Chinese Petroleum Corporation.

Propylene via Metathesis



Source: Chemical Market Analytics by OPIS
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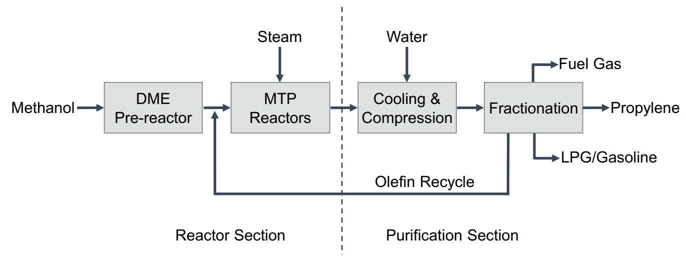
Methanol-to-Propylene



Source: Chemical Market Analytics by OPIS
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Methanol can be used to produce propylene as well in either methanol-to-olefins (MTO) facilities, which produce a mixture of ethylene and propylene, or methanol-to-propylene (MTP) units, which predominantly produce propylene. A large amount of methanol is required to make a world-scale ethylene and/or propylene plant. MTO produces between 30 and 45 weight percent of propylene and a similar level of ethylene. Depending on the production mode, MTP produces up to 71 weight percent propylene. For MTP, there are a number of commercial and near-commercial process technologies available for licensing, including Lurgi's (now Air Liquide) fixed-bed MTP process and the fluidized-bed methanol-to-propylene (FMTP) process developed jointly by Tsinghua University, China National Chemical Engineering Co., and China Huaihua Group. Additionally, the Shanghai Research Institute of Petrochemical Technology (SRIPT) has been developing its own MTP process technology (named S-MTP), and the Dominant Technology for Propylene Production (DTP™) process, developed jointly by Japan Gas Chemical (JGC) and Mitsubishi Chemical, has successfully completed demonstration tests and is said to be ready for licensing.

Coal can also be used to produce propylene in areas where abundant coal supply provides advantaged feedstock, such as in mainland China. In a coal-to-olefins complex, synthesis gas (syngas) is produced via non-catalytic partial oxidation of coal in a coal gasification unit. The syngas is then converted into methanol by reacting pressurized syngas through a converter reactor in the presence of a catalyst. Either methanol produced from coal or purchased methanol is then catalytically converted into light olefins much like in the methanol-based olefins/propylene processes described above. Major coal gasification licensors include GE Energy, Shell, CB&I, and Siemens.

Production Economics

Explanatory Notes

The following pages provide economic snapshots for propylene. All values are in current US dollars unless stated otherwise. The underlying assumptions are listed below.

- Propylene economics provided for the United States include propane dehydrogenation, propylene purification, and alkylation. For West Europe and Southeast Asia, only propane dehydrogenation economics are modeled while for Northeast Asia, snapshots are included for coal-to-olefins, methanol-to-olefins, and propane dehydrogenation.
- Incremental costs include the raw materials costs, coproduct credits, and other variable costs, such as utilities.
- Propylene prices are typically quoted on a delivered basis. As a result, in order to get an accurate assessment of cash costs and margins, delivery costs are removed from prices.
- Plant fixed costs include items such as labor, maintenance, insurance, taxes, and plant overhead.
- Maintenance, insurance, and plant overhead costs are estimated as a function of plant size and total fixed investment.
- The plant overhead term includes overhead only at the plant site, such as managers, shift foremen, etc.
- The before-tax margin is simply the total revenue minus total cash cost to produce and does not include corporate overhead, depreciation, or cost of capital.

United States

Propane Dehydrogenation

2023 US Propylene Via Propane Dehydrogenation Economics UOP Oleflex Process					
	Factor Per Pound Product	**Quantity & Units**	**Price Per Unit**	**Cents/Lb**	**$/Ton**
Product					
Polymer-grade Propylene	1.0 Pound	861.3 MM Pounds	40.8 ¢/Pound	40.8	899
Freight				1.0	22
Revenue				**39.8**	**877**
Fuel	0.008 MMBtu	7.0 MM MMBtu	2.661 $/MM Btu	2.2	47
Electricity	0.054 KWH	46.9 MM KWH	4.648 ¢/KWH	0.3	6
Cooling Water	137.000 Pound	117994.5 MM Pounds	0.008 $/M Pound	0.1	2
Boiler Feed Water	0.200 Pound	172.3 MM Pounds	0.012 $/M Pound	0.0	0
Catalyst, Chemicals & Others				1.0	21
Variable Operating Costs				**3.5**	**77**
Propane	0.284 Gallon	244.2 MM Gallons	70.94 ¢/Gallon	20.1	443
Raw Material Costs				**20.1**	**443**
Hydrogen	0.055 Pound	47.5 MM Pounds	19.46 ¢/Pound	1.1	24
Fuel	0.144 Pound	124.0 MM Pounds	6.35 ¢/Pound	0.9	20
Coproduct Credits				**2.0**	**44**
Subtotal of incremental Costs*				**21.6**	**476**
Maintenance				1.5	33
Insurance & Local Taxes				0.7	15
Overhead				0.7	15
Labor				0.1	3
Fixed Costs				**3.0**	**66**
Total Cash Costs (Fixed & Incremental)				**25**	**543**
Total Cash Margin				**15**	**335**

* Incremental costs represent a subtotal of variable, raw material costs, and coproduct credits

Propylene Purification

2023 US Propylene Purification Economics	Factor Per Pound Product	Quantity & Units	Price Per Unit	Cents/Lb	$/Ton
Product					
Polymer-grade Propylene	1.0 Pound	1403.2 MM Pounds	40.79 ¢/Pound	40.8	899
Freight				1.0	22
Revenue				**39.8**	**877**
Electricity	0.004 KWH	5.0 MM KWH	4.648 ¢/KWH	0.0	0
Medium Pressure Steam	0.960 Pound	1347.1 MM Pounds	0.004 $/M Pound	0.4	9
Cooling Water	124.900 Pound	175264.8 MM Pounds	0.008 $/M Pound	0.1	2
Catalyst, Chemicals & Others				0.2	4
Variable Operating Costs				**0.7**	**16**
Propane	0.111 Gallon	155.9 MM Gallons	70.94 ¢/Gallon	7.9	174
Refinery-grade Propylene	1.005 Pounds	1410.3 MM Pounds	18.92 ¢/Pound	19.0	419
Raw Material Costs				**26.9**	**593**
Propane	0.112 Gallon	157.5 MM Gallons	70.94 ¢/Gallon	8.0	176
Coproduct Credits				**8.0**	**176**
Subtotal of incremental Costs*				**19.7**	**433**
Maintenance				0.3	6
Insurance & Local Taxes				0.3	6
Overhead				0.1	3
Labor				0.0	1
Fixed Costs				**0.7**	**16**
Total Cash Costs (Fixed & Incremental)				**20**	**450**
Total Cash Margin				**19**	**428**

* Incremental costs represent a subtotal of variable, raw material costs, and coproduct credits

Alkylation

2023 US Gulf Coast Propylene Alkylation Economics
Hydrofluoric Acid Process

	Factor Per Gallon Product	Quantity & Units	Price Per Unit	Cents/Gallon	$/Ton
Product					
Propylene Alkylate (HF)	1.0 Gallon	119.4 MM Gallons	285.12 ¢/Gallon	285.1	1083
Revenue				**285.1**	**1083**
Fuel	0.006 MMBtu	0.7 MMM Btu	2.661 $/MM BTu	1.6	6
Electricity	0.051 KWH	6.1 MM KWH	4.648 ¢/KWH	0.2	1
Medium Pressure Steam	0.813 Pound	97.0 MM Pounds	0.004 $/M Pound	0.4	1
Cooling Water	288.581 Pound	34451.1 MM Pounds	0.008 $/M Pound	0.2	1
Catalyst, Chemicals & Others				0.3	1
Variable Operating Costs				**2.7**	**10**
Propane	0.261 Gallon	31.1 MM Gallons	70.94 ¢/Gallon	18.5	70
Isobutane	0.725 Gallon	86.5 MM Gallons	100.49 ¢/Gallon	72.8	276
Refinery-grade Propylene	2.440 Pound	291.3 MM Pounds	21.80 ¢/Gallon	53.2	202
Raw Material Costs				**144.5**	**549**
Propane	0.261 Gallon	31.1 MM Gallons	70.94 ¢/Gallon	18.5	70
Coproduct Credits				**18.5**	**70**
Subtotal of incremental Costs*				**128.7**	**489**
Maintenance				1.2	5
Insurance & Local Taxes				0.8	3
Overhead				0.8	3
Labor				0.5	2
Fixed Costs				**3.2**	**12**
Total Cash Costs (Fixed & Incremental)				**132**	**501**
Total Cash Margin				**153**	**582**
Propylene Breakeven Netback Poly Value (RG Price + Cash Margin) $/Ton Propylene Basis					**1,865**

* Incremental costs represent a subtotal of variable, raw material costs, and coproduct credits

West Europe

Propane Dehydrogenation

2023 West Europe Propylene Via Propane Dehydrogenation Economics
UOP Oleflex Process

	Factor Per Ton Product	Quantity & Units	Price Per Unit	Euro /Ton	$/Ton
Product					
Polymer-grade Propylene	1.0 Ton	504.0 kTons	1087.5 €/Ton	1087.5	1176
Freight				24.8	27
Revenue				**1062.7**	**1149**
Fuel	16.890 GJ	8.5 MM GJ	10.501 €/GJ	177.4	192
Electricity	120.000 KWH	60.5 MM KWH	0.103 €/KWH	12.4	13
Cooling Water	137.000 Ton	69048.0 kTons	29.541 €/Ton	4.0	4
Boiler Feed Water	0.200 Ton	100.8 kTons	36.394 €/Ton	0.01	0.01
Catalyst, Chemicals & Others				19.6	21
Variable Operating Costs				**213.4**	**231**
Propane	1.200 Ton	604.8 kTons	482.67 €/Ton	579.2	626
Raw Material Costs				**579.2**	**626**
Hydrogen	0.055 Ton	27.8 kTons	1488.86 €/Ton	82.2	89
Fuel	0.218 Ton	109.6 kTons	582.75 €/Ton	126.7	137
Coproduct Credits				**208.9**	**226**
Subtotal of incremental Costs*				**583.7**	**631**
Maintenance				21.1	23
Insurance & Local Taxes				10.0	11
Overhead				10.0	11
Labor				3.0	3
Fixed Costs				**44.1**	**48**
Total Cash Costs (Fixed & Incremental)				**628**	**679**
Total Cash Margin				**435**	**470**

* Incremental costs represent a subtotal of variable, raw material costs, and coproduct credits

Northeast Asia

Propane Dehydrogenation

2023 Northeast Asia Propylene Via Propane Dehydrogenation Economics
UOP Oleflex Process

	Factor Per Ton Product	Quantity & Units	Price Per Unit	Cents/Lb	$/Ton
Product					
Polymer-grade Propylene	1.0 Ton	516.6 kTons	841.7 $/Ton	38.2	842
Freight				0.0	0
Revenue				**38.2**	**842**
Fuel	17.820 MMBtu	9.2 MMMMBtu	9.935 $/MMBtu	8.0	177
Electricity	120.000 KWH	62.0 MM KWH	9.739 $/KWH	0.5	12
Cooling Water	137.000 Ton	70774.2 kTons	29.559 $/Ton	0.2	4
Boiler Feed Water	0.200 Ton	103.3 kTons	36.970 $/Ton	0.00	0.01
Catalyst, Chemicals & Others				2.1	21
Variable Operating Costs				**10.9**	**214**
Propane	1.200 Ton	619.9 kTons	626.00 €/Ton	34.1	751
Raw Material Costs				**34.1**	**751**
Hydrogen	0.055 Ton	28.5 kTons	1602.09 €/Ton	4.0	88
Fuel	0.144 Ton	74.4 kTons	522.56 €/Ton	3.4	75
Coproduct Credits				**7.4**	**164**
Subtotal of incremental Costs*				**37.5**	**801**
Maintenance				1.1	24
Insurance & Local Taxes				0.5	11
Overhead				0.5	11
Labor				0.1	3
Fixed Costs				**2.2**	**49**
Total Cash Costs (Fixed & Incremental)				**40**	**851**
Total Cash Margin				**-2**	**-9**

* Incremental costs represent a subtotal of variable, raw material costs, and coproduct credits

Coal-to-Olefins

2023 Northeast Asia Coal-to-Olefins
Projected General Process - Spot Product Pricing Basis

	Factor & Product (per Ton)	Quantity & Units	Price Per Unit	Per Product Basis ($/Metric Ton)
Product				
Propylene (Spot)	0.500 Ton	250.2 k Tons	841.7 $/Ton	421
Ethylene (Spot)	0.500 Ton	250.2 k Tons	831.6 $/Ton	416
Revenue				**837**
Power	2040.000 KWH	1020.8 GWH	82.5 $/MWH	168
Fuel	46.400 mill. Btu	23.2 Trill Btu	1.70 $/mill. Btu	79
Boiler Feed Water	34.000 Ton	17013.5 k Tons	1836.0 $/Ton	62
Catalyst and Chemicals				56
Variable Operating Costs				**366**
Coal	4.848 Ton	2425.9 k Tons	71.7 $/Ton	348
Raw Material Costs				**348**
C4+ Hydrocarbons	0.219 Ton	109.6 k Tons	689.5 $/Ton	151
Coproduct Credits				**151**
Subtotal of Incremental Costs*				**562**
Labor				21
Maintenance				126
Insurance & Local Taxes				76
Plant Overhead				126
Sales and Administration				50
Fixed Costs				**399**
Total Cash Costs (Fixed & Incremental)				**962**
Total Cash Margin				**-125**

* Incremental costs represent a subtotal of variable, raw material costs, and coproduct credits

Methanol-to-Olefins

2023 Northeast Asia Methanol-to-Olefins Projected General Process - Spot Product Pricing Basis				
	Factor & Product (per Ton)	**Quantity & Units**	**Price Per Unit**	**Per Product Basis ($/Metric Ton)**
Product				
Propylene (Spot)	0.500 Ton	204.0 k Tons	841.7 $/Ton	421
Ethylene (Spot)	0.500 Ton	204.0 k Tons	831.6 $/Ton	416
Revenue				**837**
Power	330.000 KWH	134.7 GWH	193.9 $/MWH	64
Fuel	21.400 mill. Btu	8.7 Trill Btu	3.96 $/mill. Btu	85
Cooling Water	3.000 Ton	1224.2 k Tons	561.8 $/Ton	2
Catalyst and Chemicals				48
Variable Operating Costs				**198**
Methanol	3.030 Ton	1236.5 k Tons	260.1 $/Ton	788
Raw Material Costs				**788**
C4+ Hydrocarbons	0.219 Ton	89.4 k Tons	689.5 $/Ton	151
Coproduct Credits				**151**
Subtotal of incremental Costs*				**835**
Labor				9
Maintenance				12
Insurance & Local Taxes				40
Plant Overhead				12
Sales and Administration				6
Fixed Costs				**78**
Total Cash Costs (Fixed & Incremental)				**914**
Total Cash Margin				**-77**

* Incremental costs represent a subtotal of variable, raw material costs, and coproduct credits

Southeast Asia

Propane Dehydrogenation

2023 Southeast Asia Propylene Via Propane Dehydrogenation Economics
UOP Oleflex Process

	Factor Per Ton Product	Quantity & Units	Price Per Unit	Cents/Lb	$/Ton
Product					
Polymer-grade Propylene	1.0 Ton	485.1 kTons	798.7 $/Ton	36.2	799
Freight				0.0	0
Revenue				**36.2**	**799**
Fuel	17.820 MMBtu	8.6 MMMMBtu	10.356 $/MMBtu	8.4	185
Electricity	120.000 KWH	58.2 MM KWH	10.035 $/KWH	0.5	12
Cooling Water	137.000 Ton	66458.7 kTons	30.052 $/Ton	0.2	4
Boiler Feed Water	0.200 Ton	97.0 kTons	37.462 $/Ton	0.00	0.01
Catalyst, Chemicals & Others				2.1	21
Variable Operating Costs				**11.2**	**222**
Propane	1.200 Ton	582.1 kTons	652.57 €/Ton	35.5	783
Raw Material Costs				**35.5**	**783**
Hydrogen	0.055 Ton	26.8 kTons	1391.75 €/Ton	3.5	77
Fuel	0.144 Ton	69.9 kTons	544.74 €/Ton	3.6	78
Coproduct Credits				**7.0**	**155**
Subtotal of incremental Costs*				**39.7**	**850**
Maintenance				1.2	25
Insurance & Local Taxes				0.5	12
Overhead				0.5	12
Labor				0.1	2
Fixed Costs				**2.3**	**51**
Total Cash Costs (Fixed & Incremental)				**42**	**901**
Total Cash Margin				**-6**	**-102**

* Incremental costs represent a subtotal of variable, raw material costs, and coproduct credits

Price Forecast

Methodology

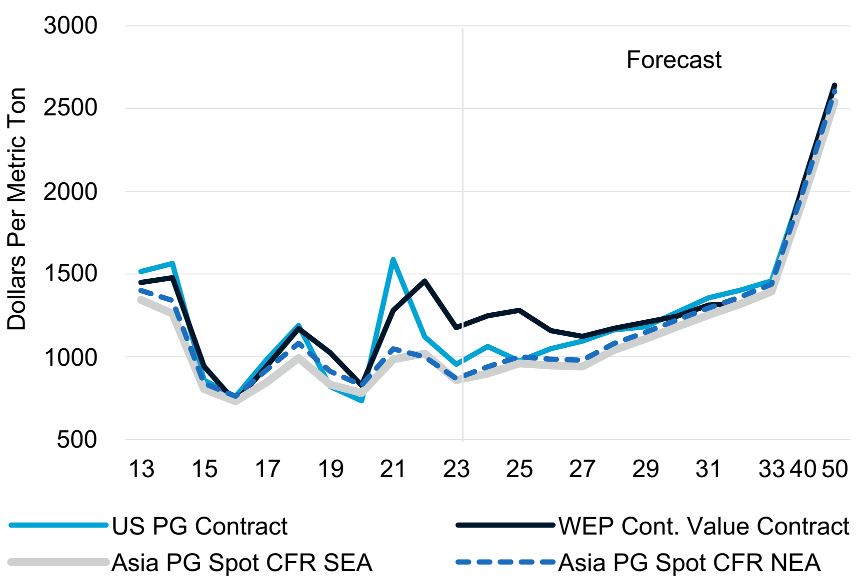
The Chemical Market Analytics price forecast methodology considers numerous factors within the framework of a “cost plus margin equals price” approach.

First, production costs are generated from detailed econometric models and cost curves of chemical manufacturing facilities throughout the world. In our models, cash costs do not include depreciation, corporate overhead, interest payments, taxes, or a return on investment. Only variable (raw material, utilities, and by-product credits) and fixed costs are included in the development of cash-cost forecasts.

Second, Chemical Market Analytics considers numerous factors when projecting margins. These factors include energy costs, economic growth, production costs, alternate values, competitive pressures, trade flows, and availability of supply/capacity. Underlying energy costs will largely drive the production costs of chemicals. Economic growth, or lack thereof, will drive demand, which heavily influences the overall supply/demand balance. One interesting trend in the current market has been that producers are more than willing to also adjust supply by idling or shutting down excess capacity to influence the regional supply/demand dynamics and therefore margins.

An analysis of supply and demand will give an indication of when to expect periods of excess capacity, when prices can frequently approach cash costs, or periods that are capacity constrained, when prices can result in a significant return on the investment. We also review historical margins and why a trend may or may not be repeated in the future.

World: Regional Propylene Market Prices



Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

The Chemical Market Analytics light olefins annual price forecast methodology is based on modeling the incremental cost and expected return for two olefin production units, both located in mainland China: an integrated naphtha steam cracker/PE/PP production facility and an integrated PDH-to-PP production facility. When generating the forecast, many other factors are taken into account, including the global and regional supply/demand outlook, expected trade flows, and alternative technologies. The econometric models employ the technology dominant in the region and represent a generic unit, unless we are modeling the long-term price forecast, at which point we model a greenfield world-scale production unit in mainland China as the primary price-setter. Like other standard economic forecasts, the Chemical Market Analytics price forecast is “surprise free,” meaning that it does not anticipate external shocks, such as regional conflicts or weather-related events that could cause a sudden rise or decline in prices and/or margins.

Price, cost, and margin forecasts for propylene are currently provided for four market centers including North America (based on US contract pricing), West Europe, Northeast Asia, and Southeast Asia. In the United States and West Europe, contract pricing determines the transaction price for most propylene consumed. Spot market transactions represent a small portion of the overall propylene market. In Chemical Market Analytics' experience, several other countries utilize one or both of these contract marker prices in establishing local contract prices or transfer values for propylene. For example, several in Asia have contract price mechanisms, which can be formulated based on US and West European contract price markers as well as on the local price of naphtha or spot propylene. As a result, the price forecast for both Northeast Asia and Southeast Asia focuses on the "freely negotiated" spot prices for propylene.

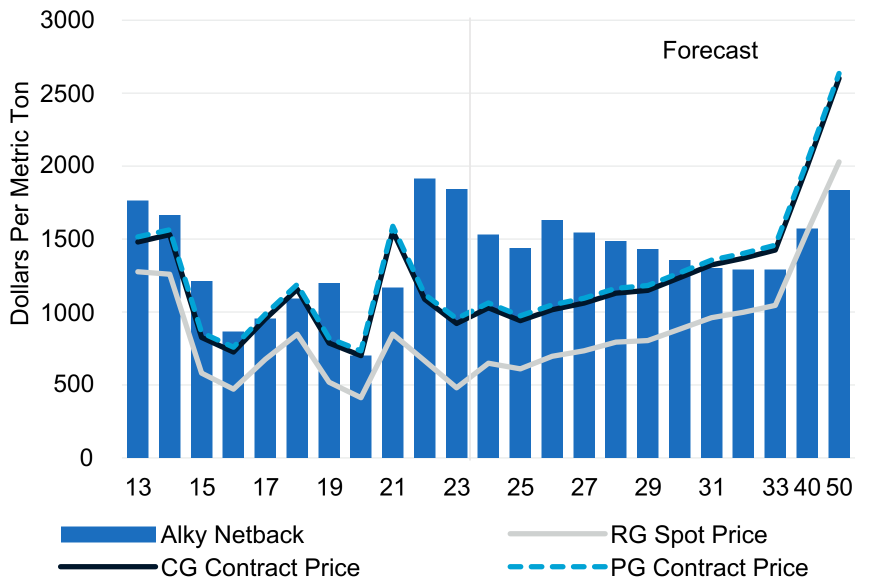
Although the methodology remains consistent, the absolute numbers contained in the price forecast continue to change as underlying assumptions change. Only the specific propylene prices and underlying base assumptions used in the price and margin forecasts presented here are included in the World Analysis. The complete coverage of the global propylene markets is available in our Market Advisory Services: *North America Light Olefins, European/Middle East Olefins,* and *Asia Light Olefins*. As noted in the Explanatory notes–Online resources section, these Market Advisory Services provide access to Chemical Market Analytics' online proprietary price and production economics database.

United States

The benchmark polymer-grade propylene (PGP) prices shown in the graph below refer to pipeline-delivered PGP prices in the US. The benchmark PGP prices shown are nondiscounted reference prices while refinery-grade propylene (RGP) refers to weighted average spot prices, and the bars represent a key alternative disposition for RGP: the refinery netback price level for converting RGP into conventional alkylate, a blending stock for the motor gasoline pool.

Currently, the majority of the propylene produced in the US is generated as a coproduct, either through ethylene production in steam crackers or as a coproduct of motor gasoline production in fluidized catalytic cracking (FCC) units in crude oil refineries. Virtually all propylene coproduced in steam crackers is sold into the petrochemical market, which leaves FCC-sourced propylene streams and on-purpose propylene production units to absorb derivative demand swings or seize the arbitrage opportunity. Since RGP production from FCC units can find outlets in dispositions in motor gasoline blending and fuel product blending, pricing of these alternate markets can significantly influence propylene pricing.

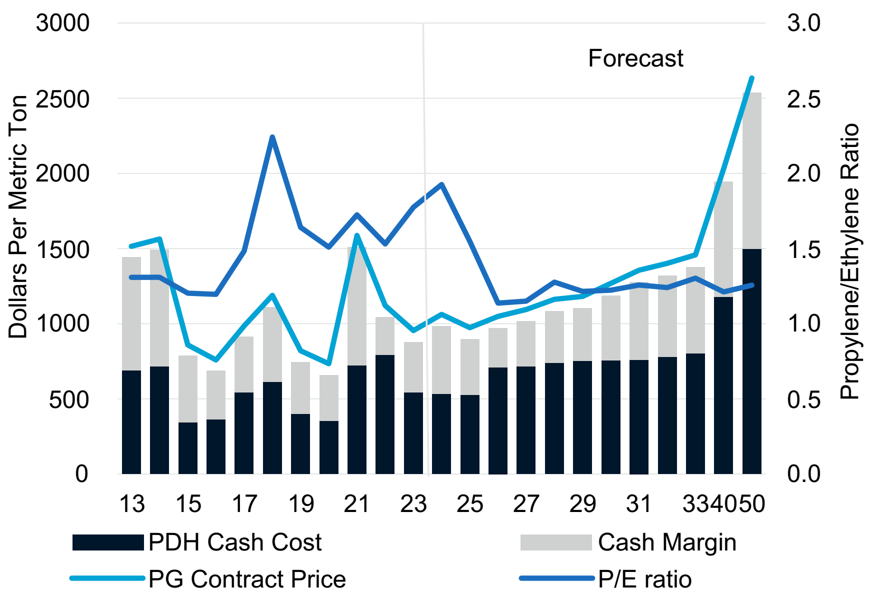
United States: Propylene Prices



Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

In the last 10-15 years, the shale gas revolution has transformed the landscape of petrochemicals in North America. As a result, the amount of ethylene produced from lighter feedstocks (specifically ethane) has increased and significantly driven the amount of propylene produced from steam cracking downward as the resultant yield of propylene is much less with ethane as it is with the heavier feedstocks. As a result, propylene prices in the US rose sharply between 2010 and 2014 as supply was insufficient to meet growing demand. However, as propane and butane supply swelled and effectively became stranded regionally for most of 2015, propylene supply became abundant as these liquefied petroleum gases were fed to maximum levels in the steam crackers and prices declined sharply.

United States: Propylene Economics



Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

This oversupply situation changed in 2016 when investments in terminal capacity allowed higher levels of propane and butane to exit the North American market and push ethane into the forefront of favored steam cracker feedstocks. Coincidentally, in late 2015, Dow's propane dehydrogenation (PDH) unit came online, offsetting the shift of cracker to ethane. However, this unit had spotty operations in its first year with dramatic effects on the regional propylene market. As Enterprise's PDH asset came onstream at the end of 2017, the propylene supply markedly improved; however, increased structural flow to exports did as well and never allowed the North American market to reach balance until late 2018, when polypropylene (PP) imports increased (lowering PP demand) and shifts in cracker feedslates moved toward heavier feedstocks in response to rising ethane prices. Nonetheless, this balanced condition did not last long and the North America propylene market then quickly flipped to a long position with a remarkably high level of inventory observed in early 2019. Such oversupplied condition was further underscored by the dampened demand from the acrylonitrile and PP sectors owing to prolonged outages and strong destocking activities. The supply overhang was carried over into 2020, an eventful year of crude oil price war, COVID-19 pandemic, and heavy hurricane season. With the supply curtailment from the refining sector combined with steady demand recovery, the propylene market gradually drifted to a more balanced direction.

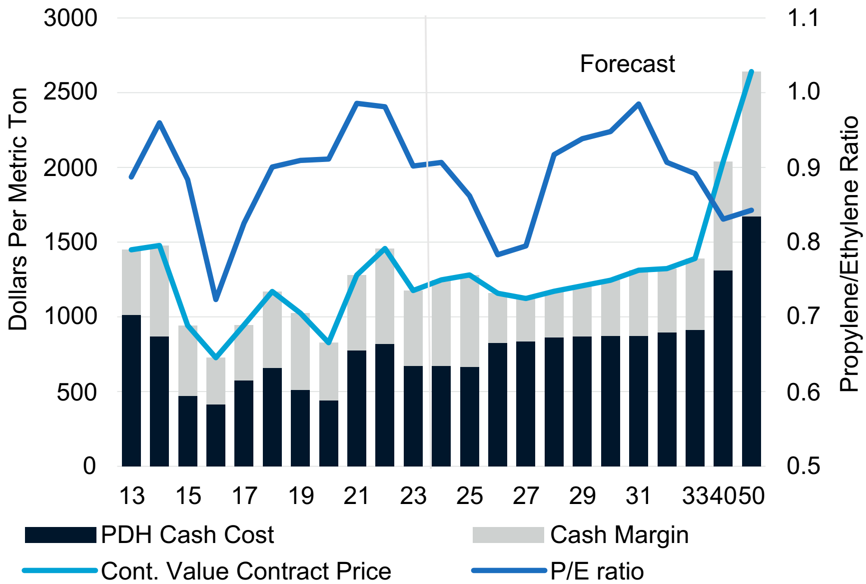
The propylene/ethylene (P/E) price ratio has increased in the past five years as the supply/demand balance for propylene tightened against a lengthening market for ethylene as new crackers came up as demand growth slowed in Asian polyethylene markets. During the near-term forecast period (2024-25), the P/E price ratio is expected to remain comparably high before returning to the 1.1–1.2 level in the following years and remaining above parity throughout the forecast period, suggesting the rate of demand growth for ethylene and propylene will be more closely aligned than in the past.

For refinery-grade prices, propylene splitters require a spread of 5 cents per pound, or $120 per metric ton, to cover operating costs and a reasonable return on capital, which sets the typical minimum between refinery-grade and polymer-grade propylene prices (prior to discounts). In the past five years, the spread between refinery-grade and polymer-grade prices has considerably increased as current splitter operators have been able to leverage their logistics position within both the RGP and PGP markets to maintain attractive splitter margins and hence keep the RGP-to-PGP spread well above the minimum level.

West Europe

The polymer-grade propylene (PGP) prices shown in the graph below are benchmark reference prices delivered in West Europe. The propylene-to-ethylene (P/E) price ratio is a useful comparison of the strength of the propylene price relative to the ethylene price. As in the US, the current P/E ratio in Europe is higher when compared with historical data, because of the increased value of propylene derivatives. However, producers in Europe are still producing plenty of propylene from naphtha crackers, so the ratio of propylene to ethylene prices is currently not forecast to move as high as in the US.

West Europe: Propylene Economics



Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Historically, Europe was a net importer of propylene monomer, and therefore the global market conditions together with the availability of propylene monomer largely influenced prices. For example, if the global propylene market was tight, and Europe needed to attract imports, regional prices would have to increase. From 2008, however, Europe was a small net exporter of propylene. Recent losses of local supply have pushed it back to being an importer. The interest and demand for imports would be more substantial than the global market can supply and the result is a relative modest imbalance in European trade. In 2023-24, Western Europe is forecast to remain a net importer of propylene monomer, approaching a more balanced trade position starting in 2025 when new propane dehydrogenation (PDH) supplies materialize. In the short term, with an import requirement, propylene monomer trade is expected to support European prices, although longer term, with a smaller monomer trade exposure, the market will sit closer to other regional values with the deep-sea arbitrage rarely opening. In addition to variations in monomer trade, changes in Europe in the net trade position of propylene derivatives—specifically, polypropylene (PP)—are expected. As the region becomes a net importer of PP, the propylene price will be influenced by the cost for producing incremental PP versus importing the incremental PP.

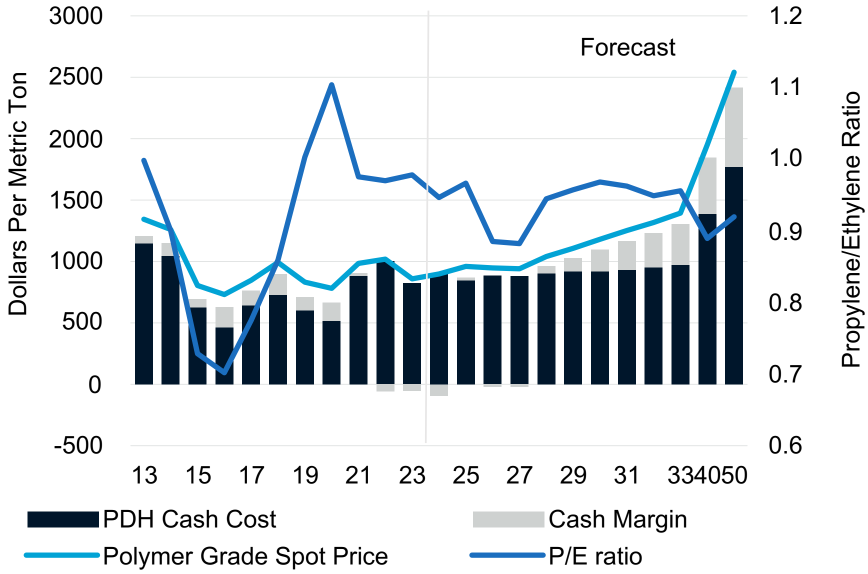
Propylene prices will also be driven by the costs associated with alternative uses for propylene, on-purpose production of propylene, and increases in refinery activity. In addition to nonintegrated PP margins in the region, propylene prices are influenced via comparing the cost of pulling propylene away from refinery liquefied petroleum gas (LPG) or gasoline uses versus the cost of encouraging PDH units or metathesis units to operate. Blending into propane can be the only viable option for propylene in some West European refineries owing to the relatively small number of alkylation units in Europe, so propane prices can set a floor value in a very long market.

Asia

In Asia, the spot propylene prices represent an average cost and freight (CFR) import price. As most of Southeast Asia's propylene production is well integrated with the local derivative markets, the spot market is relatively small in comparison to the much larger Northeast Asian market.

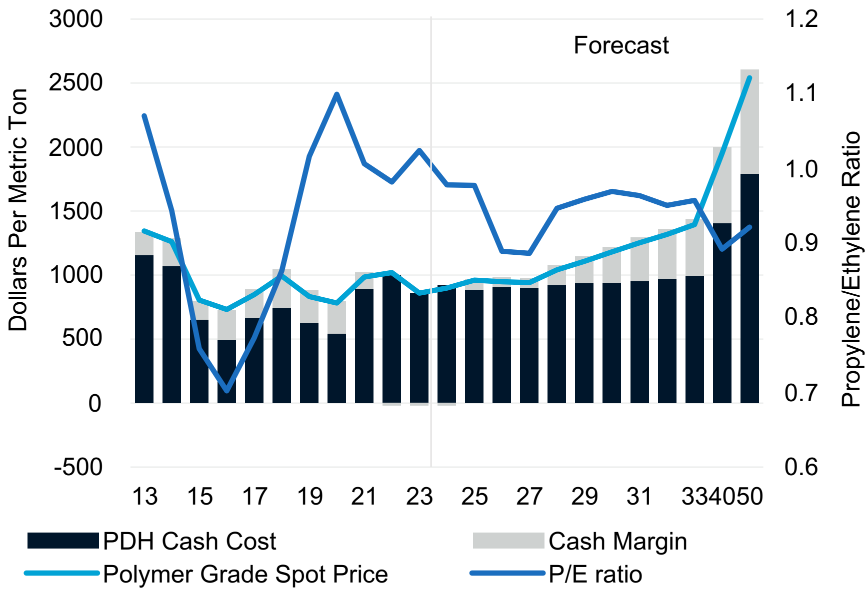
In the past, the Southeast Asian propylene market was mostly balanced either through on-purpose propylene production or imports. This market dynamic contributed to a higher cost structure, with prices in Southeast Asia often considerably higher than in the United States, which had been the marginal supplier to Asia. As a result, prices were often based on US polymer-grade propylene (PGP) prices and the average freight cost to deliver propylene to Southeast Asia, particularly when a trading arbitrage between the regions was open. However, in 2010, the region turned into a net exporter of propylene monomer as it became more self-sufficient with capacity additions. In the next five years, regional trade is forecast to be mostly balanced, requiring only minimal amounts of propylene imports from other regions. Consequently, the influence of international monomer prices on regional propylene prices will decrease, with Northeast Asian nonintegrated PP margins expected to set propylene prices in Northeast Asia in addition to Southeast Asia via netback pricing. Furthermore, the region is poised to become a net exporter of polypropylene during the forecast period, and propylene prices will be determined, in part, by the ability to export additional polypropylene.

Southeast Asia: Propylene Economics



Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

Northeast Asia: Propylene Economics



Source: Chemical Market Analytics by OPIS © 2024 Oil Price Information Service, LLC.

With new propylene investment in Southeast Asia and even more so in the key Northeast Asian region, the additional supply of propylene has and will continue to depress propylene prices in the region. As a result, the propylene/ethylene (P/E) price ratio is expected to hold close to 1.0 through the long-term forecast period. With around 60% of the propylene capacity in Southeast Asia coming from steam crackers, the impact of the P/E ratio remains somewhat significant to the spot propylene market. For example, in a strong ethylene price scenario, cracker operators will be able to lower the price of propylene as the high ethylene prices will mitigate the overall production cost to the producers.

Propylene Price Forecast Tables

Price/Margin Forecast Assumptions

	Energy								
	WTI $ per BBL	Brent $ per BBL	Dubai $ per BBL	US Ethane cpg	US Naphtha cpg	Europe Naphtha $/ton	SE Asia Naphtha $/ton	NE Asia Naphtha $/ton	Natural Gas USGC Burner Tip $ per MM Btu
2013	98	110	106	26	213	903	912	921	3.8
2014	93	99	97	27	198	836	851	861	4.5
2015	49	52	51	18	108	462	476	491	2.8
2016	43	43	41	20	94	385	384	399	2.5
2017	51	54	53	25	115	485	486	496	3.2
2018	65	71	69	33	143	602	606	614	3.2
2019	57	65	64	22	115	505	514	523	2.7
2020	39	42	42	19	77	355	366	380	2.1
2021	68	71	69	31	156	635	637	646	3.9
2022	94	101	96	48	191	770	755	785	6.5
2023	78	83	82	25	152	643	626	649	2.7
2024	77	81	82	22	159	680	667	692	3.2
2025	75	78	78	25	167	670	650	676	3.4
2026	77	83	83	31	172	690	706	729	3.6
2027	79	82	81	36	172	684	701	725	3.9
2028	80	83	82	39	176	699	716	741	4.2
2029	81	84	83	42	176	710	728	752	4.6
2030	80	84	83	44	175	711	730	754	4.8
2031	80	84	82	46	175	719	739	763	5.0
2032	81	85	83	48	178	733	753	778	5.2
2033	83	87	85	51	182	750	771	796	5.6
2040	114	119	115	72	264	1084	1112	1137	7.3
2050	139	144	140	126	336	1385	1424	1452	9.0

Data as of January 2024

GDP deflator and Currency Exchange rates have been removed as we no longer have the rights to share these datasets as part of World Analysis Services.

Source: Argus (History), Chemical Market Analytics & Rystad Energy (Forecast)

World Propylene Economics

	United States						West Europe			Southeast Asia			Northeast Asia		
	Alky Netback Value $/Metric Ton	Refinery Grade Spot, Avg $/Metric Ton	Chemical Grade Contract $/Metric Ton	Polymer Grade Contract $/Metric Ton	PDH Cash Costs $/ton	PDH Cash Margin $/ton	Contained Value* Contract Del'd $/Metric Ton	PDH Cash Costs $/ton	PDH Cash Margin $/ton	Polymer Grade Spot CFR SE Asia $/Metric Ton	PDH Cash Costs $/ton	PDH Cash Margin $/ton	Polymer Grade Spot CFR NE Asia $/Metric Ton	PDH Cash Costs $/ton	PDH Cash Margin $/ton
2013	1762	1276	1480	1515	689	754	1449	1013	436	1344	1148	58	1400	1157	181
2014	1665	1259	1530	1563	717	775	1478	869	609	1261	1047	102	1340	1070	215
2015	1212	581	826	859	345	443	942	472	470	805	625	69	839	654	142
2016	866	471	726	759	364	323	727	413	314	731	463	165	761	491	237
2017	955	676	953	986	543	371	946	577	369	847	643	121	923	664	225
2018	1091	848	1156	1189	614	498	1170	660	510	992	730	168	1081	743	302
2019	1198	519	787	820	399	344	1025	512	513	832	602	110	912	624	256
2020	701	413	701	734	354	303	827	440	387	782	516	147	828	543	251
2021	1166	849	1554	1587	723	787	1280	777	503	985	893	14	1048	895	127
2022	1915	666	1088	1121	791	253	1457	821	636	1019	1003	-59	999	999	-9
2023	1841	481	921	954	545	333	1176	673	503	859	825	-55	868	858	-16
2024	1530	649	1029	1062	534	451	1248	673	574	898	902	-93	940	919	-9
2025	1436	610	941	974	525	371	1280	666	614	960	867	3	1000	886	84
2026	1629	697	1016	1049	709	263	1158	826	331	948	887	-15	985	906	79
2027	1544	734	1061	1094	714	303	1123	838	285	941	882	-18	979	902	78
2028	1485	794	1129	1162	739	345	1171	861	310	1040	903	58	1080	924	156
2029	1429	804	1148	1182	752	350	1208	870	338	1107	918	109	1148	938	209
2030	1356	883	1235	1268	758	431	1245	873	372	1181	921	177	1222	942	280
2031	1299	961	1323	1356	759	517	1312	871	441	1252	932	236	1294	952	342
2032	1288	998	1369	1402	781	539	1323	896	427	1318	951	280	1361	972	389
2033	1292	1045	1425	1458	801	575	1391	914	477	1394	973	333	1438	994	444
2040	1571	1549	1998	2031	1177	766	2040	1313	726	1950	1388	460	2001	1407	594
2050	1834	2028	2602	2635	1500	1039	2641	1671	970	2541	1770	644	2604	1789	815

*Quotation does not refer to an actual stream price (polymer, chemcial or refinery grade) but is the price paid based only on the contained propylene, propane is given no value.

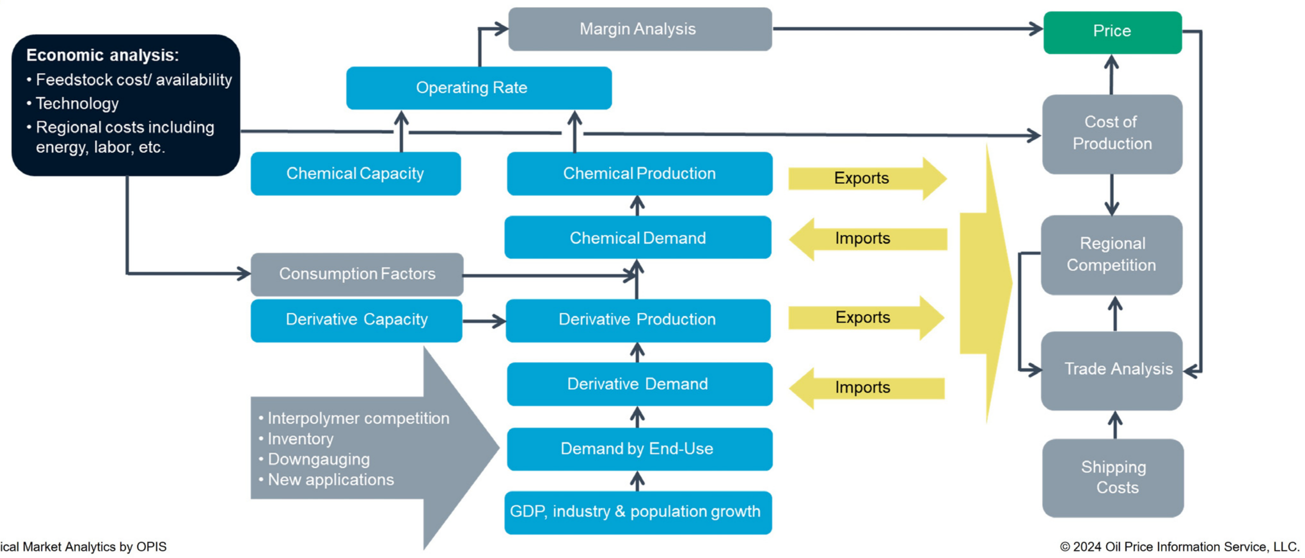
Data as of January 2024

Supply/Demand Forecast Methodology

The methodology for analyzing market dynamics and developing supply/demand forecasts for major commodity chemicals and plastics takes into account the complex interactions between consumption drivers, supply positions including capacity builds, and regional trade. The supply/demand forecast in the short-to-medium terms reflects the expected movements of the business cycle, followed by a trend forecast over the longer term. The highest levels in operating rates mark peaks in the business cycle, while troughs are characterized by low points in plant utilization. Driving the business cycles for most chemicals and plastics, apart from the impact of macroeconomic cycles, where downturns (recessions) alternate with long expansionary phases, is the timing of capacity additions. Investment decisions of producers in response to sustained higher cash margins often coincide, leading to overcapacity and lower operating rates, especially for high-cost producers, once the new facilities come onstream. The ensuing lower margin environment effectively prevents investment in new capacity, which will tighten market conditions over time and again support higher prices and margins.

Chemical Market Analytics builds its own in-house projections for supply and demand from the bottom up starting with individual countries/territories that are then aggregated to arrive at regional and global totals. Forecast changes in demand are typically based on factors such as fundamental economic drivers including GDP and population growth, end-use industry trends, the impact of substitution opportunities or threats emanating from other products, potential penetration of the product into existing and new markets, as well as government policies and regulations.

Supply, Demand and Trade Forecast



Source: Chemical Market Analytics by OPIS

Supply

On the supply side, announced capacity projects are identified and added to the existing nameplate capacity based on feasibility considerations. Beyond announced investment projects, hypothetical capacity volumes are added in advantaged geographies in order to maintain production and operating rates at reasonable levels. Future production forecasts are based on the amount of product that must be produced for any given year to meet the anticipated demand arising from direct domestic consumption and/or exports (if any). Production levels are adjusted to reflect anticipated operating rates that may be impacted by capacity additions and the level of imports coming into the country. Production levels, therefore, are reflective of the amount of capacity available to produce the products in question and the competitive position of the country under study, as low-cost producers are generally given export preference.

Finally, trade flows are factored into the overall supply and demand framework to obtain a net balanced global position. Preference for exports is given to producers with access to low-cost feedstocks or sites located in close proximity to geographies with large demand. Market supply/demand dynamics thus are closely interrelated with the competitive economics of each producer and our in-house regional price and margin forecasts.

Demand

Chemical demand via intermediates or direct retail applications can be linked proportionally to broad industry segments, such as durable and nondurables goods, or specific industries, including automotive, construction, and electronics. Each end-use industry has its own market dynamics that can change over time in relation to GDP and population growth. Substitution based on functional requirements, consumer preferences, and cost considerations can also significantly alter product demand. In addition, government policies and regulations, either promoting or prohibiting the use of certain chemicals and polymers, can prompt sudden increases or decreases in demand, as well as step changes over time to reach policy targets at specific timelines. The growing utilization of recycled materials at various stages of the chemical product chain is expected to limit demand for virgin product over time, although the penetration of recycled materials depends on availability along with the functional requirements of end-use products. Chemical Market Analytics considers each individual country/territory and builds up a demand profile for each product based upon:

- GDP outlook, historical economic growth rates, and GDP elasticities
- Major developments and trends in different sectors of the economy and end-use industries
- Chemical product per capita consumption of countries/territories at various stages of economic development (where relevant)
- Product penetration, including new applications, and substitution effects
- National and international government policies and regulations
- Recycling projections and sustainability initiatives

The demand in each country/territory is then aggregated at the regional and global level.

GDP is a robust measurement of the macroeconomic performance of a country/territory. The ratio of demand growth for a product to GDP growth is known as the GDP elasticity, which differs by product and also by country/territory. The GDP elasticity of a product can be calculated historically and is used along with other measures, detailed above, to forecast product demand.

Hypothetical Capacity

Demand for a product within a country/territory typically will continue to grow and at some point, exceed the installed plus announced capacity. Future demand increments can be met either by increasing imports/decreasing exports into or out of the country/territory, or by the addition of hypothetical capacity augmenting available supplies. Preferred locations for hypothetical capacity include the availability of low-cost feedstocks or proximity to large demand centers.

The additional demand volumes required to support medium- and longer-term end use and economic growth projections will increase plant operating rates beyond what is considered feasible based on historical production levels and anticipated technological advances. Reducing average plant operating rates at the global, regional, and national levels to reasonable levels requires a certain amount of hypothetical capacity that can be calculated and then allocated to individual countries/territories. The following considerations are taken into account when adding hypothetical capacities:

- Regions without competitive feedstock costs and without a growing domestic market are unlikely to install much or any new capacity; in these locations, small capacity increments typically are added via debottlenecking of existing facilities or creep.

- Regions with advantaged feedstock costs generally will grow their capacity to match the availability of feedstocks. Their low production cost, when compared with other regions, will allow them to build capacity well in excess of domestic demand, leading to higher export volumes.

- Regions with the highest netbacks for exporters, deriving from a combination of freight rates and prevailing market prices based on the local cost of production, are the most likely destinations.

- Regions with a fast-growing domestic market will typically install as much capacity as they can once the imports from lower-cost producing regions have been absorbed. Protective tariffs and duties can alter the competitive cost positions of regions and thereby the trade flows and market pricing mechanism.

Hypothetical capacity is also used to indicate the location and timing of future projects that are in the very early planning stages or still tentative in nature. Negative hypothetical capacity indicates expected future rationalizations and industry consolidations, where plants that will be closed have not yet been identified.

Trade

Imports and exports are an important component of the supply/demand balances as a sizable percentage of production is traded for most chemicals and plastics. Note that the regional import and export totals in the supply/demand balances are the summation of all national trade volumes, and therefore include shipments to other countries within the same region. The only exception here is the West Europe region, which is treated as a single country/territory in our supply/demand balances with all intraregional trade being excluded. A detailed view of trade flows between regions and countries/territories is included in our Trade Grid Excel files.

The difference between imports and exports indicates the net trade position of a country or region, which is represented in net export terms, so that net exporters show a positive net trade balance and net importers show a negative net trade balance. Our regional experts utilize global cost curves and other competitive production analyses to determine a country's/territory's export position or the amount of imports that will likely enter a country/territory in any given year. Particularly during periods of global surplus capacity, preference is given to low-cost producers as they will prevail in a more competitive international market environment. In contrast, import flows will be directed toward countries and regions with high production costs and may lead to rationalizations of older production units during downturns in the business cycle.

Tariffs and duties can limit or even prevent trade flows and lead to distortions in the relationship of pricing in regional markets. Generally adopted as a protection of higher-cost markets, regional prices tend to move more independently from each other and result in wider price ranges globally. High freight rates, as seen in 2021, can have a similar impact, although they tend to adjust more quickly with increasing supply.

Net Equivalent Trade

For each region in this study, graphs depicting ethylene net equivalent trade are provided in the main report, the Excel appendix also contains data tables for both regions as well as countries/territories. Most movements of propylene between countries/territories and regions do not occur as trade of propylene monomer, but rather as trade of "equivalents" in the form of ethylene derivatives. Chemical Market Analytics defines net equivalent trade as the net sum of imports and exports of monomer summed with the equivalent monomer contained in the net trade of derivative products also being imported and exported for a given country or region.

- Net equivalent trade = equivalent exports minus equivalent imports
- Equivalent exports = sum of monomer exports and monomer contained in its derivatives that are being exported.
- Equivalent imports = sum of monomer imports and monomer contained in its derivatives that are being imported.

For purposes of clarity and consistency for every region in the study, net exports out of a region or country are always positive values, and net imports into a region or country are always negative values.

Conversion factors

The conversion factors generally used to calculate the equivalent monomer contained in the various olefins derivative products, which is then used to generate the supply/demand balances for the regions and individual countries/territories, are shown in the table below. It should be noted that many olefin derivatives such as acrylonitrile, polypropylene, and cumene have conversion factors that change with improving technology. It is also important to note that the conversion factors for each country vary depending upon the sophistication of the local process technology and operational skills. In these cases, Chemical Market Analytics has used its best estimates to change the conversion factors to more accurately reflect the actual situation.

Propylene Conversion Factors

		Weight of Olefin/Weight of Derivative	
Olefin	Derivative	Range	Most Common
Propylene	Acrylic Acid	0.700 - 0.760	0.730
	Acrylonitrile	1.080 - 1.150	1.100
	Butyraldehyde	0.700 - 0.750	0.720
	Cumene	0.352 - 0.410	0.390
	Dodecene	1.000 - 1.300	1.300
	Epichlorohydrin	0.700 - 0.800	0.720
	Ethylene Propylene Rubber	0.400 - 0.500	0.400
	2-Ethylhexanol	0.900 - 0.930	0.900
	Glycerine	0.700 - 0.900	0.780
	Heptene	0.450 - 1.700	0.580
	Isobutanol	0.700 - 0.770	0.750
	Isopropanol	0.750 - 0.800	0.780
	n-Butanol	0.700 - 0.770	0.750
	Nonene	1.000 - 1.300	1.100
	Polypropylene	1.020 - 1.080	1.030
	Propylene Oxide		
	Chlorohydrin process	0.800 - 0.900	0.850
	POSM Process	0.750 - 0.800	0.790

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