Confidential
Final Report

Propane Dehydrogenation and Polypropylene

Feasibility Study
March 2024

Prepared for
Alujain

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Section 1

Executive Summary

1.1 SYNOPSIS

The Alujain National Industrial Company (Alujain or Sponsor) intends to construct a petrochemical facility (the Project) at a site in the Yanbu Industrial City, on the Western coast of the Kingdom of Saudi Arabia (KSA). The propane dehydrogenation (PDH) and polypropylene (PP) complex will produce a range of polypropylene product grades which will be made available for the local market and for export outside KSA.

Figure 1.1 Project Location

Propane is the main feedstock, which is to be converted to propylene in the PDH unit, and then finally transformed into PP in the polymerisation unit. The Project has secured an allocation of propane volumes from the Ministry of Energy sufficient to cover the anticipated requirements of the PDH/PP complex.

Lummus Technology LLC (Lummus) has been selected to provide the CATOFIN® PDH process for propylene production at a design capacity of 600 000 tons per year. A polypropylene unit with a design capacity of 500 000 tons per year will be developed as the second licensed unit. Basell Poliolefine Italia S.r.l. will provide the LyondellBasell (LYB) SPHERIZONE® PP process technology. Both technologies are well-demonstrated in the market.

The definition of the Utility, Offsites (UTOS) and supporting infrastructure required for the Plant will be developed by the FEED contractor, Samsung Engineering Co Limited (Samsung).

Analysis of the polypropylene market reveals a notable current oversupply. However, estimates suggest a forthcoming shift towards equilibrium as demand grows faster than supply, with projections indicating that the market is poised to rebalance by the year 2028.

The Project is anticipated to have one of the most competitive polypropylene production costs, both ex-works and in delivery to Western Europe and the North-East Asian markets, among all regional leaders reviewed. This is attributed to several factors, including favourable propane costs, the selected technology, and logistics costs.

NexantECA has developed an adaptable discounted cash flow model (DCF) to evaluate the Project's economics, drawing on base case assumptions from both NexantECA and Alujain. The Project demonstrates an 11 percent IRR and a 15 percent Equity IRR, with funding divided at 30 percent equity and 70 percent debt in the base case. The price of propane emerges as the principal determinant of PP production costs, with a 20 percent hike in propane prices leading to a negative NPV and decreasing both Project and Equity IRRs to 8 and 11 percent, respectively.

Table 1.1 Base Case Complex Financial Results

(Price inputs – NexantECA's US$80 per barrel Medium Oil Scenario)

		Complex
Investment (incl. initial WC)	*MM$*	2 174
Net Present Value (8% discount rate)	*MM$*	611
Project IRR		11%
Equity IRR		15%
**IRRs with Terminal Value*		

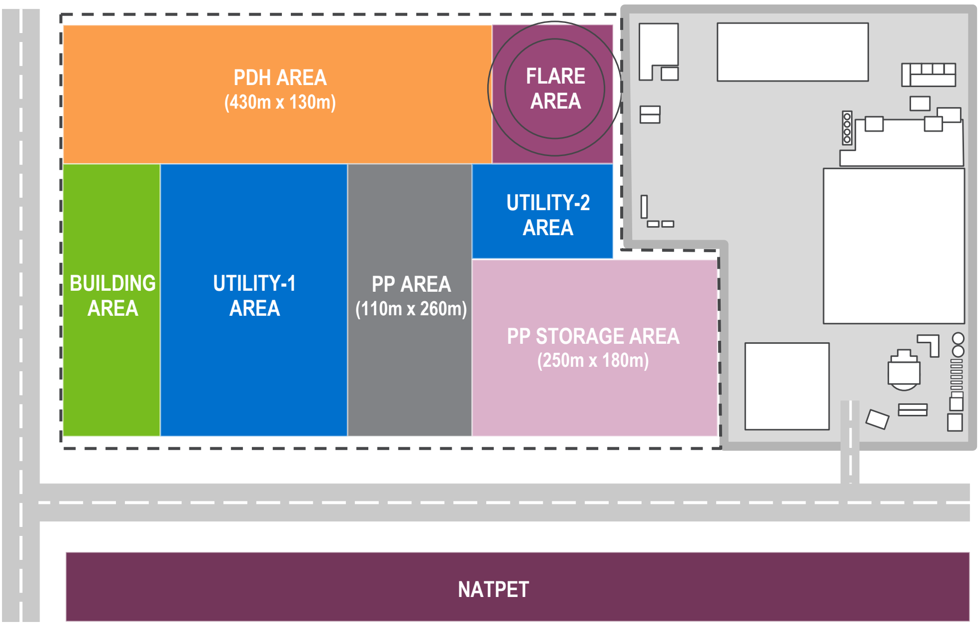
Note: the investment value excludes US$50 million allocated for the finance cost in the Project CAPEX.

1.2 EXECUTION STRATEGY

The Plant will consist of all systems and subsystems in order to build and operate a PDH/PP complex consisting of:

- A PDH plant based on CATOFIN® Technology supplied by Lummus Technology;
- A PP plant based on SPHERIZONE® Technology supplied by LyondellBasell;
- Utility and off-site (UTOS) plant providing all utilities, power, infrastructure, tankage, logistics and off-site facilities, systems, and subsystems for the completion and operation of the PDH-PP complex, inside battery limit (ISBL) facilities and offsite battery limit (OSBL) facilities including any synergies with the existing NATPET plant. Samsung has been selected for undertaking the UTOS.

Figure 1.2 Project Plot Plan – FEED Phase I Preliminary Version



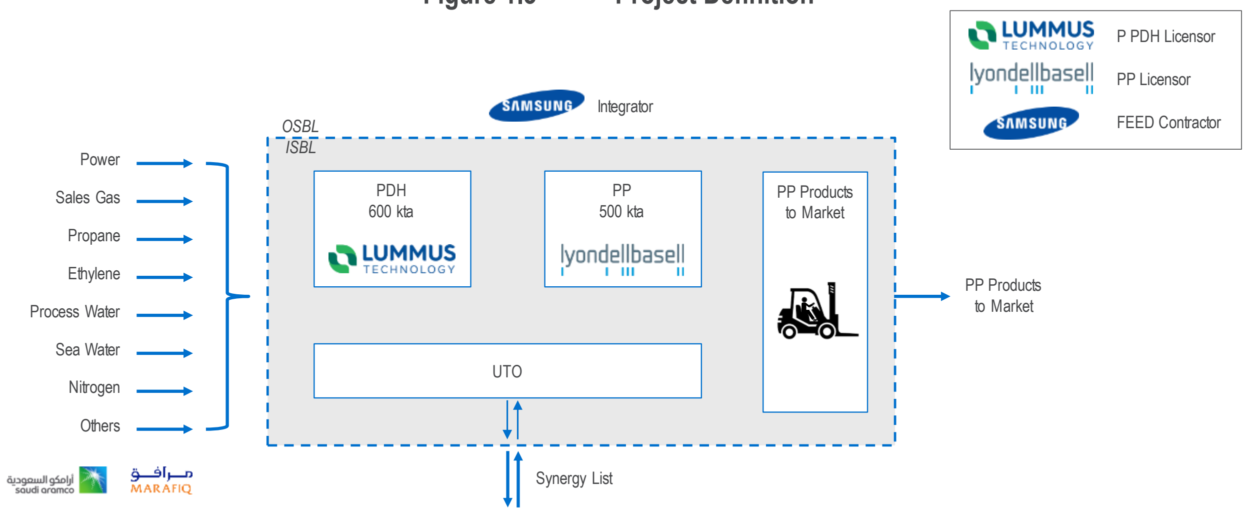
Alujain has signed agreements with the licensors for the selected technologies to be utilised in the Project in March 2023:

- Lummus Technology – will provide PDH CATOFIN® technology and engineering services including a comprehensive Process Design Package (PDP)
- LyondellBasell – will provide PP SPHERIZONE® technology and engineering services from including a comprehensive Process Design Package (PDP).

NexantECA notes that both technologies considered are proven at the proposed scale for implementation.

The figure below summarises the Project definition.

Figure 1.3 Project Definition



Alujain has finalised the organisation structure that will oversee the implementation of the Project. The organisation consists of the Project Directorate and the Technical & Project Services Support. The Project Directorate will be assisted by the Deputy Chief Project Officer from LyondellBasell. Other members of Project Directorate come mainly from Alujain and oversee different components of the Project.

A third-party project management consultant (PMC) will be engaged for the implementation phase of the project to oversee the EPC contractor consortium on behalf of the sponsor company. Worley was appointed to act as a PMC on behalf of the sponsor team in overseeing the production of the FEED. The Technical & Project Services Support shall mainly consist of PMC representatives with some assistance from LyondellBasell secondees.

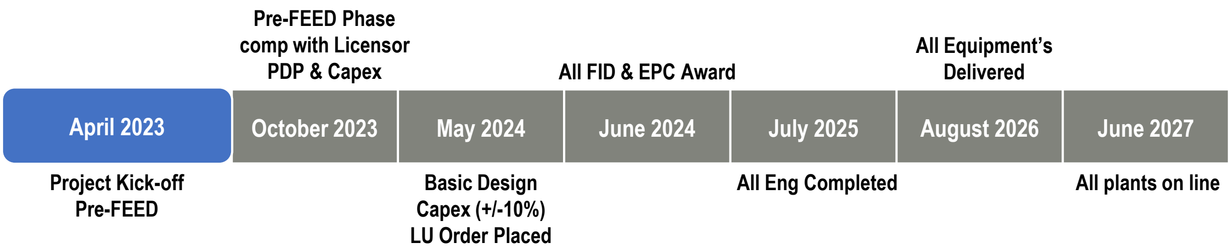
NexantECA notes the establishment of a well-defined structure for the project organisation, with clear channels of communication, and should be a positive indication for the future implementation of the project.

Alujain outlined a preliminary schedule for the Project which is used as the basis for its tendering strategy. The scheduled time for completion (passing of performance test and handover of facility to sponsor) is 57 months from the commencement date of the Project in Q4 2022. The scheduled time for the completion of all works until overall ready for the start-up is 36 months, from EPC award, forecast to occur in Q3 2024, to completion in Q3 2027. However, the firm contractual schedule will need to be confirmed following appointment of an EPC contractor.

Pre-FEED was completed in October 2023. The FEED study is ongoing at the time of reporting and will be completed by early June 2024. The EPC contract award is scheduled for June 2024. The Project is a greenfield construction with expected start of operation in 2027.

Figure 1.4 Timeline of the Project

(as of February 2024)



1.3 REPORT STRUCTURE

NexantECA has been retained by Alujain to assess the commercial and economic viability of the Project by undertaking a feasibility study (the Study). The Study includes an evaluation of the market, pricing, marketing strategy, competitiveness, and a financial evaluation of the proposed Project.

The Study also includes an assessment of technology options for each of the main project units based on the licensor companies that Alujain has signed agreements with.

The feasibility study is divided into the following sections:

- **Section 1 – Executive Summary:** a summary of the main conclusions of the report.
- **Section 2 – Project Overview**: an overview of the Project and key project stakeholders.
- **Section 3 – Project Execution Strategy:** a review of the Alujain organisational plan to manage and carry out the implementation of the Project. The key objective is to provide an understanding of the overall project schedule and key milestones.
- **Section 4 - Market Dynamics:** a review of historic and forecast supply/demand balance for propylene and polypropylene. The key objective is to provide an understanding of the drivers of the product markets and future market potential for the main products from the proposed Project and help define the key target markets and a preliminary marketing plan.
- **Section 5 – Marketing Plan:** an assessment of possible sales channels for international sales of product and consideration of market growth rates and changes in regional trade balances over the forecast period, incorporating market forecasts and netback pricing analysis. The key objective is to provide a preliminary marketing plan based on the market and netback analysis. The proposed sales split is used in the Financial Analysis Section.
- **Section 6 – Pricing:** a review of historical pricing data and profitability trends for the major regions as well as pricing projections for the product chemicals. The key objective is to understand the netbacks the project will make from the proposed target markets for use in the Economic Evaluation.
- **Section 7 - Technology Overview:** an independent high-level review of major licensed processes for the products of the proposed Project configuration. The key objective is to describe technologies based on NexantECA's internal data, supplemented by information provided by the Licensors, if available.
- **Section 8 – Capex and Opex:** a summary of major costs relating to the plant which may impact CAPEX and OPEX.
- **Section 9 – Cost Competitiveness:** an assessment of the Project's competitive cost position. The key objective is to understand the relative competitive position of the Project against major archetype competitors in delivering polypropylene to the proposed target markets.
- **Section 10 – Economic Evaluation:** a financial model to simulate Project configuration and evaluate the economic feasibility and bankability from a Sponsor and Lenders perspective. Section 10 presents the key assumptions and operating parameters used in this model, as well as summarising the results for the Project.

1.4 MARKET DYNAMICS

NexantECA has presented the market dynamics for propylene and polypropylene. Historic and forecast volumes of annual production, consumption and net trade have been presented, covering the historical period 2012 to 2022, the estimate is for 2023 and forecast period from 2024 to 2050.

The covered regions for propylene and polypropylene are:

- Global
- Turkey
- Europe will be covered as Western Europe and Central Europe
- CIS countries will be covered as Russia and Other Eastern Europe
- North Africa
- Middle East
- North-East Asia
- South-East Asia

1.4.1 Propane

There is no open commercial market for buying and selling oil and gas products in KSA. The Ministry of Energy determines the supply fundamentals based upon the macro pictures on oil and gas developments within the country. The relevant Ministries therefore allocate discrete volumes of oil and gas to key offtakers under long term supply deals.

The detail of the deals is not widely published but the key determinants are the pursuit of objectives while adhering to its Vision 2030, of adding wealth to Saudi Arabia. This can be in terms of financial, improving health and education, local employment to its nationals etc.

The Ministry of Energy has clearly informed the Sponsors of its ability to receive an allocation of propane to permit development of a world-scale PP business within Saudi Arabia. The basic terms of the Project specific propane supply agreement were not available at the time of the report.

1.4.2 Propylene

1.4.2.1 Consumption

The global demand for propylene is dominated by Asia Pacific, estimated to account for nearly two thirds of global consumption in 2023. Global propylene consumption growth was close to zero in 2022 as Western markets struggled to deal with inflation and high interest rates, and many developing economies lost spending power due to soaring energy and food costs. COVID-19 lockdowns in China restricted derivative growth to very low levels, creating brutally competitive derivative markets as new capacity entered the market.

Polypropylene remains the main growth engine of propylene demand, now accounting for two-thirds of consumption and thus effectively setting the rate of propylene consumption growth. Polypropylene, however, has considerable exposure to large purchase items such as vehicles and also the construction sector. Polypropylene is the mainstay for the production of low-cost plastic household items such as bowls and pails and has consistently taken share from other materials in the packaging sector, particularly via BOPP (biaxially oriented polypropylene film).

The main dynamic of the global propylene market is the massive polypropylene build currently underway in China. China’s polypropylene capacity has increased from 28 million tons per year in 2020 to an estimated 41 million tons per year annualized capacity in 2023. Although still a net importer, China’s exports of homopolymer polypropylene alone increased to an estimated 1.5 million tons in 2023, significantly impacting propylene demand in other countries.

Propylene oxide is the next largest derivative, driven mainly by demand into polyols which in turn create polyurethanes for diverse applications ranging from furnishing to buildings insulation. The exposure to the automotive sector has been problematic in recent years, and growth rates have declined significantly.

Acrylonitrile and isopropanol have a relatively low growth outlook, although demand for hand sanitisers transformed the market for isopropanol briefly during the most intense periods of the COVID-19 lockdowns. High oil prices favour substitution by fermentation ethanol. The cumene/phenol sector has been affected by the rapid maturation of the market for the key derivative polycarbonate and a capacity build in China, which has depressed phenol output in other regions. Acrylonitrile production growth has been very low due to the long-term substitution trend of acrylic fibre with other fibres, particularly polyester, which has forced acrylic fibre out of all applications which do not require particular UV and weather resistance, or hand/texture characteristics that can be achieved with acrylic fibre in apparel uses. The ABS sector and the acrylamide industry are now the major growth drivers for acrylonitrile, and while carbon fibre represents good potential long-term growth, current volumes are small. Its use in wind turbines is, however, an attractive and fast-growing sector.

Butanol and 2-ethylhexanol are part of the group of products known as oxo-alcohols, which are so named because of the "oxo-process" by which they are produced. Butanols have performed better in recent years through underlying growth in the market for its key derivative butyl acrylate, mainly in water-based coatings. Isobutanol is coproduced with *n*-butanol and is frequently in oversupply. It is used as a solvent, and to a lesser extent in the production of amines. The 2-ethylhexanol market has been under pressure for several years due to health and safety concerns surrounding its main derivative; the plasticiser, dioctyl phthalate (DOP). 2-ethylhexyl acrylate is however a fast-growing sector, mainly for coating and adhesives, and 2-ethylhexyl nitrate is achieving high growth as a diesel fuel additive (cetane improver). As with acrylonitrile, the rapid development of capacity in China undermined propylene demand into oxo-alcohols in other regions, although the market has now absorbed much of the excess capacity.

Propylene demand for acrylic acid has frequently been the fastest growing of the major derivatives, although its contribution to the overall market growth remains very small. The market has become turbulent however, with rapid capacity expansion in some areas causing production to stagnate and indeed drop in others. Demand growth globally has been significantly faster than the market as a whole.

Figure 1.5 Global Propylene Consumption by End-Use, e-2023

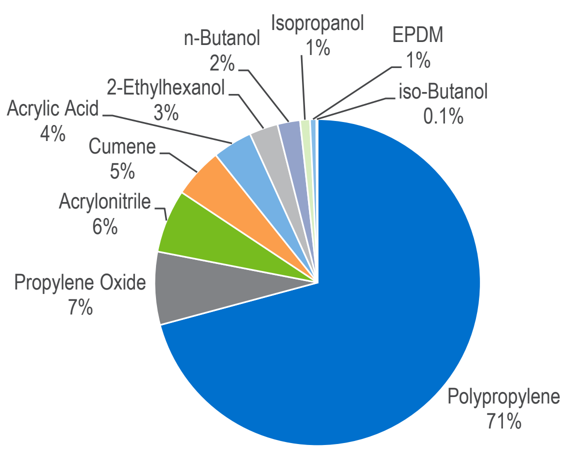
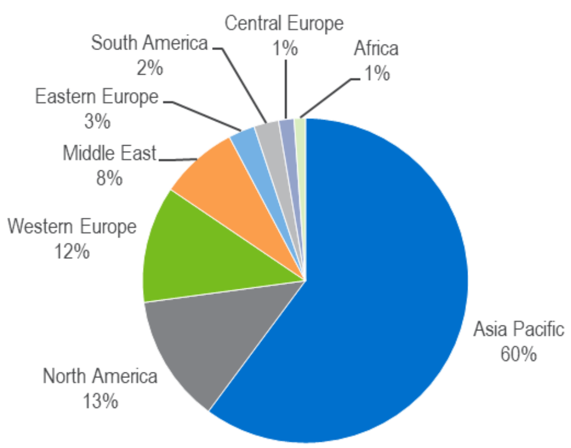


Figure 1.6 Global Propylene Consumption by Region, e-2023



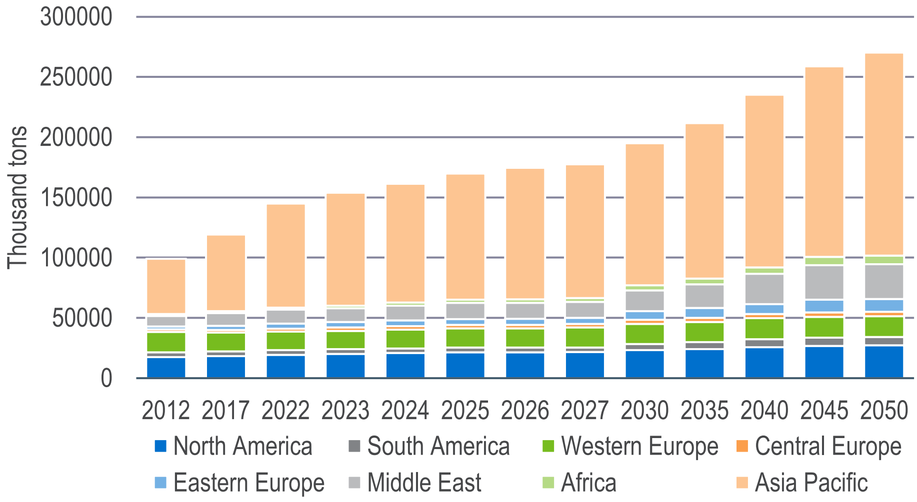
1.4.2.2 Supply

The global propylene supply base has expanded by 22 percent over the last five years and is set to expand at exactly the same rate over the next five years. This growth is substantially higher than consumption growth, and has led to intense competition, low prices, and pressure on laggard operators. The last five year cycle included the addition of 13 million tons per year of steam cracker propylene and eight million tons per year of PDH. Over 2022-2027 the volumes will switch, with seven million tons per year of steam cracker propylene and 10 million tons per year of PDH. FCC propylene additions will be much lower at 1-2 million tons per year over the next five years. There will be minimal addition of stand-alone metathesis plants, and propylene supply growth from methanol will drop from four million tons per year over 2016-2021 to only one million tons per year over the coming five years.

Propylene capacity is mainly split between North America, Western Europe and Asia Pacific. The share held by Middle Eastern producers is comparatively small relative to their presence in the ethylene market, due to the prevalence of gas-based steam crackers. Major investment in PDH, the move towards mixed-feed steam crackers and finally metathesis has increased propylene capacity in the Middle East, but the region's share of the global supply base is only nine percent compared with 18 percent for ethylene. Western Europe and Asia Pacific derive most propylene from steam cracking naphtha and other heavy feeds, while supply in the United States is based to a greater extent on refinery production.

The surge in steam cracker development has come alongside major new refinery developments, most of which are configured around hydrocracking and aromatics production. This surge in refining capacity is taking share from older and frequently FCC-based refineries in all regions, thus eroding FCC-based propylene supply globally.

Figure 1.7 Global Propylene Capacity



1.4.2.3 Supply, Demand and Trade

Global propylene operating rates dropped four percent and reached 83 percent level in 2022 as capacity growth of over six million tons per year coincided with moribund demand. Operating rates declined further by three percent in 2023, primarily from the increase in production capacity.

The very high crude oil and naphtha prices in late 2021 and much of 2022 encouraged maximum light feed at flexible crackers with access to deep sea imports, disadvantaging liquids cracking versus competitors within regions with advantaged NGL feedstock. These factors depressed the global ratio for steam cracker propylene production relative to ethylene. This was offset to some extent by the high value of the gasoline related coproducts from naphtha cracking such as benzene and butadiene raffinates.

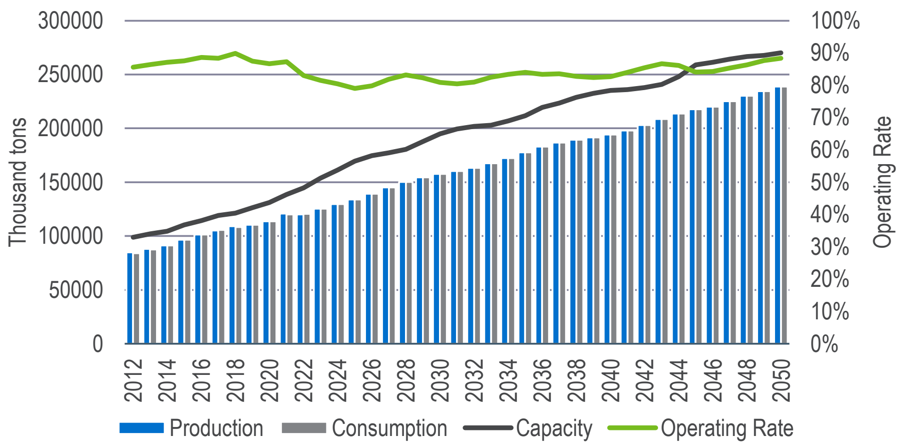
FCC propylene supply was severely curtailed in regions such as Europe and the United States due to confinement measures in 2020, and the gap was filled mainly by increased naphtha cracking and growth in PDH capacity in Asia. The resurgent economy in 2021 however provided for strong gasoline values and higher FCC propylene availability. The outbreak of hostilities in Ukraine meant the loss of access to some Russia fuel exports, propelling gasoline valuations even higher in Europe and North America. While this supported naphtha cracking in Europe, it was not sufficient to outweigh the feedstock price differential in the United States, and heavier feed consumption declined.

PDH margins generally remained the highest in the olefins industry but dropped to unusually low levels in China in 2023 from its highs in 2022. Globally PDH margins have mostly remained attractive, spurring several additional new projects, mostly in China. While the growth will be partly accommodated by consumption growth and FCC closures, it will contribute to a further decline in global operating rates towards 2025.

The market remains dynamic regarding both supply and consumption growth, but the broad base of propylene derivatives and the application areas they serve provides reliable demand growth for propylene. The rate at which the market will absorb the new capacity will depend on the condition of the global economy. There were already recessionary signals and high oil prices, along with increasingly alarming signals regarding debt in the property sector in China before the conflict in Ukraine. China's economic recovery post-COVID-19 will be limited to some extent by weaker demand for Chinese manufacturing exports in the coming years.

Chinese propylene imports are mainly driven by non-integrated producers of derivatives other than polypropylene. Although some of these companies have back-integrated with propylene production of their own, Chinese imports dropped slightly to around 2.5 million tons in 2020 and increased to 2.9 million tons in 2023.

Figure 1.8 Global Propylene Supply and Demand



1.4.3 Polypropylene

1.4.3.1 Consumption

Global polypropylene demand was estimated at 84.2 million tons in 2023, an increase of 3.7 percent from 2022, after growing by 0.6 percent in the previous period. The slowdown in the Chinese market as well as other key markets in Western Europe and North America led to the fall in demand growth after growth of five plus percent in the previous two years. New regulations targeting debt-funded construction in China as well as severe COVID-19 lockdowns led to the fall in polypropylene demand there while inflationary pressures led to decreased consumer spending and higher interest rates in North America and Europe. This was primarily caused by the conflict in the Ukraine which began in February 2022 and led to inflation in key energy commodities as well as other goods due to market disruption.

Polypropylene markets had shown strong growth over a number of years, thanks to the polymer's versatility, performance and competitive value which have enabled substitution for other polymers used in film, injection moulding and blow moulding. In particular, the evolution of BOPP films, including their role in stand-up pouches which have replaced large amounts of blow-moulded retail packaging, has been a major demand driver for several years.

The dominant regional market is China with over 40 percent of global demand. China's demand share for polypropylene is higher than for other polyolefins due to its usage in many forms of exported manufactured goods such as durable containers, luggage, garden furniture and automotive components. Asia excluding China is the second largest market followed by North America and Western Europe. Injection moulding applications lead global market, followed by fibre and film. The consumption profile is not expected to change dramatically in the foreseeable future.

The global polypropylene market is expected to increase by 3.4 percent in 2024. With inflation abating and a return to economic growth globally, the market demand growth is also expected to recover. However, strong economic headwinds remain and will limit growth to less than historic rates.

Figure 1.9 Global Polypropylene Demand by Region, 2023

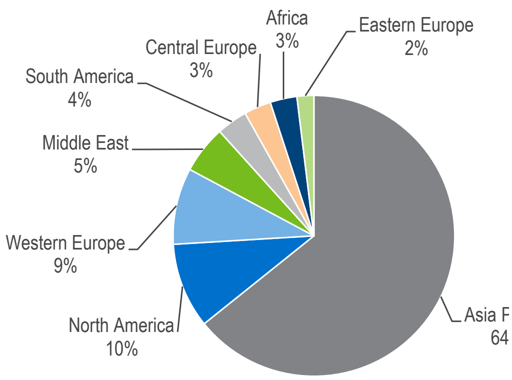
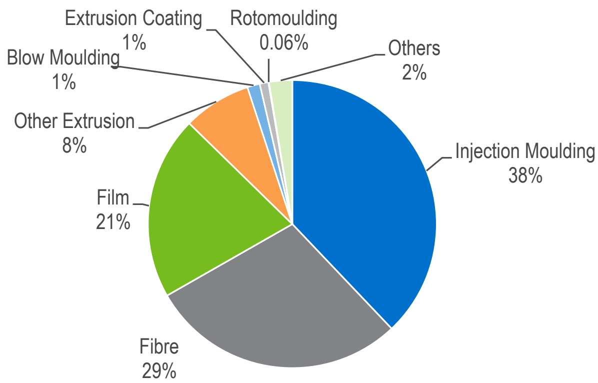


Figure 1.10 Global Polypropylene Demand by End-Use, 2023



1.4.3.2 Supply

Global capacity to produce polypropylene was estimates at 107.1 million tons per year in 2023 with an additional 8.3 million tons per year of capacity added. In 2023, an additional nine million tons per year of capacity were expected to be added. By 2025, an additional 25 million tons per year of capacity are expected to be added based on current estimates, although not all projects are likely to go ahead in the given timeframe.

Of this firm capacity, 60 percent of the additions have been announced for China. China accounts for 38 percent of global polypropylene capacity in 2022 and its market share will increase to 42 percent by 2025 based on current announcements.

Figure 1.11 Global Polypropylene Capacity Share by Marketer, 2023

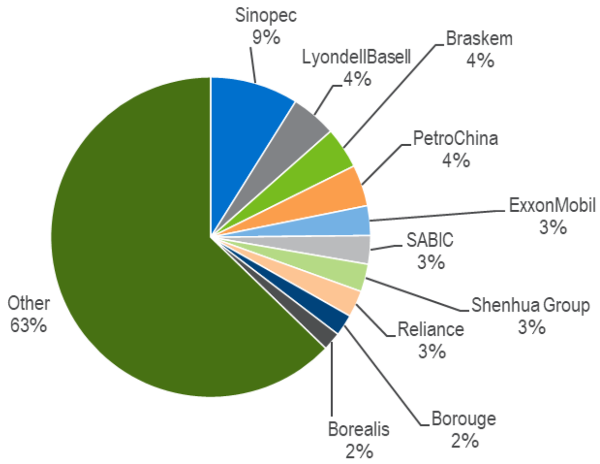
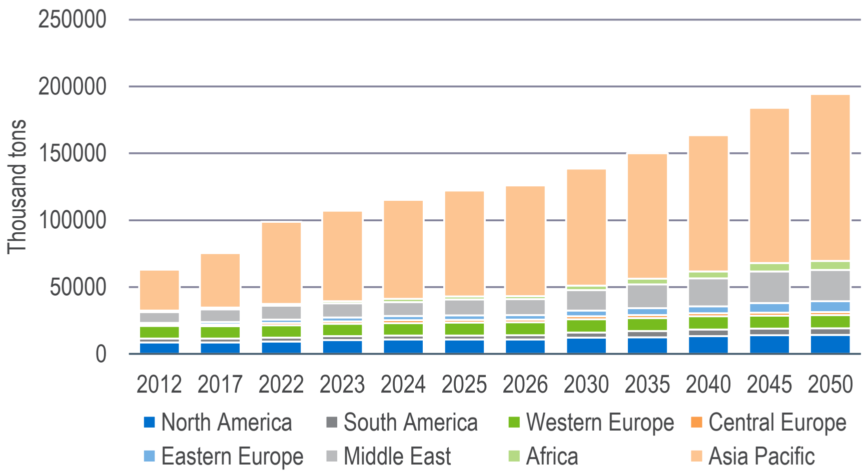


Figure 1.12 Global Polypropylene Capacity



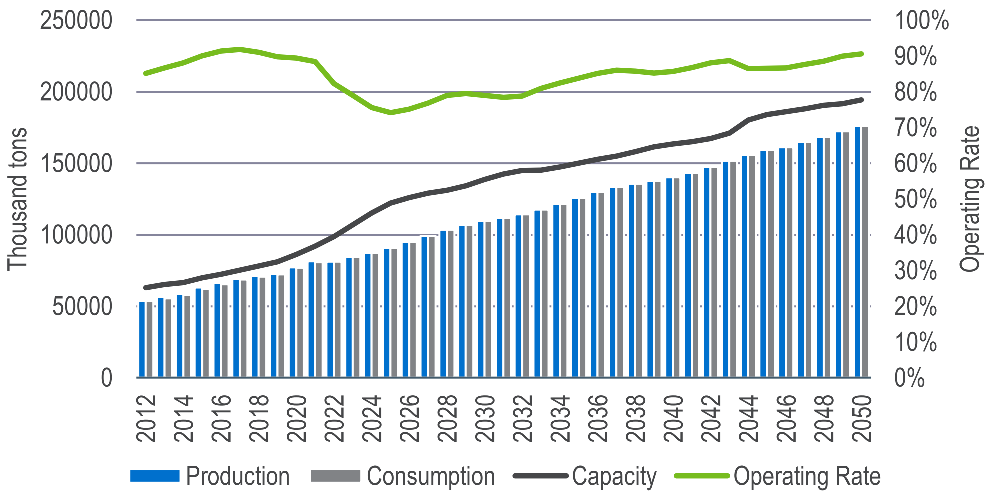
1.4.3.3 Supply, Demand and Trade

Global operating rates in 2023 fell about three percent, indicating a slowdown in operating rate drop from about six percent observed in 2022 as slow demand growth was met by the wave of new Chinese capacity growth. Despite recovering demand growth, the amount of capacity coming online in the near term is expected to depress rates through to 2025 before recovering.

The Middle East remained the largest global exporter of polypropylene in 2023, most of which is homopolymer. The region is expected to retain this position through the forecast with exports expected to increase given the favourable feedstock situation and ambitions of regional governments. South Korea is the next single largest exporter followed by Singapore and the United States. Capacity additions in China are expected to impact marginal exporters in the main exporting regions to the country – the Middle East, North-East Asia and South-East Asia. Rates in other regions are also expected to be negatively impacted as the new volumes come online and trade routes begin to re-organise.

The current state of the polypropylene market reflects a significant oversupply. However, estimates indicate a forthcoming shift towards equilibrium, with the market poised to rebalance by the year 2028.

Figure 1.13 Global Polypropylene Supply and Demand



1.5 MARKETING PLAN

Based on the supply, demand and trade balances supplied in Section 4 of this report, NexantECA has prepared a high-level marketing strategy for polypropylene sales for the Project. NexantECA has considered the net trade position as well as the overall market size and consequent penetration into the major target markets. Furthermore, NexantECA has also considered the competitiveness of the Project compared to other international producers supplying the products into the target markets in its analysis.

The marketing plan considers 100 percent of produced polypropylene (500 000 tons of polypropylene per year) to be placed in target regions.

For the target market analysis, NexantECA has taken into consideration regions which are projected to maintain a net-importing position over the forecast period, as well as the regions with a significant domestic market.

Table 1.2 Marketing Plan for Polypropylene per Target Region
(Forecast, 2027)

Region	Regional Market		Product Placement	
	Demand	Net Trade	Sales	Sales
			(ktpa)	*(percent)*
Western Europe	7 732	260	50	10%
Central Europe	2 952	(1 273)	75	15%
Eastern Europe	1 790	813		
North Africa	1 067	(342)	50	10%
Turkey	2 511	(1 237)	125	25%
Middle East excl. Turkey *	5 340	5 203	50	10%
North-East Asia	47 260	(153)	50	10%
South-East Asia	7 634	(333)	100	20%
Total			500	100%

Note: The positive net trade indicates the net export position, whereas the negative net trade indicates the net import position.

*The Middle East placement refers to product being distributed as local sales in Saudi Arabia, in line with Alujain's comments. The product placement volumes align with the base case of the Financial Model, with the option to adjust volumes sold to each target market based on current market conditions.

The global polypropylene market is very large and commoditised and the Project's location is well-placed to supply both the western and eastern hemispheres. The selected target markets should secure sufficient offtake opportunities.

The analysis provides an initial view of a possible marketing plan for the Project. The proposed plan could be refined as the Project advances further.

The disruption of shipping in the Red Sea due to attacks attributed to the Houthis in Yemen, aimed at supporting Hamas in its conflict with Israel, has significantly impacted global chemical industry supply chains. This escalation of hostilities has led major shipping companies to avoid the Red Sea route for safety reasons.

The necessity to divert shipping routes away from the Red Sea has introduced substantial delays and increased costs for the chemical industry. Normally, a significant portion of the world's ocean carrier traffic passes through the Red Sea. However, the current situation has forced rerouting around the Cape of Good Hope at the southern tip of Africa, extending transit times by up to several weeks. This shift not only affects shipping rates but also the efficiency of global supply chains in the chemical sector, underscoring the broader economic implications of geopolitical conflicts on international trade.

When COVID-19 emerged a few years back, the chemical industry faced sudden and significant price hikes across the board, with container rates soaring from US$3 500 to US$20 000, for instance. However, the recent disruptions have not uniformly affected all shipping lines; the attacks by the Houthis have specifically targeted vessels bound for Israel.

Currently, logistics costs have not reverted to the peak levels experienced during the COVID-19 pandemic, yet, the financial impact on shipping and the broader supply chain depends on the duration and intensity of these disruptions.

1.6 PRICING

1.6.1 Propane Pricing

Propane production is predominantly a by-product of natural gas and crude oil operations, making it less responsive to propane-specific demand. Propane prices exhibit a seasonal trend, peaking in winter due to heightened residential heating fuel usage. The provided annual average price assessment conceals these seasonal fluctuations.

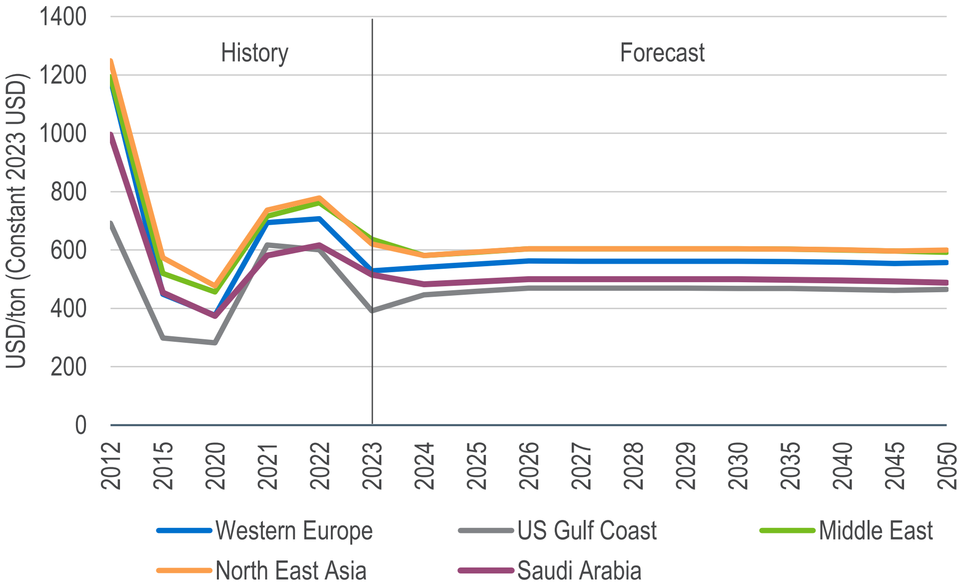
Competing with natural gas on an energy equivalence basis, propane floor prices are influenced by natural gas prices. Limited substitution in regions without mains gas, such as Western Europe during the Russia-Ukraine conflict, led to increased propane prices in 2022. However, as natural gas prices fell in 2023, propane prices followed suit.

Global propane trade, dominated by refrigerated liquid shipments, tightly links prices across markets. Geopolitical tensions from the Russia-Ukraine crisis and ensuing sanctions heightened gas market turbulence, impacting supply chains and fostering uncertainty.

The U.S. sets the global propane price floor, leveraging its surplus and strong export position, while Asia defines the ceiling due to structural deficits and high import demands. Despite a surge in U.S. supply and a mild European winter, propane prices remained stable compared to ethane. Multi-year contracts with major Asian buyers supported U.S. propane exports, although low pricing led to occasional sourcing from the Middle East. China experienced a significant drop in propane prices in Q3 2023, while the U.S. saw a more modest decline.

In 2023, Middle East had the highest propane price at US$637 per ton, with the US Gulf Coast recording the lowest at US$392 per ton. Saudi Arabia's propane price is anticipated to be the second lowest in the forecast period, following the US Gulf Coast.

Figure 1.14 Global Propane Prices, 2012 – 2050
(Constant 2023 USD, Medium oil scenario)



NexantECA has taken note of Saudi Aramco's recent announcement regarding the hike in prices for certain feedstocks and fuel, communicated to various petrochemical and cement companies. Notably, domestic ethane prices have seen a 43 percent increase and methane prices have climbed by 40 percent from 1

January 2024. However, the changes did not affect the prices of LPG feedstock, including propane and butane. Thus, viability of the PDH/PP projects will likely remain unaffected until the Saudi government announces new LPG pricing strategies.

1.6.2 Propylene Pricing

Propylene is typically traded in three grades based on purity:

- Polymer-grade: Minimum 99.5 percent propylene content, used for polypropylene production.
- Chemical-grade: Minimum 94 percent propylene content, suitable for most derivatives except polypropylene.
- Refinery-grade: Minimum 60 percent propylene content, used in cumene/phenol production or upgraded to higher purity chemical- or polymer-grade material.

Key factors influencing propylene pricing include:

- Pricing of propylene derivatives
- Production economics and competitiveness of naphtha crackers versus other feedstocks
- Value to petrochemicals producers compared to alternative uses in a refinery
- The price of propane

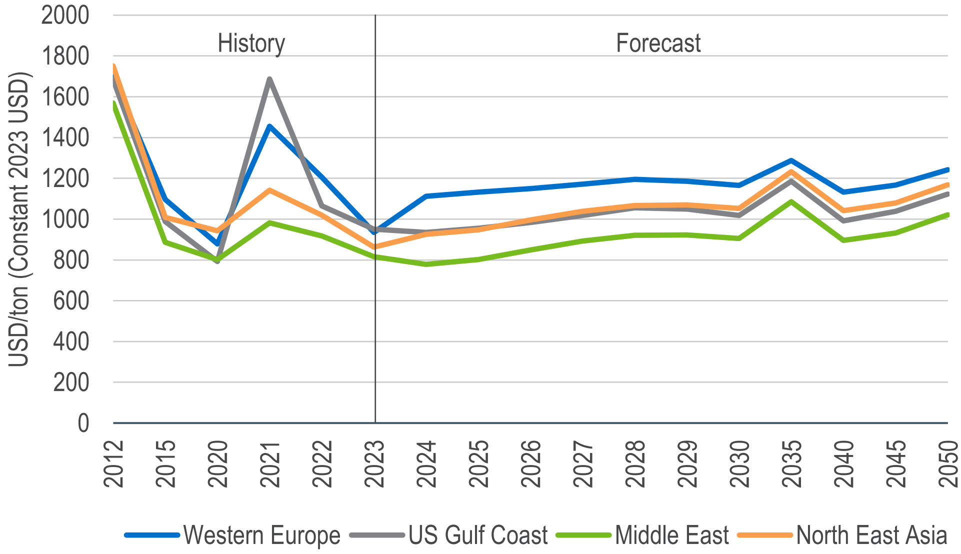
Propylene supply is heavily influenced by demand, especially with the rise of on-purpose production through PDH. Prices are closely tied to key derivatives, particularly polypropylene. The competitiveness of ethane crackers over naphtha crackers impacts propylene supply, as the former does not produce propylene. The value of propylene in the petrochemical industry compared to its use in refining also influences pricing.

The refining process often consumes refinery-grade propylene on-site, impacting its availability for chemical use. The alkylation value of propylene historically set a floor for prices in the United States but changing market dynamics have altered this influence, with Middle East propylene now setting the floor price. Additionally, the price of propane directly affects the profitability and potential supply of propylene from PDH plants.

Propylene prices, closely linked to crude oil prices, experienced fluctuations influenced by the pricing of key derivatives. Oversupply in 2019, exacerbated by the COVID-19 pandemic in 2020, led to lower prices. Record highs in 2021 were followed by market tightness, ongoing supply-demand imbalances, and disruptions in 2022. The return to equilibrium in 2022, with record-high U.S. supply levels, marked a shift. Global capacity growth in 2023, led by China, is anticipated to depress profitability, holding propylene at a discount to ethylene. Investment in new on-purpose capacity aims to reduce volatility. Competitive pressures and weakened domestic markets capped U.S. propylene prices through quarter three.

NexantECA forecasts an upside in olefins pricing in 2035 to reflect the natural volatility in pricing trends. This trend is also captured in their downstream derivatives.

Figure 1.15 Global Propylene Prices, 2012 – 2050
(Constant 2023 USD, Mid (80) Crude Price Scenario)

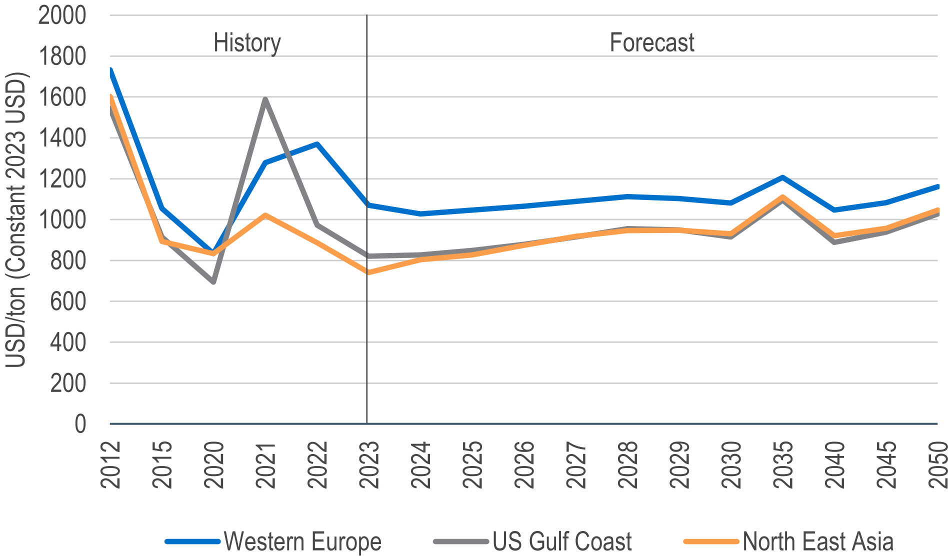


Netback pricing is a comprehensive financial assessment that delves into the intricacies of costs associated with bringing a product from its production facility to its destination markets. In essence, it calculates the net revenue a producer receives at the plant gate after deducting all relevant expenses. The netback pricing analysis takes into consideration a multitude of factors, including tariffs and customs duties, freight costs, and port and handling fees. By accounting for these expenses, netback pricing provides a clear understanding of the actual revenue generated from product sales in specific target markets.

In the context of the Project, netback pricing calculations for propylene sales into key markets, such as Western Europe, the U.S. Gulf Coast, and North-East Asia, offer valuable insights for strategic decision-making. The assessment considers Saudi Arabia's free trade agreements, tariffs with specific countries, and supplementary fees like those for transiting through the Suez Canal. Freight and port costs are also incorporated, reflecting the understanding of transportation dynamics between regions.

The netback pricing analysis serves as a powerful tool for producers and investors, providing a holistic view of the financial implications associated with selling a product in different markets. By factoring in all relevant costs, from production to transportation, netback pricing allows for informed decision-making, optimizing market positioning, and maximizing profitability. As the Alujain plant gears up for its operational phase in 2027, the netback pricing analysis becomes a crucial element in shaping a successful and financially sound business strategy. The netback prices for both the U.S. Gulf Coast (USGC) and North-East Asia exhibit a notable proximity, indicating a balanced competitive landscape. Specifically, the North-East Asia price is anticipated to be lower in 2023, reflecting regional dynamics and market trends. Looking ahead in the forecast period, the USGC price is expected to be lower, showcasing a nuanced shift in relative pricing dynamics.

Figure 1.16 Alujain Propylene Netback Pricing, 2012 – 2050
(Constant 2023 USD, Mid (80) Crude Price Scenario)



1.6.3 Polypropylene Pricing

Polypropylene prices are determined through direct negotiations between major producers and converters, similar to the process for other commodity polymers. The pricing equilibrium balances resin value to converters with production costs. Transparent pricing is prevalent in key regional petrochemical markets. Polypropylene resins are classified into homopolymer and copolymer grades, with the former being predominantly propylene-based and the latter incorporating ethylene for enhanced impact resistance.

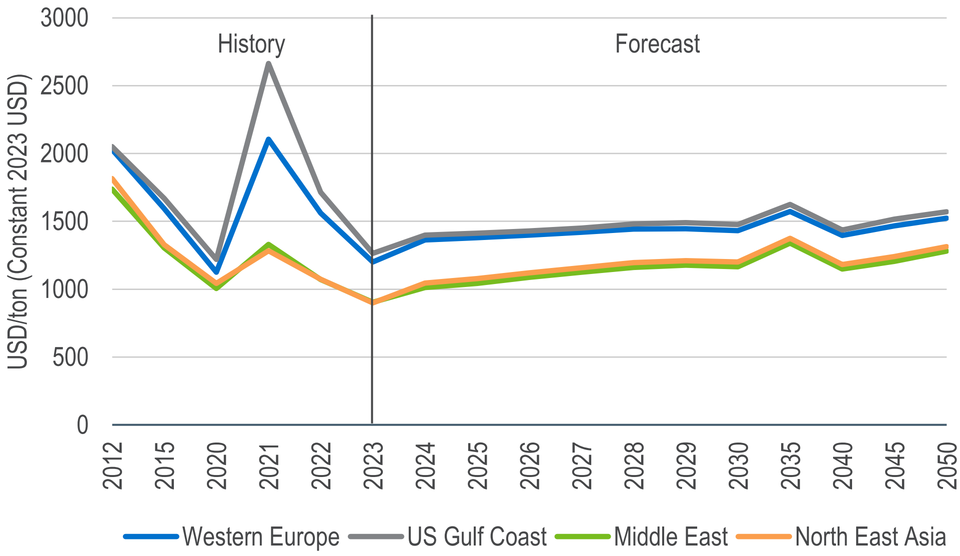
Factors influencing price negotiations include production economics, competition from other polymers, supply/demand balance, regional pricing disparities, and profitability of converters. Propylene feedstock costs, accounting for about 90 percent of PP production expenses, significantly impacts PP pricing. Integrated polypropylene producers enjoy a price advantage over those purchasing propylene from the merchant market due to lower transportation costs.

Polypropylene prices are influenced by crude oil prices through naphtha, primarily due to the significant role of propylene feedstock costs, which make up around 90 percent of total production expenses. However, pricing is also influenced by competition with other polymers and consumer-driven factors, resulting in a less direct correlation with crude oil compared to propylene and propane.

Continued lockdowns in China, capacity expansions in Asian markets, and elevated crude oil prices exacerbated pressure on margins. Asian spot CIF prices set the floor for regional prices, with pricing dynamics reflecting regional market conditions and trade flows. The Middle East is poised to become the largest exporter of polypropylene by 2030.

Figure 1.17 Global Polypropylene Prices, 2012 – 2050

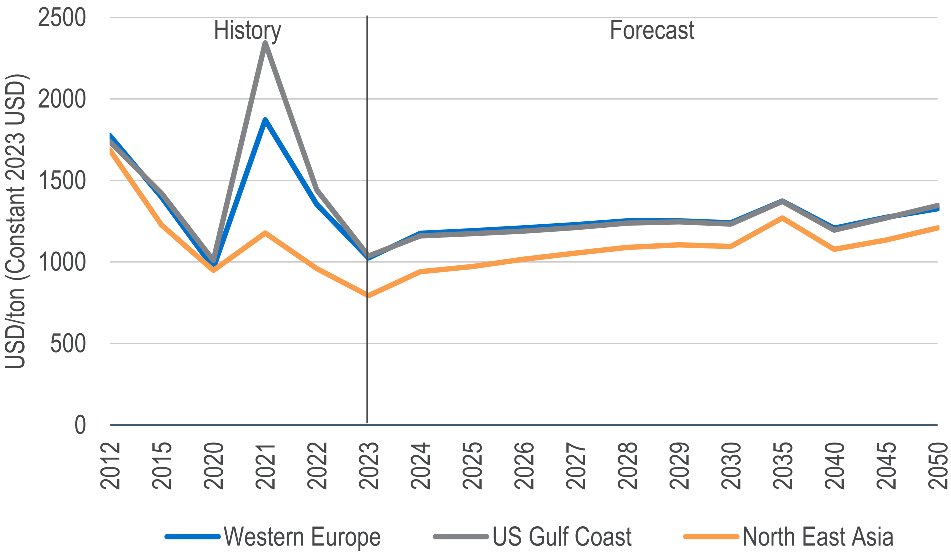
(Constant 2023 US$, Medium oil scenario)



In contrast to propylene netbacks, the netback prices of polypropylene from Western Europe and the US Gulf Coast (USGC) demonstrate close alignment, at around US$1 500 per ton. Various factors such as including logistical efficiencies, market integration, and trade dynamics are the cause of this.

Conversely, Northeast Asia presents the lowest netback price for polypropylene. This can be influenced by factors such as regional demand-supply dynamics, production costs, and trade routes. Additionally, competition among suppliers and the presence of export-oriented production facilities in the region contribute to the competitive pricing observed in North-East Asia.

Figure 1.18 Alujain Polypropylene Netback Pricing, 2012 – 2050
(Constant 2023 US$, Mid (80) Crude Price Scenario)



1.7 TECHNOLOGY OVERVIEW

Alujain has selected the CATOFIN® PDH technology, licensed by Lummus Technology for the Project's PDH plant. The PDH unit for the Project has a name plate capacity of 600 000 tons per year, which sits within the range of the Lummus CATOFIN® technology proven capabilities.

The Project's polypropylene unit will be based on LyondellBasell SPHERIZONE™ technology. With a nameplate capacity of 500 000 tons per year, this capacity has been demonstrated in other licensed projects before. Alujain has confirmed that the PP (polypropylene) plant is capable of operating at a capacity of 550 000 tons per year. This operational capacity has been incorporated into the Financial Model, allowing for increased PP availability for sales. Adjustments for the required propylene and propane supply have also been taken into account.

1.7.1 PDH Technology Options

Several technologies have been commercialised for propane dehydrogenation, including Honeywell UOP's (is used in existing Alujain PDH plant) Oleflex™ process, Lummus Technology's CATOFIN® process, and Thyssenkrupp's STAR process®, along with new offerings such as Dow's UNIFINITY™ fluidised catalytic dehydrogenation process and KBR's K-PRO™ process have also emerged in recent years.

There are three basic types of PDH technology available today: fixed bed, moving bed, and fluidized bed. The Lummus Technology CATOFIN® process and Thyssenkrupp STAR process are examples of fixed bed technology. The CATOFIN® process has a heritage that goes all the way back to the Houdry process that was developed in 1936. This catalytic cracking process was developed for the selective conversion of crude petroleum to gasoline and was a semi-batch, fixed bed process. In the 1940s, the process was adapted for the production of butadiene and later of isobutylene. It wasn't until 1992 that CATOFIN® was commercialised in PDH service. The ThyssenKrupp STAR process is based on tubular reactors and steam reformer furnace technology. The STAR process was commercialized in 2010. These technologies are semi-batch in nature and utilise multiple reactors operating on a cyclical basis to achieve continuous production. While one or more reactors are on-line processing propane, one or more other reactors are off-line in catalyst regeneration and when the on-line reactors have reached their conversion capacity, feed gas is switched to the regenerated reactors while the spent reactors are regenerated.

The process characteristics of the five licensed propane dehydrogenation technologies are summarized in the table below.

Table 1.3 Propane Dehydrogenation Process Characteristics

Licensor	Lummus Technology	UOP	ThyssenKrupp	Dow	KBR
Process	CATOFIN®	Oleflex™	STAR process®	FCDh	K-PRO
Commercial	Yes	Yes	Yes	Yes (licensed)	Yes (licensed)
Catalyst	Chromium oxide + aluminum oxide on alumina	Platinum-tin on alumina	Platinum + zinc and calcium aluminate	Gallium oxide and platinum on alumina	Zinc oxide + modifiers on titania support
Pressure	~0.5 bara	1.05 bara at last reactor	2-6 bara	1.3-1.7 bara	1.5 bara
Temperature	600 °C	600-650 °C	550-590 °C	600-650 °C	550-650 °C
Partial Pressure Control	Vacuum (no hydrogen or steam dilution)	N/A	Steam	N/A	N/A
Coke Control	None	Hydrogen recycle	Steam injection	Short residence time	Short residence time
Reactor Type	Fixed-bed	Moving-bed	Fixed-bed	Fluid-bed	Fluid-bed
Reaction Catalyst Residence Time	7-15 minutes	5-8 days	11 hours reaction 1 hour regeneration	< 2 minutes	minutes
Catalyst Life	4 years	4 years	5 years	2-3 years turnover rate	N/A
Heat Method	Furnace preheat of process stream, cyclic, coke burn-off	Furnace reheat of the process stream and coke burn-off	Heat recovery, top-fired reformer, steam injection, coke burnoff	Heat recovery, coke burnoff, supplemental fuel in regenerator	Heat recovery, coke burnoff, supplemental fuel in regenerator
Regeneration Method	Cyclic (in-situ)	Continuous Catalyst Regeneration (CCR)	Cyclic (in-situ)	Fluid bed	Fluid bed
Conversion, %	45	30-40	29-31.5	43-48	45
Selectivity, wt%	87+	85.5-88	87.6-92.	88-92	87-90
Fresh Propane (95 wt%) per ton of Propylene	1.2021 tons	1.1725 tons	1.1833 tons	1.1782 tons	1.2199
Fresh Propane Requirement for 600 000 tons per year of Propylene	721 263 tons per year	710 905 tons per year	710 000 tons per year	706 941 tons per year	731 920 tons per year

The client has selected the CATOFIN® process for their PDH unit, which is a well-established and widely used by the industry.

1.7.2 Lummus Technology CATOFIN® Process

Lummus Technology currently has twelve CATOFIN® PDH plants in operation (10 PDH and 2 PDH plus BDH plants that include world's largest dehydrogenation plant) producing more than six million tons per year of propylene. CATOFIN® operating plants range in capacity from 250 000 tons per year to 900 000 tons per year of propylene with a maximum offered capacity of one million tons per year.

Lummus Technology's experience in dehydrogenation also includes applications of CATOFIN® technology in more than 50 projects worldwide. Many are commissioned in the production of isobutylene and propylene, as well as several units in butadiene production.

1.7.3 Polypropylene Technology Options

The processes for PP can be grouped into three main categories: gas phase, bulk, and slurry/improved slurry. This generally refers to the first reactor system, as all state-of-the-art processes employ either a gas phase or bulk reactor system to produce homopolymer and random copolymer, followed by a gas phase reactor system for the sequential production of impact copolymer. Several of these processes are capable of producing metallocene-based resins.

The technology licensing market has changed over the years. With industry consolidation, the number of participants has been reduced and the major players are more likely to have access to in-house technology, thus reducing the number of third-party licenses. Also, merged companies may decide not to license one of their technologies in favour of another technology. In addition, some technologies are no longer made available for third-party licensing and are only used by the technology holder and joint venture partners. Another factor affecting licensing is that as plant scale grows and/or demand growth slows, the number of individual licenses required is reduced. The major licensors that produce polypropylene are presented in the figure below.

Figure 1.19 Polypropylene Licensors

Process Type (Homopolymer Reactor)		
Gas Phase	**Bulk**	**Slurry**
Grace UNIPOL	Borealis BORSTAR	Amoco/Chisso
INEOS INNOVENE PP	ExxonMobil	Hercules
JPP HORIZONE	LyondellBasell SPHERIPOL	Mitsubishi
Lummus Novolen Technology NOVOLEN	Mitsui HYPOL II	Montedison
LyondellBasell SPHERIZONE	Sinopec ST-PP	Sumitomo
Sumitomo	HFEC SPG/ZHG	Others

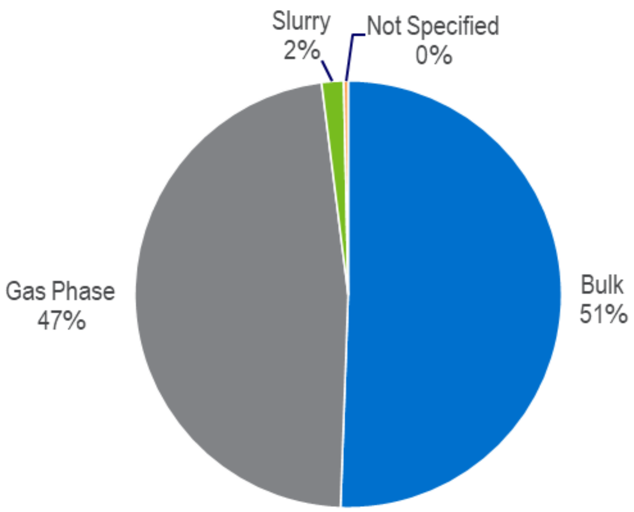
The process characteristics of the main licensed gas-phase polypropylene technologies are summarized in the following table.

Table 1.4 Features of Main Gas-Phase Polypropylene Technologies

Licensor	LyondellBasell	INEOS	Lummus	Grace
Process	SPHERIZONE™	INNOVENE®	NOVOLEN	UNIPOL
Commercial	Yes	Yes	Yes (licensed)	Yes (licensed)
Reactor	Gas-phase Multi-Zone Circulating Reactor (MZCR)	Condensed gas-phase Horizontal stirred gas phase reactor (HSBR)	Gas-phase Vertical stirred bed reactor (VSBR)	Condensed gas-phase Fluidized bed reactor (FBR)
Catalyst	General-purpose phthalate catalyst Ziegler-Natta and metallocene	Ziegler-Natta and metallocene	Ziegler-Natta and metallocene	Ziegler-Natta
Pressure	25-30 bara	22-30 bara	20-35 bara	25-35 bara
Temperature	70-90°C	60-85°C	50-105°C	60-70°C
C_2 content	Up to 8% wt	22% wt	Up to 22% wt	Up to 19% wt
Residence Time	~ 1 hour	~ 1 hour	~ 1 hour	~ 1 hour
Propylene per ton of Polypropylene	1.001 tons	1.001 tons	1.001 tons	1.001 tons

The top three technologies (SPHERIZONE, UNIPOL, and NOVOLEN) account for over 50 percent of the market. The bulk and gas phase processes lead the production of PP as summarised in the figure below.

Figure 1.20 Installed Polypropylene Capacity by Process Type, 2023



The Project will be adopting the LyondellBasell SPHERIZONE Technology for the production of PP.

1.7.4 SPHERIZONE Technology Overview

The SPHERIZONE™ process was commercialized by LyondellBasell in 2002 and has been offered for license since 2003. Its introduction was a major fundamental process technology development for polypropylene. SPHERIZONE™ is a mainly gas phase, non-metallocene polypropylene process that features a Multi-Zone Circulating Reactor (MZCR), which can produce a homogenous two-phase polypropylene in one reactor. The principle behind the MZCR is a reactor that offers two reaction zones with different process conditions, specifically temperature, hydrogen, and comonomer concentrations. This technology is said to produce more uniform polymers with broader molecular weight distribution and advanced performance capabilities. A single reactor can be used to produce homopolymers (narrow to very broad MWD) and random copolymers with a better property balance than conventional polypropylenes, as well as new families of multiple phase propylene polymers, including twin random copolymers or homo/random grades. According to LyondellBasell, the extension of the polymer properties compared with those achieved with conventional technology is significant.

LyondellBasell has plants recently started up or are under construction at a number of locations, the SPHERIZONE PP technology with plants at or around 500 000 tons per year licensed capacity.

LyondellBasell continues to offer process enhancements, expanding the grade range available from its technology. Some developments include:

- Development of new medical grades and soft pipes is ongoing in the areas of random and heterophasic copolymers (hecos).
- Development of ex-reactor high stiffness heterophasic copolymers with higher MFR, giving higher purity products at reduced operating costs.
- Soft hecos development with differentiated structures and enhanced gas phase reactor productivity for a wide family of specialty hecos and TPO (bi-polymer content greater than 30 percent) in a single gas phase reactor without substantial throughput penalty.

1.8 CAPEX AND OPEX

1.8.1 CAPEX

In the process of developing a PDH-PP complex, Alujain supplied estimated capital expenditure (CAPEX), based on the Class 3 estimate (-20 to +30 percent of accuracy), developed during the pre-FEED study, which is summarised in the table below.

Table 1.5 Alujain CAPEX Breakdown
(US$ million)

Budget Items	Value
Building/Infrastructure	111
PDH	780
PP	560
Tie-ins	103
UTOS	575
Initial Working Capital	45
Finance Cost	50
Total	**2 223**

We understand that Alujain is currently working on completing the FEED study for the project with their engineering company. Once the FEED study is completed, this may lead to a revision of the above CAPEX.

NexantECA classified the provided CAPEX values into inside battery limits (ISBL), outside battery limits (OSBL), and other project costs (OPC) categories based on Alujain's estimates, as illustrated in the table below.

Table 1.6 Project CAPEX Allocation
(US$ million)

	Propylene	Polypropylene	Complex
Capacity, thousand tons per year	600	550	
ISBL	780	560	1 340
OSBL	459	329	788
OPC	55	40	95
Total	**1 294**	**929**	**2 223**

1.8.2 OPEX

NexantECA has estimated Project OPEX based on its internal database for a PDH/PP plant of the similar size. OPEX can be split into variable and fixed costs.

1.8.2.1 Variable Cost

The annual variable costs are directly related to the production volume and dependent on the plant's operating rate. Variable cost per ton of products consists of raw materials/feedstocks, utility costs, plus credits for any relevant co-products and by-products.

Raw materials costs include the cost of feedstocks, catalysts and auxiliary chemicals. Raw materials are valued into the plant at their purchase price or estimated value in the case of intermediate product streams. Products are credited either at their plant (cost of production) or market price, depending on their final use.

Utilities typically include such items as power, steam, fuel (natural gas, fuel oil etc.), water (cooling water, process water, boiler feed water, etc) and inert gases (nitrogen, etc.).

1.8.2.2 Fixed Costs

The fixed costs in the project can be split by Direct Fixed Costs and Allocated Fixed Costs. The table below shows the values estimated for the Project.

Table 1.7 NexantECA Annual Fixed Costs Assumptions, 2027

Cost		**Propylene**	**Polypropylene**
Labour	US$/person	38 000	38 000
Foreman	US$/person	48 000	48 000
Supervision	US$/person	143 000	143 000
Factors			
Labour	# person	29	29
Foreman	# person	8	8
Supervision	# person	1	1
Direct Overheads Factor	% of Labour	45.0%	45.0%
General Plant Overheads Factor	% of Direct Fixed Costs	55.0%	55.0%
Maintenance Factor	% of ISBL	2.0%	2.0%
Insurance Factor	% of ISBL+OSBL	0.4%	0.4%
Environmental Factor	% of ISBL+OSBL	0.5%	0.5%
Direct Fixed Costs			
Labour	$ million	1.1	1.1
Foreman	$ million	0.4	0.4
Supervision	$ million	0.1	0.1
Direct Overheads	$ million	0.7	0.7
Direct Employment Cost	**$ million**	**2.4**	**2.4**
Maintenance Cost	$ million	16.9	12.1
Total Direct Fixed Costs	**$ million**	**19.2**	**14.5**
Allocated Fixed Costs			
General Plant Overheads	$ million	10.6	10.6
Insurance/Tax	$ million	4.7	3.4
Environmental	$ million	6.7	4.8
Total Allocated Fixed Costs	**$ million**	**22.0**	**18.8**
TOTAL FIXED COSTS	**$ million**	**41.2**	**33.3**

1.9 COST COMPETITIVENESS

NexantECA has conducted a cost competitive analysis of the polypropylene production of the Project compared to selected regional leaders on the ex-works and delivered cash cost basis. The delivered markets were selected as North-East Asia (using Shanghai as a reference) and Western Europe (using Rotterdam as a reference).

The PP plant modelled is assumed to be 500 000 tons per year in each location. For upstream integrated PDH plants, UOP Oleflex technology was analysed as this was the leading process used in 2023 globally. The PDH plant modelled at each location is assumed to be 600 000 tons per year in size. Capacities of the modelled PDH and PP archetypes are in line with the Project design capacities. The selected regional leaders are summarised in the table below.

Table 1.8 Selected Regional Leaders and PP Plant Configurations

Region	PDH/PP integrated	PP non-integrated
Middle East	✓	
Western Europe		✓
USGC	✓	✓
SEA	✓	✓
NEA		✓

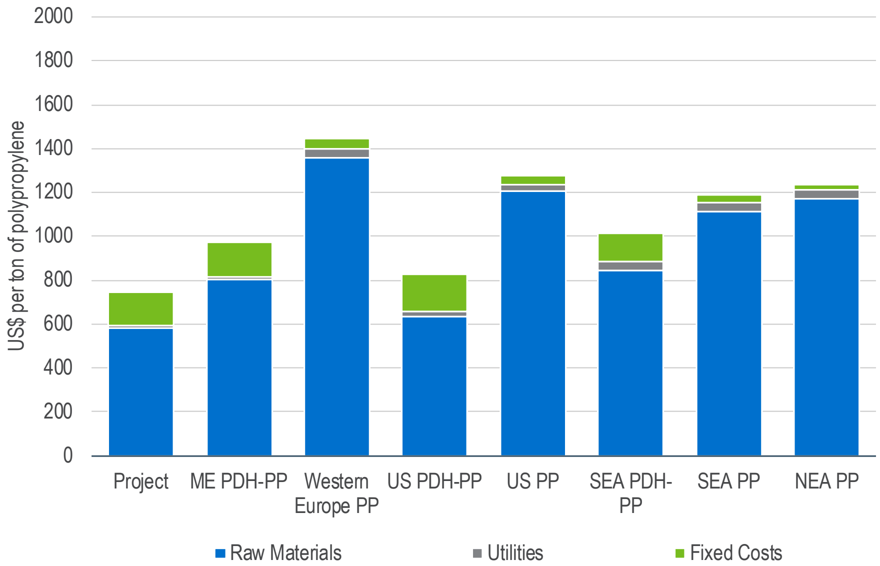
For all non-integrated PP plant, the propylene is assumed to be purchased at the market price which is an important determinant of polypropylene competitiveness.

The cost competitiveness analysis was performed for three crude oil price scenarios: low, medium and high. The executive summary shows only results of the assessment under the medium crude oil price scenario. The remainder of the analysis is presented in the main report.

1.9.1 Ex-works cash cost basis

Ex-works cash cost of production analysis is based on an estimation of the production cost at the factory gates based on the information received from the client and internal NexantECA database.

Figure 1.21 Ex-Works Cash Cost PP – Medium Oil Scenario
(2027, $80 per barrel)

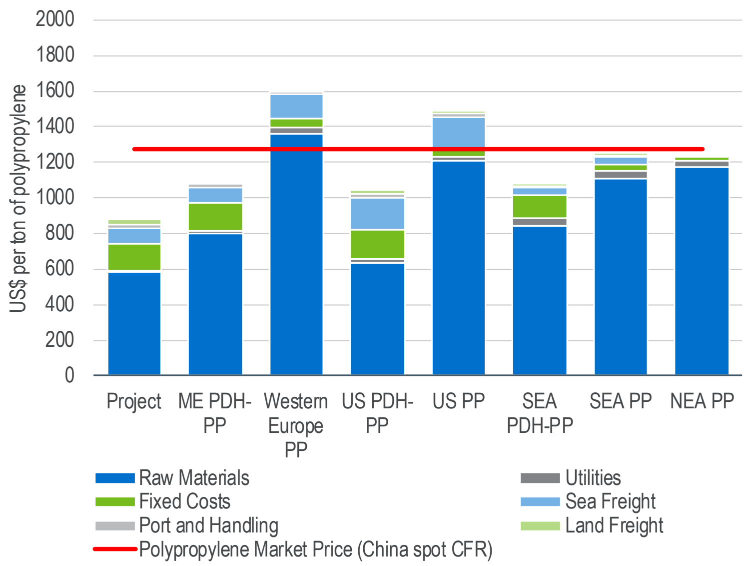


The Project is expected to have the lowest cost of propylene production among all reviewed regional leaders. The Project's raw material costs are lower than that of the Middle East integrated producer because Saudi Arabia's propane price is calculated as a Japanese propane price, minus the freight, at 20 percent discount. In contrast, the Middle Eastern price is calculated by adjusting the Asian propane price to reflect freight costs to that market. Thus, the Project's cost advantage widens under the high crude oil price scenario but narrows under the low crude oil price scenario (see report section 9). Furthermore, the Project configuration benefits from the by-product credits, such as off-gas, hydrogen, and C4 hydrocarbons, which have not been taken into account for the other regional integrated leaders.

1.9.2 Delivered cash cost basis

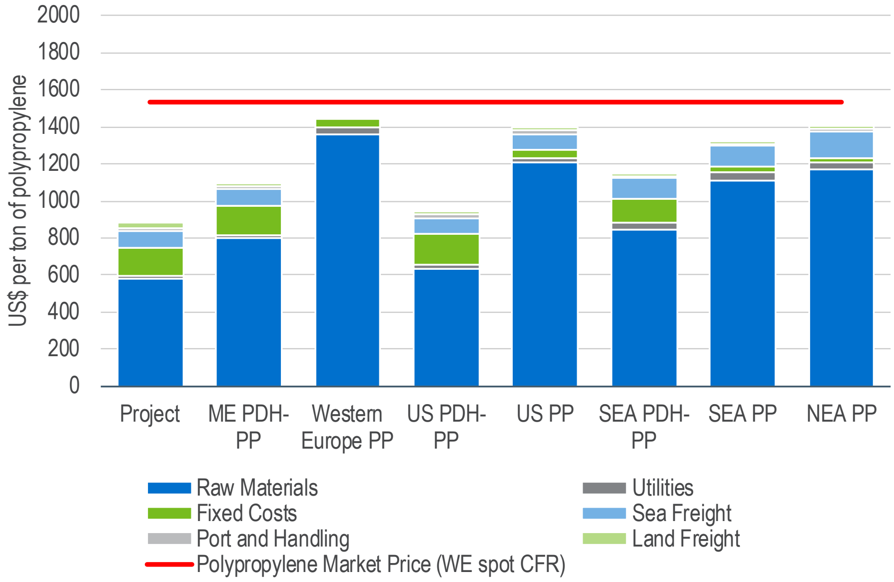
Most configurations studied could profitably deliver PP to the North-East Asia market (Shanghai reference) based on the destination market price. The only configurations that could not deliver PP profitably are the non-integrated producers in the Western Europe and US, who are disadvantaged with high raw material prices and high logistic costs due to the distance to the target market. Regions where an integrated and non-integrated PP plant were analysed show that the integrated plant with upstream PDH would be more competitive due to cheaper propylene prices compared to its market prices. This is despite higher fixed costs for integrated plants due to the contribution from the PDH plants. The Project configuration delivers the lowest delivered cash cost, lower than the Middle Eastern leader producer, due to advantageous propane price formula (see section above). The Project case had the added advantage of by-product credits which reduces the net raw materials cost further. The integrated-US configuration also has a competitive cash cost position but is disadvantaged by high freight costs compared to the Project case.

Figure 1.22 Delivered Cash Cost PP to Shanghai, China, CFR Basis – Medium Oil Scenario
(2027, $80 per barrel)



All configurations considered could profitably deliver PP to Western Europe (Rotterdam as reference) based on the destination market price. The Project case is projected to be the most advantaged due to the lower feedstock costs, contributed to by the favourable propane price formula and by-product credits. This is followed by the U.S. integrated configuration who also have advantaged feedstock costs. Non-integrated players are the most uncompetitive due to high raw material costs (propylene at market price), with Asian players at an extra disadvantage due to higher freight costs.

Figure 1.23 Delivered Cash Cost PP to Rotterdam, Western Europe, CFR Basis – Medium Oil Scenario
(2027, $80 per barrel)



1.10 ECONOMIC EVALUATION

NexantECA has developed a comprehensive, highly flexible discounted cash flow model (DCF) to evaluate the economics of the Project. Base case assumptions are drawn from inputs from NexantECA and Alujain.

The IRR and NPV for the Base case using NexantECA's medium oil price scenario (US$80 per barrel) are as follows:

Table 1.9 Base Case Complex Financial Results

(Price inputs – NexantECA's US$80 per barrel Medium Oil Scenario)

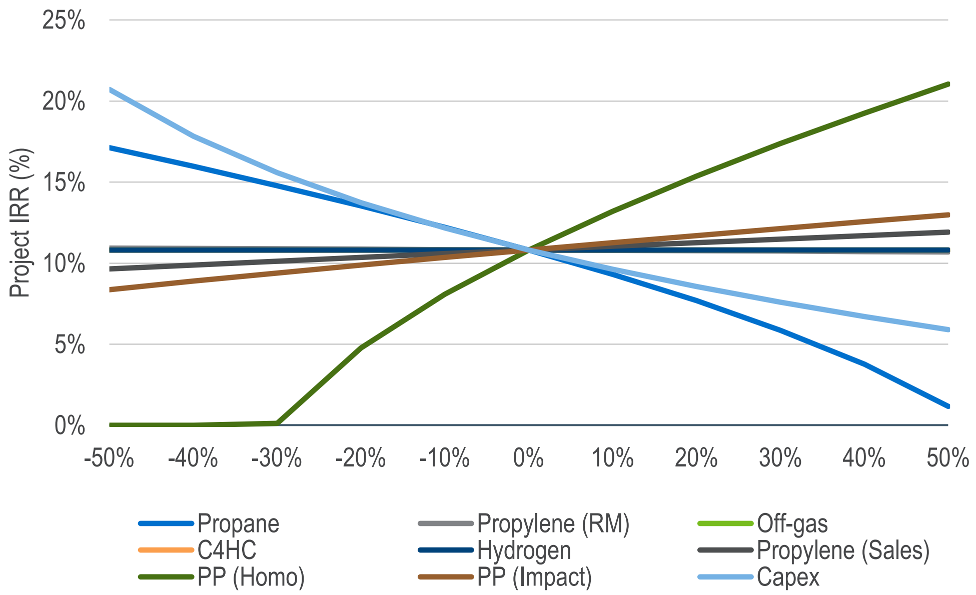
		Complex
Investment (incl. initial WC)	*MM$*	2 174
Net Present Value (8% discount rate)	*MM$*	611
Project IRR		11%
Equity IRR		15%
**IRRs with Terminal Value*		

Note: the investment value excludes US$50 million allocated for the finance cost in the Project CAPEX.

Based on the information provided by the client (i.e. CAPEX) and assumptions modelled in the FM, the Project IRR stands at 11 percent and the Equity IRR at 15 percent. The Project funding is split at 30 percent equity 70 percent debt.

The financial model's flexibility enables the user to easily change the certain assumptions and perform several sensitivities to the base case. The results of sensitivity analysis of the Project on the IRR are summarised in the figure below.

Figure 1.24 Sensitivity Analysis on Project IRR (Base Case)



The financial attractiveness of the Project is mainly influenced by variations in:

- Propane price
- Homo polypropylene netbacks
- Capex

The propane price is the single most important determinant of the cost of PP production. A high propane price not only lowers the general financial attractiveness of the Project. A 30 percent increase in the price of propane, the NPV of the Project becomes negative and the Project and Equity IRR drop to 8 and 11 percent, respectively. The increase in propane price has been assumed on a standalone basis, i.e. no changes in the costs of the associated by-products or products.

Homo PP prices have a strong influence on the Project's economics, resulting in no return for both project and equity IRR when prices have reduced by 40 percent. Polypropylene is a global commodity, and any typical single producer has limited bearing on international prices given the size of the market and limited market concentration. Typically, producers aim to optimise their marketing and sales plans to maximize their netbacks, where possible.

The CAPEX to build the facilities are another very important factor to determine the financial attractiveness of the Project. Unlike product prices, CAPEX can be optimized by choosing EPC contractors with good track records delivering projects on time and budget. Since the modelled CAPEX is based on pre-FEED level study, the sensitivity analysis can indicate the expected level of returns should the CAPEX change after finishing the FEED study.

Section 2

Project Overview

2.1 BACKGROUND

The Alujain National Industrial Company (Alujain) intends to construct a petrochemical facility (the Project) at a site in the Yanbu Industrial City, on the Western coast of the Kingdom of Saudi Arabia (KSA). The petrochemical facility will produce a range of polypropylene product grades which will be made available for the local market and for export outside KSA. The facility will be developed on a site neighbouring the existing National Petrochemical Industrial Company (NATPET). Polypropylene production plant and will be capable of supplying excess Propylene to the NATPET plant.

Alujain petrochemical facility will comprise two Licensed Process Units, the required Utility & Offsite systems and supporting infrastructure (Plant). The first Licensed Unit is a Propane Dehydrogenation Unit (PDH) taking propane feedstock and converting this into a propylene product. Lummus Technology LLC (Lummus) has been selected to provide the CATOFIN® PDH process for propylene production at a design capacity of 600 00 tons per year. A Polypropylene Unit (PP) with a design capacity of 500 000 tons per year will be developed as the second licensed unit. For the PP unit, Alujain has selected Basell Poliolefine Italia S.r.l. to provide the LyondellBasell (LYB) SPHERIZONE® PP process technology. The definition of the Utility, Offsites (UTOS) and supporting infrastructure required for the Plant will be developed by Samsung Engineering Co Limited (Samsung).

Pre-FEED was completed in October 2023 while the FEED study is ongoing at the time of reporting, and will be completed by early June 2024. The EPC contract award is scheduled for June 2024. The Project is a greenfield construction with expected start of operation in 2027.

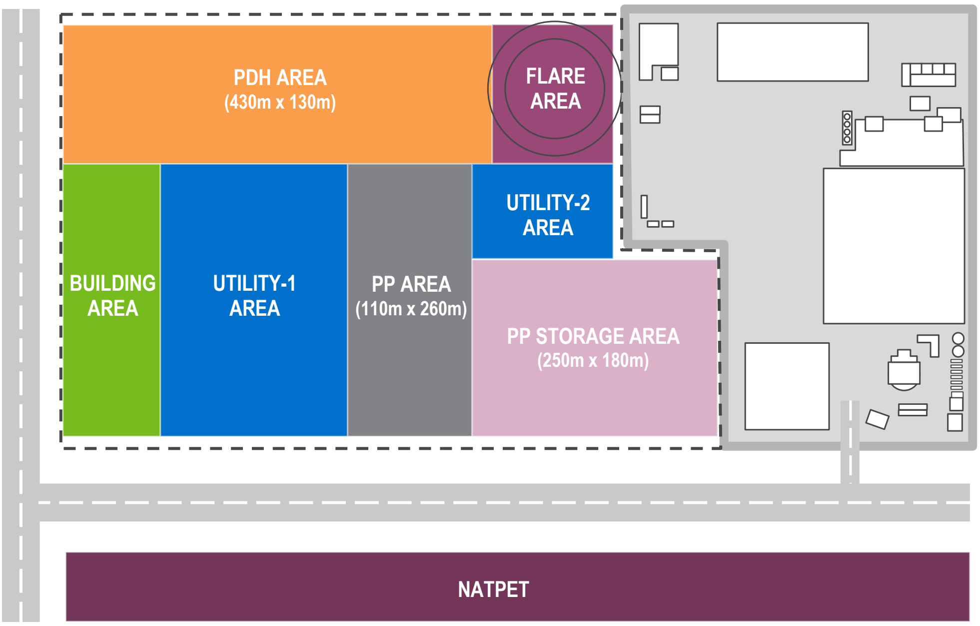
Figure 2.1 Project Location

2.2 THE PROJECT

The Plant will consist of all systems and subsystems in order to build and operate a PDH/PP complex consisting of:

- A PDH plant based on CATOFIN® Technology supplied by Lummus Technology;
- A PP plant based on SPHERIZONE® Technology supplied by LyondellBasell;
- Utility and off-site (UTOS) plant providing all utilities, power, infrastructure, tankage, logistics and off-site facilities, systems, and subsystems for the completion of the PDH/PP complex, in-side battery limit (ISBL) facilities and off-site battery limit (OSBL) facilities including synergies with the existing NATPET plant. Samsung has been selected for the UTOS Project scope.

Figure 2.2 Project Plot Plan – FEED Phase I Preliminary Version



The main feedstock for the Project is propane, which is converted to propylene in the PDH unit. The Project has secured an allocation of certain propane volumes from the Ministry of Energy sufficient to cover the anticipated requirements of the PDH/PP complex.

ALUJAIN has signed agreements with the licensors for the selected technologies to be utilised in the Project in March 2023:

- Lummus Technology – will provide PDH CATOFIN® technology and engineering services including a comprehensive Process Design Package (PDP)
- LyondellBasell – will provide PP SPHERIZONE® technology and engineering services from including a comprehensive Process Design Package (PDP).

NexantECA notes that both technologies considered proven at the proposed scale for implementation.

2.3 REPORT STRUCTURE

NexantECA has been retained by ALUJAIN to assess the commercial and economic viability of the Project by undertaking a feasibility study (the Study). The Study includes an evaluation of the market, pricing, marketing strategy, competitiveness and a financial evaluation of the proposed Project.

The Study also includes an assessment of technology options for each of the main project units based on licensor companies that ALUJAIN have signed agreements with.

The feasibility study is divided into the following sections:

- **Section 3 – Project Execution Strategy:** a review of the Client's organisational plan to manage and carry out the implementation of the Project. The key objective is to provide an understanding of the overall project schedule and key milestones.
- **Section 4 - Market Dynamics:** a review of historic and forecast supply/demand balance for propylene and polypropylene. The key objective is to provide an understanding of the drivers of the product markets and future market potential for the main products from the proposed Project and help define the key target markets and a preliminary marketing plan.
- **Section 5 – Marketing Plan:** an assessment of possible sales channels for international sales of product and consideration of market growth rates and changes in regional trade balances over the forecast period, incorporating market forecasts and netback pricing analysis. The key objective is to provide a preliminary marketing plan based on the market and netback analysis. The proposed sales split is used in the Financial Analysis Section.
- **Section 6 – Pricing:** a review of historical pricing data and profitability trends for the major regions as well as pricing projections for the product chemicals. The key objective is to understand the netbacks the project will make from the proposed target markets for use in the Economic Evaluation.
- **Section 7 - Technology Overview:** an independent high level review of major licensed processes for the products of the proposed Project configuration. The key objective is to describe technologies based on NexantECA's internal data and make appropriate recommendations.
- **Section 8 – Capex and Opex:** a summary of major costs relating to the plant which may impact CAPEX and OPEX.
- **Section 9 – Cost Competitiveness:** an assessment of the Project's competitive cost position. The key objective is to understand the relative competitive position of the Project against major archetype competitors in delivering polypropylene to the proposed target markets.
- **Section 10 – Economic Evaluation:** a financial model to simulate Project configuration and evaluate the economic feasibility and bankability from a Sponsor and Lenders perspective. Section 10 presents the key assumptions and operating parameters used in this model, as well as summarising the results for the Project.

Section 3

Project Execution Strategy

3.1 INTRODUCTION

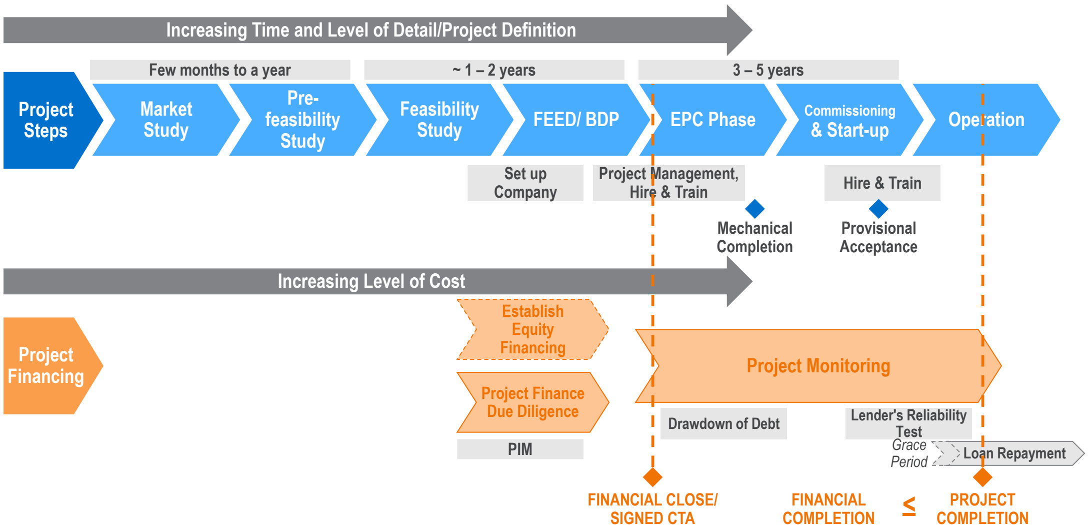
In this section NexantECA provides the typical project implementation steps and high-level schedule (Level 1) for the EPC phase of the Project. Budgeting (CAPEX) considerations for the EPC phase of the Project are provided in a different section of this report.

3.2 TYPICAL PROJECT IMPLEMENTATION STAGES

As shown in the following figure, there are distinct phases to project development, some of which are listed below:

- Feasibility Study (this study)
  - Definition of the configuration outline of the project.
  - Confirmation that the project is capable of meeting the sponsor's requirements and achieving an acceptable financial and strategic performance.
- Environmental Study and Environmental permit application
  - Satisfying relevant authorities that environmental aspects of the project have been appropriately defined with agreed actions, and with mitigating measures where appropriate.
- Basic Design
  - Definition of Project Specification.
  - Preparation of Licensor Selection.
- Licensor Selection
  - Selection of the technology to be used for process units.
- Front-End Engineering Design (FEED).
  - Design and definition to allow EPC to be prepared.
- Obtaining Regulatory Approvals
  - To allow the construction to proceed.
- Engineering, Procurement and Construction (EPC) Phase.
- Commissioning, Start-up and Performance and Creditors Reliability Testing
- Commercial Operation

Figure 3.1 Typical Project Steps



3.3 EPC CONTRACTING STRATEGY

3.3.1 Generic Types of EPC Contracts

There is no single agreed contracting approach for implementing a grassroots project. Conventional “extremes” are represented by:

- **Lump Sum Turn Key (LSTK) approach**: Whereby a contractor commits to deliver a plant, as defined, within a defined schedule and for a fixed price. The advantages of this type of a project are that the cost is defined at an early stage (upon the award of the EPC contract) and the contractor then has full single point responsibility to deliver the facility as per the contract. The contractor hence takes on completion and schedule risk for the agreed contract price (and incurs risk of price escalation for materials, labour and currency fluctuations). A disadvantage of this approach is that contractors will generally include a larger margin (compared to a reimbursable approach) in the lump sum price offered to cover these risks. The key advantage is the owner is aware of the cost for this project at an early stage in the process.
- **Reimbursable approach**: Whereby the contractor is paid for all costs incurred at agreed rates (that include a profit margin). In such cases, the contractor is providing engineering, procurement and construction services to the owner, who is exposed to all project risks (overall project cost, schedule and completion obligations). The advantages of this approach are flexibility, as the project scope can be readily changed within this structure at any stage of the project, and speed of implementation (due to the reduced tendering period). The disadvantage of the approach is that although the cost and/or completion date can be specified at the time of contract award, they are not contractually binding and are liable to change during project execution.

3.3.2 Contractor Tendering and Appointment Process

The selection process for an EPC contractor may be approached in different ways, depending on the wider project circumstances. Common methods for appointment include:

- **Competitive tendering process**: Whereby several interested parties are issued with invitation to bid (ITB) documents outlining the scope of works and owner requirements. The technical details of contractors’ subsequent proposals are reviewed, with those meeting the technical requirements progressing. Of qualified bidders, the lowest price contractor is then generally selected. A competitive bid process is generally undertaken to try to keep overall costs down, by pushing bidders to offer their best price in order to win the work. A potential drawback of this approach is that bidders may offer artificially low prices or agree to unrealistic schedules in order to win the bidding process, and then attempt to recover costs by issuing change orders and extension of time requests.
- **Sole source negotiation**: Whereby a contractor is selected early in the process, and negotiations on price, schedule, damages and guarantees begin subsequently. Prices may potentially be offered by contractor on an open-book basis, whereby the full build-up of the EPC lump sum is visible to the owner. This approach looks to prevent the potential disruption to the project that may be caused by an overly aggressive contractor that cannot meet their obligations. A drawback of this approach is that the owner may not obtain the most optimum price possible.

3.3.3 Generic Project Completion Terms

Various common terms may be used in describing and monitoring progress during the construction of a project. Certain of these terms describe "completion events" which have contractual significance in that the EPC contractor's guarantees and liquidated damages (where applicable) are linked to these events. The terminologies used here are not universal, but these "completion events" include:

- **Mechanical Completion (MC)**: Which defines the point at which the plant construction is physically completed according to specification, design drawings and other contract requirements, with utilities and processes connected to the equipment.

- **Ready for Start-up (RFSU)**: Which defines the point at which the plant is ready for the introduction of feedstock, i.e. ready to be put into operation.

The period between mechanical completion and RFSU is known as the commissioning period. It can occupy a period of as little as one day for a simple piece of equipment, up to several weeks or more for a complete process plant, and a number of months for a complete new petrochemical complex. During this period the plant is checked for cleanliness, process, instrumentation and safety systems are checked as operational, etc.

The period between RFSU and provisional acceptance (see below) can occupy a period of as little as one day for a simple piece of equipment, up to several weeks or months for a process plant complex. During this period the plant performance is checked, any trouble-shooting is undertaken, the plant is worked up to producing on-specification product and "lined-out" at the 100 percent production rate, and the performance tests demonstrated and agreed between owner and contractor.

- **Taking Over of Works**, or provisional/initial acceptance, defines the point at which the plant has passed all performance tests, as defined in the contract with the party responsible for the plant construction/performance. Provisional completion is the key sign-off between owner and contractor, and the point at which the contractor is fully paid up for his services.
- **Final Completion** defines the point at which the contractor's warranties expire, and all performance securities issued by the contractor are returned.

In general, for major refining and petrochemical projects, performance tests are for a duration of 3-5 days in which the contractor is to demonstrate that the plant can operate at the guaranteed production rates without excessive feedstock/utility consumption. The warranty period is typically one or two years from the taking over of the works.

3.3.4 EPC Scope

As the EPC contractor has not been selected yet, the definition on the scope of work is not yet available. In NexantECA experience, this will generally be defined in an annex to the EPC contract with reference to the facilities described in the FEED study carried out for the project.

The EPC contractor or consortium will be responsible for the full development of the project from the FEED study undertaken to handover of the completed works (the facilities noted above) to the sponsor. This includes the following elements of work:

- Detailed engineering
- Procurement of all materials
- Construction of facilities
- Project management of works
- Pre-commissioning, commissioning and start-up of facilities
- Completion tests
- Clearance of EPC site facilities

In the absence of the detailed scope of work for the EPC contract, there are some areas where the extent of the EPC contracting contractor's responsibilities is not clear. These include:

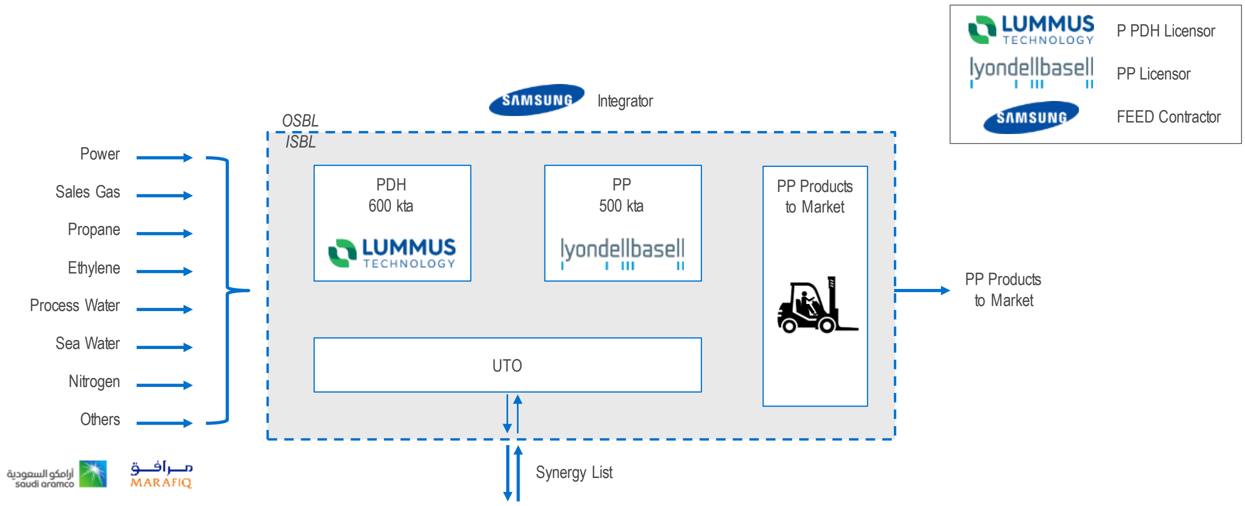
- **Activities from start-up to handover** – in general, the plant remains under the custody of the EPC contractor personnel until the performance tests are passed, but operated by the sponsor (or its appointed O&M contractor). Exact responsibilities during this period have not yet been defined.
- **Training provision** – the EPC contractor is often responsible for the provision of training to the operator personnel of the sponsor. This may be provided from the technology provider, as part of the novated technology licence agreement.

- **Provision of catalyst, chemicals and spare parts** – the EPC contractor is generally required to provide the initial fill of catalysts and chemicals for the facility, as well as capital spare parts and anticipated requirements for the first two years of operation. The initial catalyst fill and spare parts provision is generally reimbursable at additional cost to the contract LSTK price. In some circumstances, the owner will be wholly responsible for the supply of these, often in close communication with the vendors or the licensors. Where the EPC contractor is required to supply these, it will be so recorded in the engagement contracts between the parties.

3.4 PROJECT DEFINITION

For the development of the PDH/PP plant, Lummus Technology will be the licensor for the PDH plant; LyondellBasell will be the licensor for the PP plant and Samsung will be the FEED Contractor. Several other companies, or stakeholders, will be involved in provision of feedstock (propane), utilities, offsites and other key services to the Project. The following figure summarises the Project definition.

Figure 3.2 Project Definition



The Plant will consist of all systems and subsystems in order to build and operate a PDH/PP complex consisting of:

- A PDH plant based on CATOFIN® Technology supplied by Lummus Technology;
- A PP plant based on SPHERIZONE® Technology supplied by LyondellBasell;
- Utility and off-site (UTOS) plant providing all utilities, power, infrastructure, tankage, logistics and off-site facilities, systems, and subsystems for the completion of the PDH/PP complex. Samsung has been selected for design of UTOS and as s an integrator for the entire PDH/PP UTOS complex.

More detailed information about the Project is provided above, in Section 2 Project Overview.

3.5 PROJECT ORGANISATION

The FEED Services will be executed by Samsung which will act as an integrator for the entire PDH/PP and UTOS complex based on the Basic Design and Engineering Package. The Contractor will design (open-art design) the complete set of utilities systems, inside battery limit (ISBL) facilities and offsite battery limit (OSBL) facilities including synergies with the existing NATPET plant. Currently Samsung is the utilities engineer and interface coordinator between the licensed plants and utilities.

The Design Basis prepared during the FEED shall form the basis of the engineering design and will be an integral part of the EPC Request for Proposal (RFP) documentation.

Alujain has finalised the organisation structure that will oversee the implementation of the Project. The organisation consists of the Project Directorate and the Technical & Project Services Support.

The Project Directorate will be led by Mr Fehaid Alhajri, Chief Project Officer (CPO). He will be assisted by the Deputy Chief Project Officer, Mr Timothy Rivers, from LyondellBasell. Other members of Project Directorate come mainly from Alujain and are in charge of the different components of the Project.

A third-party project management consultant (PMC) is to be engaged for the implementation phase of the project to oversee the EPC contractor consortium on behalf of the sponsor company. Worley was appointed to act as a PMC on behalf of the sponsor team in overseeing the production of the FEED. The appointment of an independent third-party company to oversee the project implementation process should provide some comfort that there will not be any conflicts of interest during the project phase. During project implementation, the project management team will need to, for example, approve work undertaken by the EPC contractor or sign off on variation orders issued by the contractor.

The Technical & Project Services Support will mainly consist of PMC representatives with some assistance from LyondellBasell secondees.

NexantECA notes that the establishment of a well-defined structure for the project organisation, with clear channels of communication, is a positive indication for the future implementation of the project.

3.6 STAKEHOLDERS

This project involves active communication among five pivotal stakeholder groups:

- Government Stakeholders
- Licensors
- Contractor
- Integrated Project Management Team (IPMT)
- Contractor's Third Parties

To ensure the seamless delivery of the project, direct communication channels will be established between licensors, IPMT, and the contractor. Likewise, the contractor and their affiliated third parties, such as the HCIS SAF Consultant, Environmental Consultant, and Vendors/Suppliers, will engage in ongoing communication. Government stakeholders will also maintain communication ties with the IPMT, while the IPMT will foster communication with the Contractor.

In addition to these core stakeholders, external entities will play a vital role as stakeholders, contributing either resources or essential work for the Project. Detailed requirements from these external stakeholders are outlined in the following table:

Table 3.1 External Stakeholder Requirements

External Stakeholders	Requirements
Royal Commissions	▪ Environmental Impact Assessment Report
Saudi Aramco	▪ Sales Gas ▪ Propane Supply
Marafiq	▪ Secure final alignment for all utilities and power
SABIC	▪ Nitrogen Supply
HCIS	▪ Consultant
Air Liquid Products	▪ Hydrogen potential tie-in
YANSAB	▪ Ethylene Vapour ▪ Polypropene

All external stakeholders' requirements shall be incorporated into Basic Design / Detail Design as required.

3.7 UTILITIES

The Project relies upon many utilities to operate successfully. Some of these utilities will be provided by third parties, namely Marafiq and NATPET. The below table shows which stakeholder will provide which utility, as well as the status.

Table 3.2 Utility Sourcing

Stakeholder	Service/Utility	Status
Marafiq (OSBL)	▪ Potable Water ▪ Process Water ▪ Industrial Wastewater ▪ Sanitary Wastewater ▪ Sea Water ▪ 115kV Power (Marafiq Sub Station 10J)	▪ Utilities Demand Form was submitted to Marafiq along with supported documents to process Utilities Allocated Request ▪ Tie-in and route are under discussion with RC, the up-to-date progress will be shared to include in the FEED Package and project cost estimation
NATPET Synergy's and Other Stakeholders	▪ Sales Gas - Saudi Aramco ▪ Propane – Saudi Aramco ▪ Nitrogen – SABIC Gas ▪ Hydrogen ▪ Ethylene ▪ Propylene	▪ The up-to-date progress will be shared to be include in the FEED Package and project cost estimation

3.8 PROJECT SCHEDULE

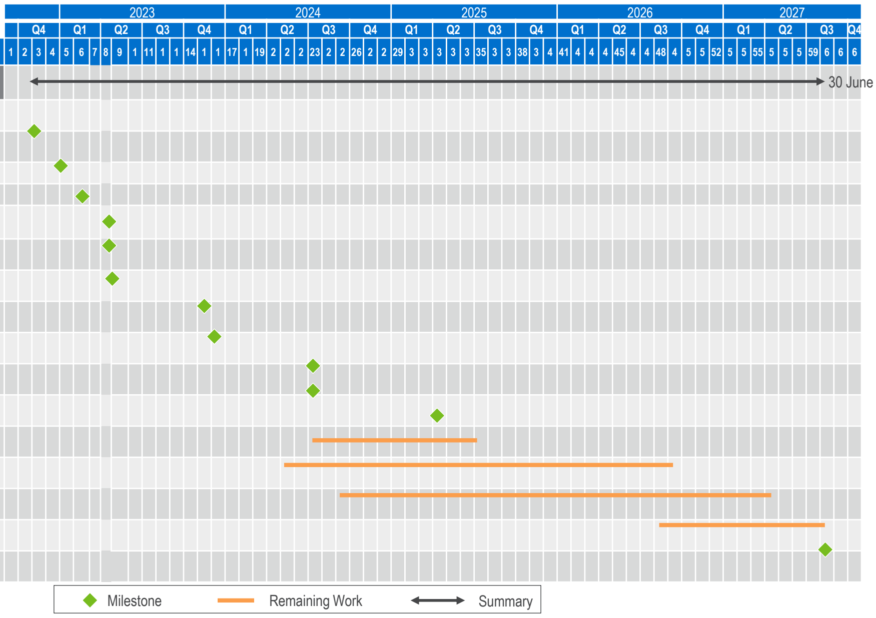
Alujain has outlined a preliminary schedule for the Project, which is being used as the basis for its tendering strategy. The scheduled time for completion (passing of performance test and handover of facility to sponsor) is 57 months from the commencement date of the Project as of Q4 2022. It should be noted that this is still a preliminary schedule, and it remains to be seen what timelines the selected EPC contractor will commit to (and agree delay damages against).

The figure below shows a high-level summary of the schedule, highlighting the key milestones and the scheduled duration of key activities.

Figure 3.3 Simplified Project Schedule

(as of February 2024)

Activity ID	Activity Name	Start	Finish
	Alujain Key Milestones	29 Sep 22 A	30 Jun 27
A1190	Royal Commission Conditional Site Allocation	29 Sep 22 A	
A1070	Feedstock Allocation Agreement with ARAMCO		04 Dec 22 A
A1000	PMC Contractor	16 Jan 23 A	
A1010	Licensing Agreement Lummus	10 Mar 23 A	
A1030	Pre-FEED Contract (Samsung)	10 Mar 23 A	
A1020	Licensing Agreement LyondellBasell	23 Mar 23 A	
A1050	FEED Contract Award		04 Oct 23 A
A1040	Pre-FEED Activities Completion		31 Oct 23 A
A1110	EPC Contract Award	02 Jun 24	
A1110	FEED Activities Completion		03 Jun 24
A1140	Financial Closure		28 Feb 25
A1150	Engineering	03 Jun 24	03 Jun 25
A1160	Procurement	01 Apr 24	30 Jul 26
A1170	Construction & Mechanical Completion	01 Aug 24	26 Feb 27
A1260	Commissioning	01 Jul 26	29 Jun 27
A1180	Plant Start-up/Operation Date		30 Jun 27

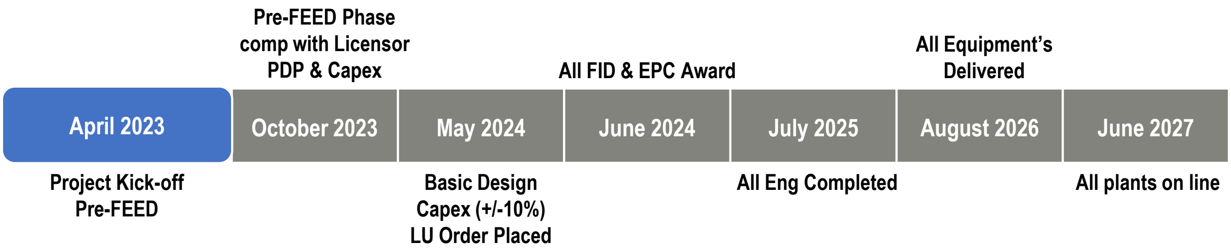


The scheduled time for the completion of all works until overall ready for the start-up is 36 months, from EPC award, currently planned for Q3 2024, to completion in Q3 2027. However, the firm contractual schedule will need to be confirmed following appointment of an EPC contractor.

Currently, the Project is in development phase with FEED Contract awarded in October 2023, FEED forecasted completion by Q2 2024 and the Project to be commissioned by Q3 2027.

Figure 3.4 Timeline of the Project

(as of February 2024)



The key milestones for the project include the following:

- **Notice to proceed** – following financial close and satisfaction of all advance payments and bond issues, the notification to proceed signals the start of the EPC process and the start of the contractual completion period.
- **Mechanical completion** – completion of all construction work according to specification, design drawings and other contract requirements, with utilities and processes connected to the equipment. At this point, commissioning of systems can begin with introduction of hydrocarbons into the plant. The current schedule anticipates this **30 months** from notice to proceed.
- **Ready for start-up** – during commissioning, the process units are run and tested. Ready for start-up is the point at which on-spec product is produced within the plant. From this point, the plant operation is ramped up to full capacity.
- **Initial acceptance** – also known as provisional acceptance, this marks the point at which the plant is operating at full capacity and has passed the performance tests. At this point the plant is handed over to the sponsor, the contractor is signed off, and the warranty period commences. The current schedule anticipates this **36 months** from notice to proceed.

The progress of the EPC contract can be monitored against defined milestones and an ongoing assessment of deemed physical progress – payments to contractor will also be scheduled against these defined milestones. The EPC contractor will issue monthly progress reports (or as agreed with owner) during the EPC implementation to provide an update against schedule.

Schedule risk for projects of this type typically falls under two distinct categories: generic downsides associated with any EPC project of this type and specific risks associated with mechanical factors, the adopted contracting approach, local factors, project/contract interfaces (e.g., utility and feedstock tie-ins), etc.

The project contracting strategy can minimise specific risks to schedule, through appointing a single EPC contractor to undertake the works (minimising interfaces), and through selection of an established well-qualified contractor to partner with the EPC Contractor. The project location is also fairly easily accessible for delivery of equipment and is a greenfield site avoiding risks of interference from other operations.

Although the project specific elements are appropriate to minimise risks against delay and the proposed 36 months schedule appears reasonable, it is not unusual for petrochemical projects of this nature and complexity to suffer delays. As a result, NexantECA recommends that the lenders consider the impact of any such delays in the financial model.

Section 4

Market Dynamics

4.1 INTRODUCTION

This section presents the market dynamics for propane, propylene and polypropylene. Historic and forecast volumes of annual production, consumption and net trade are presented, covering the historical period 2012 to 2022, the estimate is for 2023 and forecast period from 2024 to 2050.

The covered regions for propylene and polypropylene are:

- Global
- Turkey
- Europe will be covered as Western Europe and Central Europe
- CIS countries will be covered as Russia and Other Eastern Europe
- North Africa
- Middle East
- North-East Asia
- South-East Asia

The propane will be supplied by the Government as a regulated feedstock, and propylene will be largely consumed internally within the complex with some export sales; hence the market analysis in the report will largely focus on the opportunity presented to a producer of polypropylene based on the West Coast of the Kingdom.

The net trade position for the regions covered are presented for 2020, 2030, 2040 and 2050 showing the expected evolution of trade flows. This analysis highlights the principal markets to target under the marketing plan.

4.2 PROPANE

There is not an open commercial market for buying and selling oil and gas products in KSA. The Ministry of Energy determines the supply fundamentals based upon the macro pictures on oil and gas developments within the country. The relevant Ministries therefore allocate discrete volumes of oil and gas to key offtakers under long term supply deals.

The detail of the deals is not widely published but the key determinants are the pursuit of objectives while adhering to its Vision 2030, of adding wealth to Saudi Arabia. This can be in terms of financial, improving health and education, local employment to its nationals etc.

The Ministry of Energy has clearly informed the Sponsors of its ability to receive an allocation of propane to permit development of a world-scale PP business within Saudi Arabia. The basic terms of the Project specific propane supply agreement were not available at the time of the report.

4.3 PROPYLENE

4.3.1 Global

4.3.1.1 Consumption

Propylene consumption growth was close to four percent in 2023 as Western markets had managed to recover further the impact of higher interest rates and higher , energy and food costs. There is still much to do on these fronts. COVID-19 lockdowns in China restricted derivative growth to very low levels, creating brutally competitive derivative markets as new capacity entered the market.

Polypropylene remains the main growth engine, now accounting for two-thirds of propylene consumption and thus effectively setting the rate of propylene consumption growth. Polypropylene, however, has considerable exposure to large purchase items such as vehicles and also the construction sector, which was again exposed in 2023. Polypropylene is the mainstay for the production of low-cost plastic household items such as bowls and pails and has consistently taken share from other materials in the packaging sector, particularly via BOPP (biaxially oriented polypropylene film). This latter sector is however coming under pressure due to low recyclability, although its performance over alternatives is so attractive that most regions are prepared to have complex films sent for energy recovery rather than force recycling or substitution. The PureCycle polypropylene recycling technology is now being trialled at scale, and if successful, this and similar technologies could have a significant impact on the global outlook for propylene consumption towards 2030.

The main dynamic of the global propylene market is the massive polypropylene build currently underway in China. China's polypropylene capacity has increased from 37 million tons per year in 2020 to over 54 million tons per year annualized capacity in 2023. Although still a net importer, at over 2.9 million tons in 2023. China's exports of homopolymer polypropylene alone increased to an estimated 1.5 million tons in 2023, significantly impacting propylene demand in other countries.

Propylene oxide is the next largest derivative, driven mainly by demand into polyols which in turn create polyurethanes for diverse applications ranging from furnishing to buildings insulation. The exposure to the automotive sector has been problematic in recent years, and growth rates have declined significantly.

Acrylonitrile and isopropanol have a relatively low growth outlook, although demand for hand sanitisers transformed the market for isopropanol briefly during the most intense periods of the COVID-19 lockdowns. High oil prices in 2022 again favoured substitution by fermentation ethanol, and the use of sanitizers declined. The lower oil prices in 2023 reduced this opportunity for the fermentation producers.. The cumene/phenol sector has been affected by the rapid maturation of the market for the key derivative polycarbonate and a capacity build in China, which has depressed phenol output in other regions. Acrylonitrile production growth has been very low due to the long-term substitution trend of acrylic fibre with other fibres, particularly polyester, which has forced acrylic fibre out of all applications which do not require particular UV and weather resistance, or hand/texture characteristics that can be achieved with acrylic fibre in apparel uses. The ABS sector and the acrylamide industry are now the major growth drivers for acrylonitrile, and while carbon fibre represents good potential long-term growth, current volumes are small. Its use in wind turbines is, however, an attractive and fast-growing sector.

The acceleration in cumene/phenol market growth in 2017 proved short-lived, driven partly by new capacity for the conversion of phenol into caprolactam which provided a step change in demand, which has not been repeated. This process has existed for a long time but has not previously been widely licensed. Most caprolactam is produced by the oxidation of cyclohexane, which does not create an indirect demand for propylene.

Butanol and 2-ethylhexanol are part of the group of products known as oxo-alcohols, which are so named because of the “oxo-process” by which they are produced. Butanols have performed better in recent years through underlying growth in the market for its key derivative butyl acrylate, mainly in water-based coatings. Isobutanol is coproduced with *n*-butanol and is frequently in oversupply. It is used as a solvent, and to a lesser extent in the production of amines. The 2-ethylhexanol market has been under pressure for several years due to health and safety concerns surrounding its main derivative; the plasticiser, dioctyl phthalate (DOP). 2-ethylhexyl acrylate is however a fast-growing sector, mainly for coating and adhesives, and 2-ethylhexyl nitrate is achieving high growth as a diesel fuel additive (cetane improver). As with acrylonitrile, the rapid development of capacity in China undermined propylene demand into oxo-alcohols in other regions, although the market has now absorbed much of the excess capacity.

Propylene demand for acrylic acid has frequently been the fastest growing of the major derivatives, although its contribution to the overall market growth remains very small. The market has become turbulent however, with rapid capacity expansion in some areas causing production to stagnate and indeed drop in others. Demand growth in 2023 globally was significantly faster than the market as a whole.

As was the case during the SARS epidemic, COVID-19 brought a temporary surge in isopropanol demand for hand sanitizers. Only modest isopropanol (IPA) market growth is anticipated in the long term, however, as growth in smaller applications is offset by its reduced usage in coatings due to restrictions on emissions of volatile organic compounds. IPA consumption is affected by the availability of acetone, which is a by-product of phenol production. Acetone oversupply has led some consumers of IPA (such as producers of methylamines) to convert their processes to consume acetone, achieving considerable cost savings. Increasing volumes of acetone are now being recycled back to propylene, although the effect on the propylene market is not significant in most regions.

Figure 4.1 Global Propylene Consumption by End-Use, e-2023

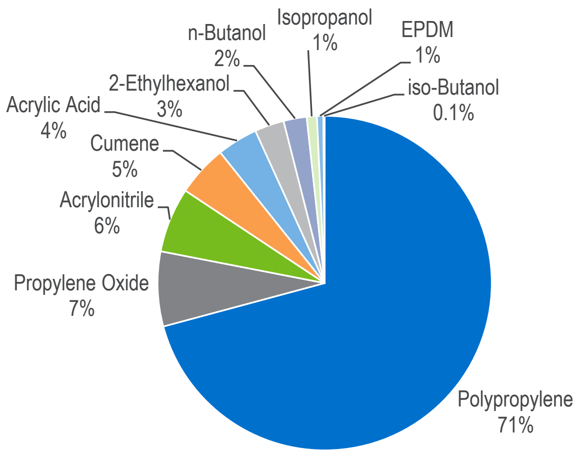


Table 4.1 Global Propylene Consumption by End-Use, e-2023
(thousand tons)

	Actual			Estimate	Forecast								Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Firm Capacity	99 002	119 136	144 956	154 285	161 811	169 463	173 070	176 491	176 491	176 518	176 491	176 492			
Speculative	1	-	(131)	(386)	(588)	210	1 548	18 523	35 242	58 600	82 342	93 686			
Total Capacity	99 003	119 136	144 825	153 899	161 224	169 672	174 619	195 014	211 733	235 118	258 833	270 178	4.1	3.4	1.6
Operating Rate	86%	88%	83%	82%	80%	79%	80%	81%	84%	83%	84%	88%			
Production	84 779	105 265	120 205	125 443	129 622	134 083	139 429	157 738	177 842	194 374	217 689	238 668	3.6	3.3	2.1
Net Export	818	(422)	(348)	-	-	-	-	-	-	-	-	-			
Consumption	83 962	105 687	120 553	125 443	129 622	134 083	139 429	157 738	177 842	194 374	217 689	238 668	3.7	3.3	2.1

Figure 4.2 Global Propylene Consumption by Region, e-2023

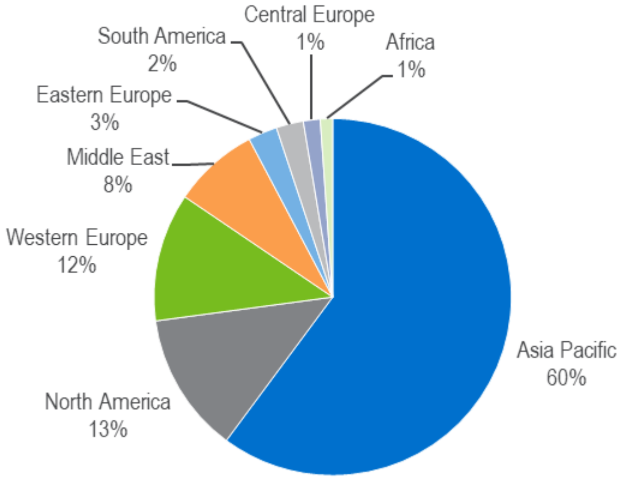


Table 4.2 Global Propylene Consumption by Region, e-2023

(thousand tons)

	Actual			Estimate	Forecast									Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2027	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
North America	15 156	15 319	15 225	15 957	16 493	16 470	16 878	17 203	18 518	20 053	21 318	22 447	23 907	0.5	2.1	1.3
South America	3 263	3 385	3 073	3 090	3 062	3 088	3 148	3 783	5 016	5 000	5 345	5 370	5 650	(0.5)	7.2	0.6
Western Europe	15 076	15 646	13 194	14 596	14 093	14 492	14 765	15 181	15 408	16 115	16 290	16 597	17 475	(0.3)	0.8	0.6
Central Europe	1 475	1 747	1 661	1 918	2 172	2 160	2 290	2 352	2 558	2 774	2 800	2 826	2 905	2.4	4.2	0.6
Eastern Europe	1 685	2 424	3 011	3 302	3 343	3 534	3 651	3 747	4 721	5 705	6 036	7 760	8 951	6.3	5.2	3.3
Middle East	6 865	9 493	10 352	9 750	9 634	10 685	10 817	11 456	14 070	17 646	21 107	24 456	26 903	3.2	5.4	3.3
Africa	1 056	1 277	1 209	1 388	1 895	1 886	1 925	1 958	2 775	3 806	4 119	5 134	5 947	2.5	10.4	3.9
Asia Pacific	39 386	56 397	72 827	75 443	78 930	81 767	85 955	89 502	94 672	106 743	117 358	133 100	146 929	6.1	3.3	2.2
Total	**83 962**	**105 687**	**120 553**	**125 443**	**129 622**	**134 083**	**139 429**	**145 181**	**157 738**	**177 842**	**194 374**	**217 689**	**238 668**	**3.7**	**3.3**	**2.1**

Note: Combined propylene consumption includes polymer, chemical and refinery grade propylene. Refinery grade propylene consumption is included in the tables on a contained basis.

4.3.1.2 Supply

The global propylene supply base has expanded by 22 percent over the last five years and is set to expand at exactly the same rate over the next five years. This growth is substantially higher than consumption growth, and has led to intense competition, low prices, and pressure on laggard operators. The last five year cycle included the addition of 13 million tons per year of steam cracker propylene and eight million tons per year of PDH. Over 2022-2027 the volumes will switch, with seven million tons per year of steam cracker propylene and ten million tons per year of PDH are forecast to be added. FCC propylene additions will be much lower at 1-2 million tons per year over the next five years. There will be minimal addition of stand-alone metathesis plants, and propylene supply growth from methanol will drop from four million tons per year over 2016-2021 to only one million tons per year over the coming five years.

The surge in steam cracker development has come alongside major new refinery developments, most of which are configured around hydrocracking and aromatics production. This surge in refining capacity is taking share from older and frequently FCC-based refineries in all regions, thus eroding FCC-based propylene supply globally.

India is the only region with significant new FCC capacity under development, although the anticipated step-out develop from Reliance which could include two million tons per year of propylene via its multizone cracking technology now seems less likely in the near term as the company focusses on renewables, and the expected sale of a share in its oil-to-chemicals business to Saudi Aramco was cancelled. The West Coast refinery project in India would have brought with it several million tons per year of FCC propylene, but now appears cancelled. India is one of the few regions with major long term demand growth expected for transportation fuels, which is expected to give rise to increases in FCC propylene supply.

Numerous large-scale liquids-based steam crackers are being built in China, South Korea, Indonesia and India, while propylene supply growth in Europe and the Americas remains driven principally by PDH. The developments in China mark a major change in the industry, with private companies entering the refinery and olefins industries to provide competitive raw materials for their existing downstream activities. The drive is spearheaded by massive Chinese polyester players which are primarily aiming to produce *para*-xylene. Companies such as Hengli and Zhejiang Petrochemical are building several world-scale oil refineries using a “crude-to-*para*-xylene” concept which maximises naphtha production via hydrocrackers. This enables a very high ratio of *para*-xylene capacity relative to the overall crude distillation capacity, and light naphtha and hydrocracker bottoms (hydrowax) for steam crackers. While some of the ethylene can be consumed into MEG for polyester production, propylene does not figure in the polyester chain, and is mainly being monetized as a co-product via polypropylene.

Propylene developments in the Middle East are focussed in Saudi Arabia, and have a higher proportion of steam cracker propylene than has been seen in the past. Developments regarding APPC’s announced cracker project are unclear, but the large scale naphtha/NGL-based Amiral cracker was confirmed in 2022. Saudi Aramco has restated plans to develop a large-scale “crude oil to chemicals” complex in the Kingdom.

The surge in production of natural gas liquids (NGLs) in the United States triggered a switch to NGL feeds at U.S. crackers, dropping steam cracker propylene production, and causing a period of tightness in the propylene market, and high prices relative to ethylene. Massive investment in NGL export capacity from the U.S. has allowed the switch to occur in other regions, and regions such as Asia and Western Europe are now receiving large quantities of U.S. ethane and propane.

Fully-integrated coal-based MTO (CTO) economics became problematic since 2021 due to soaring coal prices. The massive capex per ton of olefins left many operators struggling to cover depreciation over 2020-2021 due to low polymer prices in 2020 followed by extremely high coal prices. High oil prices and relatively low international methanol prices however provided a window of high margins for the coastal MTO units in 2022.

Supply growth in the United States fell below previous expectations, although the new 750 000 tons per year plants built by both Enterprise and Dow provided a sizable increment in supply following protracted commissioning problems. Three more large plants are now in planning in the US Gulf. In Canada, the growing availability of propane generated new PDH/polypropylene projects by Inter Pipeline and the Pembina Pipeline/Kuwait PIC, although the latter is no longer regarded as firm.

China's surge in non-conventional propylene production is well underway, with 20 of the 24 planned PDH units, and 30 of the 32 methanol-based propylene plants operating by the end of 2023. The current capacity for propylene from methanol-based processes will rise from nine to ten million tons per year, while PDH capacity will rise from 11 to 15 million tons per year by 2027.

While some FCCs are likely to close as part of ongoing refinery rationalisation, others may react to constraints of gasoline demand by investing in modifications to achieve higher selectivity towards propylene.

There is a gap between the nameplate capacity for propylene production at some steam crackers, and their actual production rates relative to ethylene. Lower prices of liquefied petroleum gas (LPG) relative to naphtha have led flexible feed crackers in many regions to increase their usage of light feedstocks, thus dropping their propylene yield. Low operating rates in regions such as the United States therefore frequently reflect a tight market rather than a long one.

Propylene capacity is mainly split between North America, Western Europe and Asia Pacific. The share held by Middle Eastern producers is comparatively small relative to their presence in the ethylene market, due to the prevalence of gas-based steam crackers. Major investment in PDH, the move towards mixed-feed steam crackers and finally metathesis has increased propylene capacity in the Middle East, but the region's share of the global supply base is only nine percent compared with 18 percent for ethylene. Western Europe and Asia Pacific derive most propylene from steam cracking naphtha and other heavy feeds, while supply in the United States is based to a greater extent on refinery production.

There is around two million tons per year of metathesis capacity operating in South Korea, Japan and Taiwan, much of which is export-oriented, serving primarily the Chinese market. The economics of these plants are variable however, with some processing ethylene and butenes contained in refinery FCC off gases, and others operating at market price ethylene. The economics are challenged by the prevailing premium of ethylene prices over propylene prices. Some of these plants also included selective hydrogenation of butadiene of full crude C4 streams for which availability has increased greatly as a result of the new steam cracker starts.

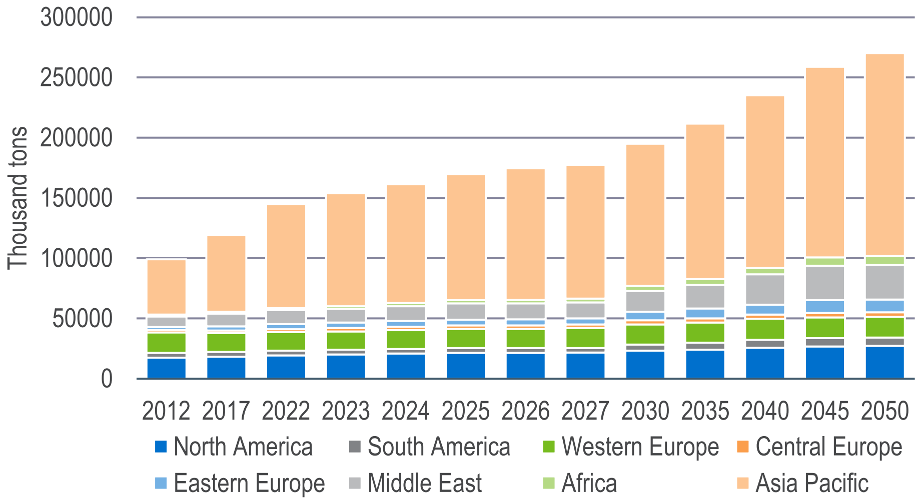
Propylene capacity in the Middle East grew rapidly until 2009 as a result of several PDH/polypropylene developments in Saudi Arabia and Oman, but the development of PDH capacity has since been much lower. The massive metathesis unit developed by Borouge in Abu Dhabi does not look likely to be repeated. Recent developments were of PDH and FCC propylene in Abu Dhabi, and steam cracker propylene in Saudi Arabia. The near term focus is on PDH plants in Iran and Saudi Arabia, while the outlook for steam cracker propylene in the region is much lower. Several refinery integrated cracker projects were considered, but the economics in the Middle East are challenging due to the much higher capital and fixed costs relative to Asia, and the glut of Asian liquids cracking capacity which has depressed the value of co-products.

Propylene capacity declined in Western Europe as a result of the closure of some small steam crackers, and a shift towards lighter cracker feedstocks. U.S. ethane imports have allowed some existing ethylene capacity to be restarted, as well as the planned INEOS cracker, and most of this supply will come at the cost of naphtha-based production.

PDH Polska is building a mid-size PDH/polypropylene complex in Central Europe, and propylene developments in Eastern Europe are also making progress, with the PDH project in Kazakhstan now advancing more quickly than the previously proposed steam cracker project.

Around Western Europe and the Mediterranean there are now two 750 000 tons per year plants planned in Belgium, and another in Turkey, which is backed by Sonatrach, the Algerian state oil company, which is a major propane exporter.

Figure 4.3 Global Propylene Capacity



4.3.1.3 Supply, Demand and Trade

Propylene operating rates dropped four percent in 2022 as capacity growth of over six million tons per year coincided with moribund demand. Operating rates declined further by three percent in 2023, primarily from the increase in production capacity

The very high crude oil and naphtha prices in late 2021 and much of 2022 encouraged maximum light feed at flexible crackers with access to deep sea imports, disadvantaging liquids cracking versus competitors within regions with advantaged NGL feedstock. These factors depressed the global ratio for steam cracker propylene production relative to ethylene. This was offset to some extent by the high value of the gasoline related coproducts from naphtha cracking such as benzene and butadiene raffinates.

FCC propylene supply was severely curtailed in regions such as Europe and the United States due to confinement measures in 2020, and the gap was filled mainly by increased naphtha cracking and growth in PDH capacity in Asia. The resurgent economy in 2023 however provided for strong gasoline values and higher FCC propylene availability. The outbreak of hostilities in Ukraine meant the loss of access to some Russia fuel exports, propelling gasoline valuations even higher in Europe and North America. While this supported naphtha cracking in Europe, it was not sufficient to outweigh the feedstock price differential in the United States, and heavier feed consumption declined.

PDH margins generally remained the highest in the olefins industry, but dropped to unusually low levels in China in 2023 from its highs in 2022. PDH margins have generally remained attractive, spurring several additional new projects, mostly in China. While the growth will be partly accommodated by consumption growth and FCC closures, it will contribute to a further decline in global operating rates towards 2025.

The market remains dynamic regarding both supply and consumption growth, but the broad base of propylene derivatives and the application areas they serve provides reliable demand growth for propylene. The rate at which the market will absorb the new capacity will depend on the condition of the global economy. There were already recessionary signals and high oil prices, along with increasingly alarming signals regarding debt in the property sector in China before the conflict in Ukraine. China’s economic recovery post-COVID-19 will be limited to some extent by weaker demand for Chinese manufacturing exports in the coming years.

Chinese propylene imports are mainly driven by non-integrated producers of derivatives other than polypropylene. Although some of these companies have back-integrated with propylene production of their own, Chinese imports dropped slightly to around 2.5 million tons in 2020 and increased to 2.9 million tons in 2023.

Figure 4.4 Global Propylene Supply, Demand and Trade

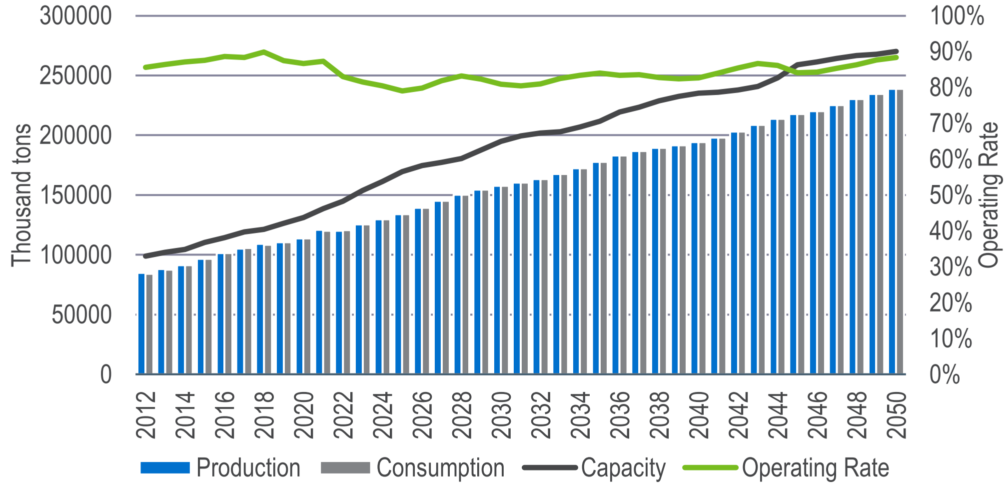


Table 4.3 Global Propylene Supply, Demand and Trade, e-2023

(thousand tons)

	Actual			Estimate	Forecast								Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Firm Capacity	99 002	119 136	144 956	154 285	161 811	169 463	173 070	176 491	176 491	176 518	176 491	176 492			
Speculative	1	-	(131)	(386)	(588)	210	1 548	18 523	35 242	58 600	82 342	93 686			
Total Capacity	99 003	119 136	144 825	153 899	161 224	169 672	174 619	195 014	211 733	235 118	258 833	270 178	4.1	3.4	1.6
Operating Rate	86%	88%	83%	82%	80%	79%	80%	81%	84%	83%	84%	88%			
Production	84 779	105 265	120 205	125 443	129 622	134 083	139 429	157 738	177 842	194 374	217 689	238 668	3.6	3.3	2.1
Net Export	818	(422)	(348)	-	-	-	-	-	-	-	-	-			
Consumption	83 962	105 687	120 553	125 443	129 622	134 083	139 429	157 738	177 842	194 374	217 689	238 668	3.7	3.3	2.1

4.3.2 Turkey

4.3.2.1 Consumption

Total propylene consumption in Turkey was 209 000 tons in 2022, a decrease of ten percent from 2021 due to deteriorating macroeconomic conditions. It increased to 223 000 tons in 2023. Polypropylene accounts for most of the propylene consumption, with around 56 percent of regional propylene demand going into this end use. The rest of demand was accounted for by acrylonitrile demand.

Petkim Petrokimya Holding is the only acrylonitrile producer in the country and the Middle East, with 105 000 tons per year of capacity in Aliaga, Turkey. The company's acrylonitrile production unit is fully integrated upstream with propylene and the output is easily placed locally due to the very large national consumer AKSA. Acrylonitrile production increased significantly in 2023 after Petkim resolved technical issues.,. The acrylonitrile production in the Middle East is therefore more for local demand than exports.

Consumption into polypropylene is expected to see strong growth over the forecast period.

Figure 4.5 Turkey Propylene Consumption by End-Use, e-2023

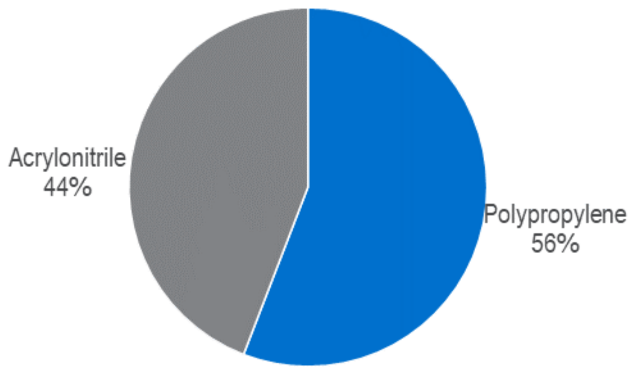


Table 4.4 Turkey Propylene Consumption by End-Use, e-2023
(thousand tons)

	Actual			Estimate	Forecast									Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2027	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Polypropylene	118	143	135	124	122	492	493	503	509	530	1 410	1 817	2 001	0.4	22.3	7.1
Acrylonitrile	107	96	75	98	99	97	96	99	93	100	98	103	112	(0.8)	(0.7)	0.9
Total	**226**	**239**	**209**	**223**	**221**	**589**	**589**	**601**	**603**	**630**	**1 508**	**1 920**	**2 113**	**(0.1)**	**15.3**	**6.5**

4.3.2.2 Supply

Currently Petkim's naphtha cracker in Aliaga is the only propylene plant in the country, producing 299 000 tons per year of propylene.

In 2018 Algerian national oil and gas producer Sonatrach and Turkish energy and construction company Ronesans Holdings signed a joint venture agreement to create Ceyhan Polipropilen Uretim, to build a 457 000 tons per year propane dehydrogenation and 450 000 tons per year polypropylene plant in Ceyhan, Turkey. Ground has been broken, and the project is scheduled to start operation in 2025, with an approximate investment of US$1.7 billion. The PDH unit will be the first to operate in Turkey. The plant will use Honeywell UOP's C3 Oleflex technology to triple Turkey's annual polypropylene production capacity, substituting 20 percent of Turkey's annual imports. Propane supply will be from Sonatrach in Algeria.

Additional Turkish proposals include a PDH plant in Mersin by CFS Petrochemical for 500 000 tons per year of propylene and a mooted methanol to olefins plant in Thrace from MetCap Petrochemicals that may see up to 600 000 tons per year of integrated polypropylene. These projects are at a less advanced stage but are understood to have political backing; however as of mid-2023, there has been no outward sign of progress in these plans.

4.3.2.3 Supply, Demand and Trade

Regional propylene capacity in the Middle East has largely been developed along with derivatives; and exports have generally been of the surplus monomer, particularly when margins on polypropylene were low. In Turkey, Petkim's naphtha cracker in Aliaga is the only propylene plant in the country, integrated downstream with its 105 000 tons per year acrylonitrile plant in Aliaga. The country is well balanced in supply and demand, with the Petkim propylene plant able to meet domestic demand, with a small surplus for export. Operating rate was 79 percent in 2022 and is expected to remain around 80 percent in the short-term forecast. Production is expected to increase in 2025 as the Ceyhan PDH unit comes online, and production is expected to grow further over the forecast period as new propylene capacity is speculated to meet increasing demand from polypropylene.

Figure 4.6 Turkey Propylene Supply, Demand and Trade

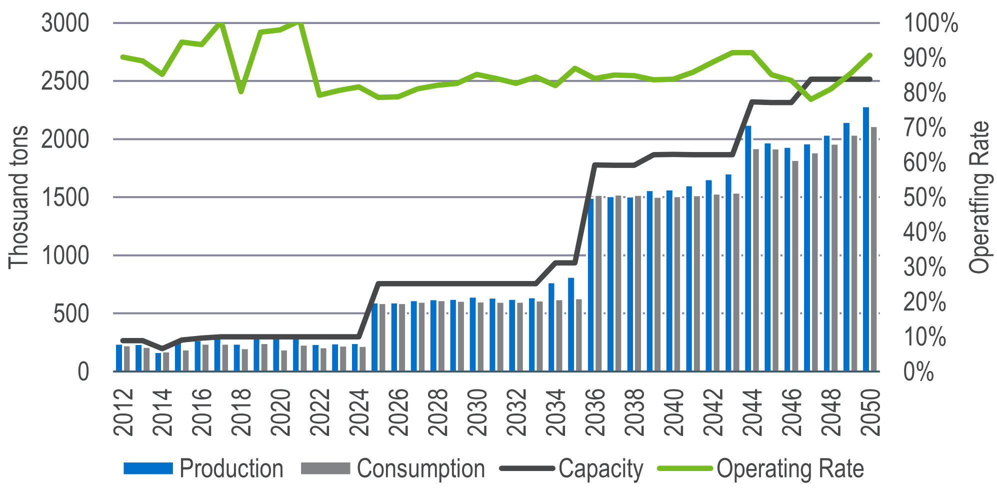


Table 4.5 Turkey Propylene Supply, Demand and Trade, e-2023

(thousand tons)

	Actual			Estimate	Forecast									Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2027	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Firm Capacity	265	299	299	299	299	756	756	756	756	756	756	756	756			
Speculative	-	-	-	-	-	-	-	-	-	180	1 112	1 559	1 759			
Total Capacity	265	299	299	299	299	756	756	756	756	936	1 868	2 315	2 515	1.1	14.2	6.2
Operating Rate	90%	100%	79%	81%	82%	79%	79%	81%	85%	87%	84%	85%	91%			
Production	239	300	237	241	244	594	596	613	644	814	1 566	1 971	2 282	0.1	15.1	6.5
Net Export	13	61	28	18	23	5	7	12	41	184	58	51	169			
Consumption	226	239	209	223	221	589	589	601	603	630	1 508	1 920	2 113	(0.1)	15.3	6.5

4.3.3 Western Europe

4.3.3.1 Consumption

Western European propylene consumption increased nearly 11 percent in 2023, one of the biggest annual increases on record. The increase was led by loosening of constraints on both demand and supply, although the increased imports suggest that the upstream impact was most severe. Highly contested derivative markets however left only limited opportunities to produce derivatives from imported propylene.

Western European polypropylene producers had achieved sustained volumes in recent years, despite increasing pressure from imports, partly by growing export sales; however, the driving force behind the sustained production changed in 2021, with domestic polypropylene demand increasing due to changes in behaviour and consumption associated with the pandemic. This led to a continuation of elevated demand for face masks and increase in consumption into food applications, with many people remaining at home and ordering more takeaway food. In contrast, net imports increased in 2023 , primarily from the Middle East as the Asian polymer markets lengthened, leading to Western Europe being a net importer of polypropylene.

Borealis and INEOS are developing new PDH projects in Belgium with the aim of underpinning the competitiveness of their polypropylene businesses; however, neither are planning additional polypropylene capacity. The competitive situation in polypropylene export markets will intensify due to new PDH/polypropylene complexes in planning in Poland and Turkey. INEOS has now prioritised plans for its ethane cracker and the PDH plant is now expected once the cracker has been completed, which is currently expected during 2026.

Economic activity in Western Europe rebounded in 2021 and returned to positive economic growth, with the impact of the pandemic being less severe compared to 2020. Western Europe has been increasingly impacted by the ongoing global manufacturing malaise which resulted in part from the ongoing United States-China trade war, which has particularly hit export driven manufacturing industries such as automotive, which had a poor 2019, a disastrous 2020, followed by an improved 2021 despite the ongoing shortage of semiconductors.

In recent years the polypropylene market has been strong, particularly compared to polyethylene, with pandemic-induced drivers and lower relative prices in part due to high volumes of feedstock propane available. These markets firmed in 2023 on strong derivative markets, in particular in health and hygiene, where face mask production and consumption increased, and demand was sustained for packaging applications with many people opting to remain at home and ordering food. Export markets remained strong into 2023, despite increased volumes of cheaper polypropylene being available in Western Europe from the Middle East and Asia (primarily Saudi Arabia, South Korea, as well as Russia). Lower Asia/Europe container freight rates in 2023 were among the factors eroding confidence in the polypropylene market in 2023.

Polypropylene trade remained remarkably stable considering the turmoil in global markets. West Europeans lost volume to major export markets such as Turkey which were more actively contested by Russia, but volumes to more destinations such as Central European countries were relatively stable. Polypropylene remains the dominant propylene application in Western Europe at approximately 60 percent of consumption, although to a lesser extent than the global average due to the diversity of other products produced in the region. As export opportunities have declined for some other propylene derivatives, polypropylene looks the most likely candidate for new derivative development, and the proportion of propylene demand into polypropylene looks likely to realign closer to the global average.

Competitive pressure and high propylene prices in Europe were the main causes of previous polypropylene plant closures in Europe, although the amount of capacity that actually closed was much less than initially proposed. The ability to build competitive PDH (based, if necessary, on imported propane) however puts the focus back on the polypropylene market itself, and the potential domestic and export opportunities for investments in Western Europe.

Western Europe is the second largest producer of propylene oxide globally after China, with ten world-scale plants, exporting propylene oxide and its derivatives to other neighbouring regions and Asia. These plants historically operated at consistently high rates, often above 90 percent of capacity, but weak demand and capacity grow in other region drove the utilisation rate down close to 80 percent in 2022. Propylene oxide accounted for 13 percent of Western Europe's propylene demand in 2022.

Cumene accounted for nine percent of Western Europe's total propylene consumption in 2022 and is the principal derivative of refinery grade propylene. CEPSA Quimica expanded its cumene plant to 500 000 tons per year in 2015. Regional consumption of propylene into cumene increased only very slightly in 2021 despite the resurgent global economy, due to the very heavy cumene/phenol capacity addition in Asia which has acted to suppress phenol operating rates in Europe. The last three years have however left this value chain fairly tight on production issues which has benefited European producers. There is scope for demand growth in this sector after INEOS commissioned at new 750 000 tons per year greenfield cumene production plant in Marl, Germany in late 2021.

The acrylonitrile sector in Western Europe had been stable in recent years before declining slightly in 2022. There is minimal scope for significant further propylene consumption growth into acrylonitrile in Western Europe as the existing facilities are already running close to the technical maximum achievable on the ageing capacity base. Consumption has been further hindered in recent years due to decreases in capacity, with INEOS decommissioning its acrylonitrile plant at Seal Sands in 2021. This led to a decrease in capacity of approximately 30 percent in Western Europe.

Acrylic acid is a small sector in Western Europe but remains active with some growth in recent years. IT was one of the few areas for positive growth in propylene demand in 2022. A new 100 000 tons per year plant in Antwerp, Belgium increased propylene production into this derivative in 2019. The plant is part of an integrated development by Nippon Shokubai which also includes the derivative superabsorbent polymers (SAP).

Figure 4.7 Western Europe Propylene Consumption by End-Use, e-2023

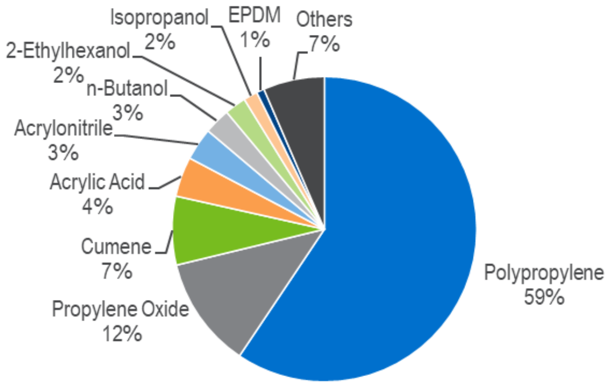


Table 4.6 Western Europe Propylene Consumption by End-Use, e-2023

(thousand tons)

	Actual			Estimate	Forecast									Average Annual Growth Rate, %		
	2012	**2017**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2030**	**2035**	**2040**	**2045**	**2050**	**2012-2023**	**2023-2030**	**2030-2050**
Polypropylene	8 039	8 629	7 159	8 672	8 137	8 450	8 615	8 919	9 258	9 752	9 922	10 063	10 707	0.7	0.9	0.7
Propylene Oxide	1 936	2 046	1 658	1 723	1 766	1 794	1 841	1 881	1 822	1 905	1 974	2 056	2 137	(1.1)	0.8	0.8
Cumene	1 122	1 033	1 163	1 062	1 065	1 085	1 102	1 127	1 155	1 226	1 215	1 266	1 337	(0.5)	1.2	0.7
Acrylic Acid	617	569	588	616	607	617	634	657	610	635	617	626	651	-	(0.1)	0.3
Acrylonitrile	807	882	542	501	498	495	498	504	541	580	653	690	777	(4.2)	1.1	1.8
n-Butanol	454	312	412	402	411	420	434	448	454	484	513	565	599	(1.1)	1.7	1.4
2-Ethylhexanol	337	335	375	333	338	363	372	386	380	418	413	427	443	(0.1)	1.9	0.8
Isopropanol	261	246	217	217	216	217	221	227	234	252	248	256	267	(1.7)	1.1	0.7
EPDM	154	145	99	120	123	128	133	128	115	132	133	145	164	(2.3)	(0.6)	1.8
iso-Butanol	-	-	-	-	-	-	-	-	2	2	6	10	11	-	-	8.5
Others	1 349	1 450	981	949	933	922	915	905	837	728	596	494	382	(3.1)	(1.8)	(3.8)
Total	**15 076**	**15 646**	**13 194**	**14 596**	**14 093**	**14 492**	**14 765**	**15 181**	**15 408**	**16 115**	**16 290**	**16 597**	**17 475**	**(0.3)**	**0.8**	**0.6**

4.3.3.2 Supply

Propylene supply in Western Europe dropped sharply in 2021 as the European olefins business was buffeted by the diverse impacts from the conflict in Ukraine. High energy prices undermined cracker economics from both a feedstock and utility cost standpoint. High gasoline values supported FCC throughput, but motivated maximum gasoline production in favour of optimising for propylene. Soaring gas prices undermined NGL extraction for those crackers consuming local NGLs. The drop in steam cracker propylene output was led both by poor production economics and weak demand. The high gasoline prices did however support naphtha cracking economics due to the high value of benzene and butadiene raffinates which are mostly used directly as gasoline blending components or in the production of gasoline-related products such as MTBE/ETBE.

Increasing ethylene imports and the new INEOS Project One 1.45 million tons per year ethane-based steam cracker suggests renewed pressure to close laggard steam crackers in Western Europe, which are primarily landlocked naphtha crackers. In the longer term, vehicle electrification will also contribute to the loss of some FCC propylene capacity. The two PDH plants planned by Borealis and INEOS will therefore be primarily for the replacement of propylene supply lost from existing sources.

The FCC propylene sector faced falling run rates over 2020, with the collapse in demand for transportation fuels resulting from coronavirus containment measures leading to some temporary refinery closures in early 2020. The pandemic continued to impact supplies of refinery propylene in 2023 as more widespread lockdowns were re-imposed, curtailing demand for transportation fuels and persistently weak refinery margins continued to curtail refinery operations. Some refineries opted to extend scheduled maintenance shutdowns. Refinery operations did however return to a more typical throughput as gasoline demand rebounded sharply from a position of distress in 2020. This resulted in 2023 FCC propylene output remaining weak compared to 2020 production.

Borealis has commenced construction of a new 750 000 tons per year PDH plant at its existing facility at Kallo in Antwerp, Belgium with ground-breaking occurring in September 2019. The plant will utilise Honeywell UOP's Oleflex technology, with propane supplied via the port of Antwerp. Maire Tecnimont is leading the EPC and commissioning. The project is expected to be commissioned in late 2024.

The INEOS 750 000 tons per year PDH plant is part of the Project One petrochemical investment but will now be built later than the steam cracker noting the more urgent requirement for ethylene. INEOS selected McDermott's Lummus CATOFIN technology, with contracts signed in 2019 with SK E&C for FEED Engineering and Wood Group in the PMC role.

Aside from ethane imports, Western European cracker operators are heavily reliant on imported propane and butane. Prices were high in early 2022 as the global market struggled to deal with the impact of the Russia-related gas price inflation during the winter season. Prices rapidly came off however and the ethylene cost from propane and butane cracking dropped significantly from quarter two. As the European LPG market has become more open, LPG has transitioned from a summer-only feedstock option to having an all year-round advantage over naphtha except in exceptional circumstances, such as extreme weather cost effects on LPG, or e.g. gasoline related effects on naphtha co-product values.

4.3.3.3 Supply, Demand and Trade

Propylene production in Western Europe increased by just under ten percent in 2023. This was slightly less than the drop in demand, which was supplemented by a slight increase in imports, mainly from the Middle East. The EU sanctions on Russia caused a loss import of fuels and refined products from Russia, but the extent to which EU refiners (and their FCC operations) could benefit from this was limited by the difficulty in reconfiguring rapidly to different crude oils. The market found its equilibrium by importing the quantity of propylene available at prices sufficiently attractive to avoid making losses on derivatives.

The outlook for the coming years appears to be one of cautious recovery as the global operating rate cycle bottoms out, and consumption in Western Europe recovers from the energy price shock. Demand in some sectors will depend on how quickly interest rates are lowered, or how quickly the market adapts to higher borrowing costs. After some signs of a potential recovery in quarter three 2022 however, market conditions took a decided turn for the worse in quarter four. An improvement in the market in 2023 was noted and was also linked to the conflict in Ukraine not escalating or resulting in e.g. extended trade sanctions with other countries.

The main source of propylene outside of Europe, the Middle East, although slightly less volume was imported from there in 2022, while imports from the United States jumped from zero in 2021 to almost 75 000 tons in 2022. Most of the propylene from the new FCC propylene unit in Lithuania continues to be imported into Western Europe, while this new supply will eventually be destined for derivative expansion by PKN Orlen in Poland. West European exports were again mainly to Central Europe, but dropped by a third in 2022.

The closure of the Porto Marghera cracker took out 265 000 tons per year of propylene capacity in 2022. The new INEOS cracker, and other market effects may contribute to other small cracker closures, particularly as Dow's previously announced plans for a 450 000 tons per year HDPE plant in Western Europe has now been withdrawn.

TotalEnergies has announced that its northern crackers are now capable of consuming up to 60 percent light feed. The feedslates include imported ethane and other NGLs, as well as refinery off-gases. New crackers in the United States, the new INEOS cracker in Belgium, and major contracts to export ethane from the U.S. Gulf to China are expected to erode the excess ethane supply in the United States. This makes further investment in ethane cracking in Europe potentially more risky and less attractive, and less investment is therefore forecast.

The new integrated PDH/polypropylene developments in Poland, Turkey, and possibly Algeria will exceed local consumption growth at least for a time, probably creating some push-back against West European polypropylene exports. This would in turn create some length in propylene supply, offsetting import requirements in the future.

Figure 4.8 Western Europe Propylene Supply, Demand and Trade

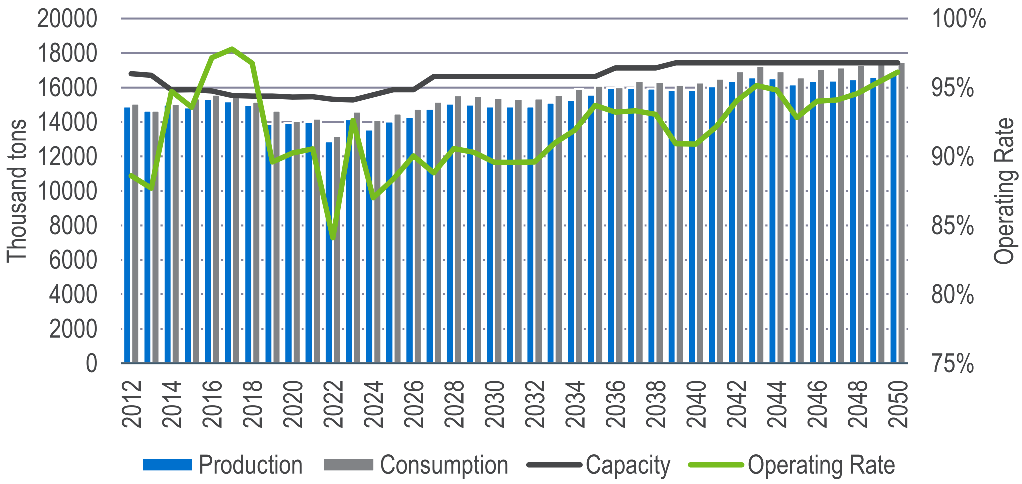


Table 4.7 Western Europe Propylene Supply, Demand and Trade, e-2023
(thousand tons)

	Actual			Estimate	Forecast									Average Annual Growth Rate, %		
	2012	**2017**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2030**	**2035**	**2040**	**2045**	**2050**	**2012-2023**	**2023-2030**	**2030-2050**
Firm Capacity	16 808	15 543	15 312	15 277	15 585	16 147	16 147	16 897	16 897	16 897	16 897	16 897	16 897			
Speculative	-	-	-	-	-	(270)	(270)	(270)	(270)	(270)	531	530	530			
Total Capacity	16 808	15 543	15 312	15 277	15 585	15 877	15 877	16 627	16 627	16 627	17 428	17 427	17 427	(0.9)	1.2	0.2
Operating Rate	89%	98%	84%	93%	87%	88%	90%	89%	90%	94%	91%	93%	96%			
Production	14 894	15 198	12 877	14 149	13 558	14 031	14 295	14 766	14 893	15 579	15 841	16 174	16 751	(0.5)	0.7	0.6
Net Export	(181)	(448)	(317)	(447)	(535)	(461)	(470)	(415)	(515)	(535)	(449)	(423)	(725)			
Consumption	15 076	15 646	13 194	14 596	14 093	14 492	14 765	15 181	15 408	16 115	16 290	16 597	17 475	(0.3)	0.8	0.6

4.3.4 Central Europe

4.3.4.1 Consumption

Propylene consumption increased by around 15 percent in Central Europe in 2023, as a result of the impact of the conflict in Ukraine, and continued domestic growth from its disappointing 2022 position. Central European refiners were among the worst affected by EU sanctions, but have continued to import Russian crude oil by pipeline where no alternative was available. The conflict had broader effects, driving inflation and other economic impacts such as increased imports of agricultural products overland from Ukraine due to the difficulties facing marine exports. On the whole, however the impact on the petrochemical industry was moderate, with one of the large groups producing more olefins in 2023 than in 2022.

The leading organisations PKN Orlen and MOL which also control Unipetrol and Slovnaft respectively, are both in the midst of expansion programs, with the MOL Group focussing particularly on propylene oxide, while others focus mainly on polypropylene.

MOL's planned 200 000 tons per year hydrogen peroxide process propylene oxide plant was not completed in 2022 as originally planned, but was instead to enter the market later in 2023. So far NexantECA have not seen confirmation that this plant has started up. Once the plant is online, it will eventually drive consumption of around 170 000 tons per year of propylene, backed up with propylene supply expansions. The propylene oxide and polyols plants are to be built at MOL's Tiszaujvaros cracker site in Hungary.

Polypropylene accounts for three quarters of propylene consumption in Central Europe and consumption decreased slightly in both of the last two years due to high levels of competition and weak demand, partly resulting from problems in the auto sector. HIP in Serbia and Zaklady Chemiczne Police (Grupa Azoty) in Poland both have plans for polypropylene units. The proposed HIP plant would have a capacity of 180 000 tons per year and would receive propylene from a new refinery propylene splitter. This project is thought unlikely to proceed until the privatisation of HIP; however, Serbia's NIS has entered into a partnership to complete the privatisation of HIP which might lead to the development of the project. PDH Polska, the venture of Grupa Azoty in Poland has a capacity of 400 000 tons per year of polypropylene and would consume most of the output from the PDH unit. This is expected to come online in 2024.

2-Ethylhexanol (2-EH) is the second largest propylene derivative in Central Europe but has a lower growth outlook than polypropylene. Zaklady Azotowe Kedzierzyn in Poland produces around 80 percent of the 2-EH in Central Europe, with the remaining production by Oltchim at Ramnicu-Valcea, Romania. These sites are both in deficit of propylene, and 2-EH production can therefore be curtailed when propylene supply is short and other derivatives offer better return.

Propylene oxide is usually Central Europe's third largest propylene derivative, and has overtaken 2-EH when MOL's new propylene oxide plant came online in 2023. The new plant will more than double the current capacity, which is currently split between Romania's Oltchim and Poland's Zaklady Chem Rokita.

Central Europe has only one acyclic acid manufacturing site, located at Sokolov in the Czech Republic, where high operating rates have been maintained since 2015, with exception to the operating rate in 2020 where they fell.

Figure 4.9 Central Europe Propylene Consumption by End-Use, e-2023

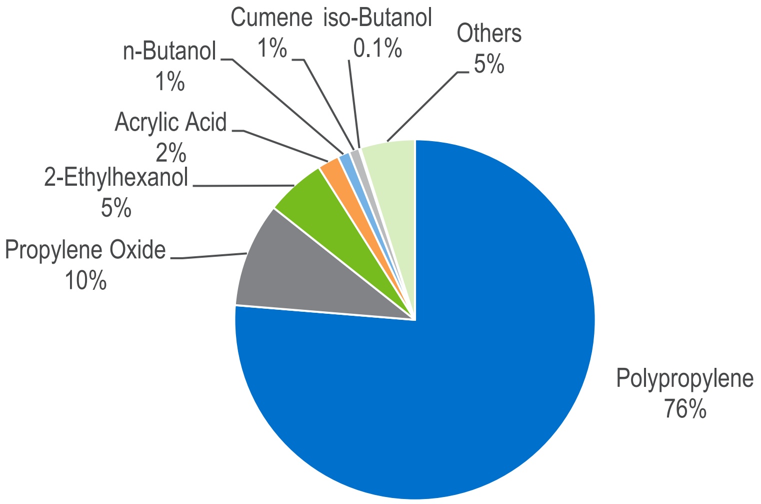


Table 4.8 Central Europe Propylene Consumption by End-Use, e-2023
(thousand tons)

	Actual			Estimate	Forecast									Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2027	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Polypropylene	1 157	1 339	1 275	1 463	1 704	1 688	1 730	1 763	1 962	2 040	2 032	1 984	1 976	2.2	4.3	-
Propylene Oxide	50	95	120	180	189	183	188	198	196	295	294	322	354	12.4	1.2	3.0
2-Ethylhexanol	102	122	95	103	106	111	116	123	126	136	126	141	153	0.1	2.9	1.0
Acrylic Acid	35	38	35	37	35	36	37	37	36	37	34	34	35	0.5	(0.5)	-
n-Butanol	40	36	20	21	21	22	23	26	24	27	27	28	30	(5.9)	2.4	1.0
Cumene	18	22	24	17	17	18	90	92	92	98	95	97	101	(0.1)	26.8	0.5
iso-Butanol	-	-	-	3	3	3	3	4	4	5	6	6	6	28.3	6.9	2.2
EPDM	-	-	-	-	-	-	-	-	-	-	27	29	42	-	-	-
Others	73	95	92	94	96	99	103	108	119	138	157	185	209	2.3	3.4	2.9
Total	**1 475**	**1 747**	**1 661**	**1 918**	**2 172**	**2 160**	**2 290**	**2 352**	**2 558**	**2 774**	**2 800**	**2 826**	**2 905**	**2.4**	**4.2**	**0.6**

4.3.4.2 Supply

Propylene supply in Central Europe is in a phase of rapid expansion, with producers pursuing all options to increase capacity.

PKN Orlen added a new metathesis plant at its Plock Petrochemical site in Poland at the end of 2019, which contributed significantly to production over 2020, as well as a PPF splitter unit capable of producing 80 000 tons of polymer grade propylene at its Mazeikiai refinery in Lithuania. PKN Orlen has since announced plans for a new 740 000 tons per year naphtha cracker at its Plock, Poland site, although the net capacity increase will be around half that amount as it will idle part of its older plant when the new unit enters service. KBR has been selected as the licensor and a consortium of Technicas Reunidas and Hyundai Engineering has been appointed to build the cracker. The project is scheduled for completion in the first quarter of 2024. PKN Orlen is also negotiating with KMG (formerly KazMunayGaz, a Kazakh state-owned company) for the purchase of Rompetrol, including its FCC propylene supply in Romania.

In 2016, MOL Petrochemicals announced a series of planned developments. These include an expansion to the cracker at Tiszaujvaros, Hungary, to give 355 000 tons per year of ethylene which was completed in 2022. The cracker expansion will also increase output of propylene and C_4s. At the same time MOL also completed the Slovnaft steam cracker intensification off-gas processing project in Bratislava, Slovakia, expanding capacity to 300 000 tons per year in 2022. McDermott was the EPC contractor, with an agreement with Lummus Technology, the licensor of the steam cracker unit.

While these developments will allow significant development of downstream activities for both producers, the PDH Polska development is more significant in terms of capacity and regional competitiveness. The project includes deepwater access to provide propane supply on large vessels, thus maximising feedstock competitiveness. The 400 000 tons per year PDH plant is be integrated with a new NOVOLEN technology polypropylene unit, of the same size. The plant has started limited production in November 2023 and is expected to ramp up gradually next year. PDH Polska is a subsidiary of Grupa Lotos and will therefore come into the PKN Orlen organization if the takeover progresses as expected.

Naphtha crackers account for just over half of Central Europe’s propylene supply, with mixed feed steam crackers and FCC offgas recovery each accounting for around a quarter of capacity. The region’s main production sites are located in the Czech Republic, Hungary and Poland, which produce propylene from both steam crackers and refineries. Additional steam crackers are located in Serbia and Slovakia, with the only other refinery based propylene production in Romania.

In Serbia, HIP plans a propylene splitter to derive propylene from an existing refinery FCC unit. This development may not however be possible before the company is privatized; however, Serbia's NIS (a joint asset of Gazprom Neft and the Serbian government), the Serbian government and HIP-Petrohemija, Serbia's largest producer of petrochemicals, have now signed an agreement on strategic partnership. The project is currently not viewed as firm.

Lukoil was currently considering expanding its propylene capacity at its site in Burgas, Bulgaria; however, no public facing update on an expansion has been communicated and it appears less likely given the recent capacity expansions in the region this appears less likely.

SABIC has recently entered into a (Memorandum of Understanding) MOU with Saudi Aramco and PKN Orlen to explore the potential of petrochemical expansion projects in Central and Eastern Europe. Under the terms of the agreement, the investment opportunities will include a new chemical production facility in Poland, the expansion of various existing assets and development of a new world-scale cracker. Upon the completion of the exploration phase the parties may enter into a separate project joint development agreement (JDA). This could see further projects come to the region in the coming years.

4.3.4.3 Supply, Demand and Trade

Propylene imports and exports decreased in 2022, but the increase in exports was much larger. This resulted primarily expanded capacity . Germany is the main supplier of exports to Central Europe, but had less material available due to cracker operation cuts.

Downstream developments are expected to keep pace with future supply in the long-term to maintain the region's import position, although trade will become smaller relative to the size of the market. The region has little by way of feedstock advantage, and the expected capacity developments are motivated by existing demand and downstream opportunities in sectors such as polypropylene and propylene oxide/polyols.

Central Europe's import requirements are largely due to Poland importing propylene for consumption into derivatives such as PP and propylene oxide . The Karpatneftekhim cracker in Ukraine does not have propylene derivatives, and exported most of its production into Central Europe until its closure close to the beginning of 2022. Poland is by far the largest importer. Imports have mostly been from Germany, Ukraine, and Russia. Slovakia imports around 100 000 tons per year, almost all as internal transfers from MOL in Hungary to Slovnaft.

Exports outside of Central Europe are driven by Serbia, Romania, and Poland and are primarily to Western Europe with large amounts exported to Germany. The vast majority of Serbian propylene goes to the export market. Romania is also a net exporter with the majority of shipments for OMV's Burghausen site in Germany for polypropylene production.

Figure 4.10 Central Europe Propylene Supply, Demand and Trade

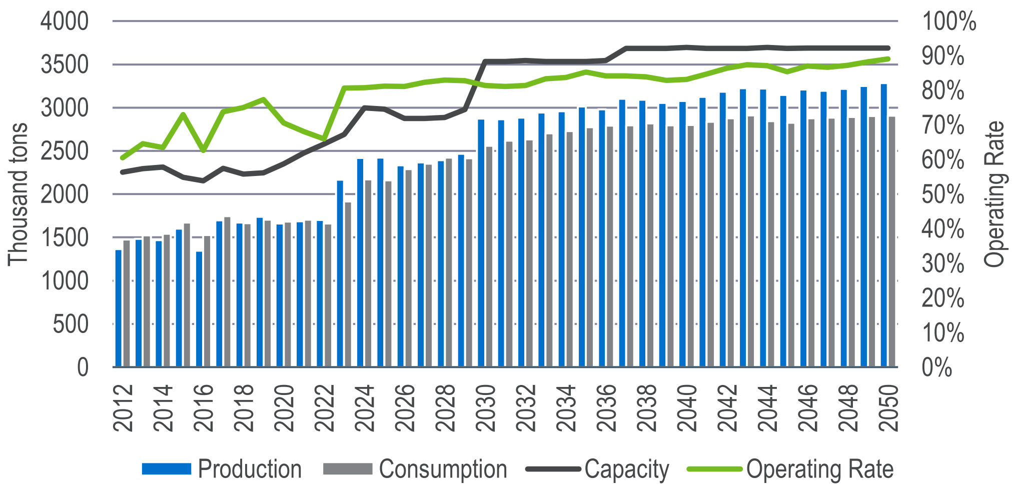


Table 4.9 Central Europe Propylene Supply, Demand and Trade, e-2023
(thousand tons)

	Actual			Estimate	Forecast									Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2027	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Firm Capacity	2 253	2 300	2 579	2 689	2 996	2 982	2 877	2 877	2 877	2 877	2 885	2 877	2 877			
Speculative	-	-	-	-	-	-	-	-	657	657	812	810	810			
Total Capacity	2 253	2 300	2 579	2 689	2 996	2 982	2 877	2 877	3 534	3 534	3 697	3 687	3 687	1.6	4.0	0.2
Operating Rate	61%	74%	66%	81%	81%	81%	81%	82%	81%	85%	83%	85%	89%			
Production	1 363	1 699	1 701	2 168	2 420	2 423	2 334	2 367	2 875	3 012	3 076	3 149	3 284	4.3	4.1	0.7
Net Export	(112)	(48)	40	251	248	263	45	16	317	238	276	322	378			
Consumption	1 475	1 747	1 661	1 918	2 172	2 160	2 290	2 352	2 558	2 774	2 800	2 826	2 905	2.4	4.2	0.6

4.3.5 Eastern Europe

4.3.5.1 Consumption

Russia

Propylene consumption decreased by approximately one percent in 2023 due to the impact of sanctions on polypropylene exports, and the intense competition in export markets for almost all derivatives. This came after a sharp increase in 2021 as global markets recovered from COVID-19 and the Basinet plant came onstream. The new Dioctyl terephthalate (DOTP) plant in Perm increased demand for propylene into 2-ethylhexanol but the start-up and ramp-up of the ZabSibNeftekhim cracker and polypropylene plant at the end of 2019 had the most impact on the propylene consumption.

The steam cracker projects at Nizhnekamsk and Amur which have been put in limbo by the withdrawal of their Western technology licensors both included propylene, and their delay erodes the potential for propylene consumption growth in the coming years.

The Russian economy has proved relatively robust in the face of sanctions, but the near-term outlook remains challenging, and it is hard to gauge how some demand areas will be affected due to restrictions on data.

68 percent of propylene consumption in 2023 was for polypropylene, similar to the global average. The propylene oxide market in Russia is relatively small, while acrylonitrile and the cumene/phenol chain account for a relatively high proportion of demand. While Russia has been a long-standing exporter of these products, both of these sectors have previously been hit hard by capacity expansion in China which was an important market for Russian exports.

The surge in polypropylene production in 2020 and 2021 has made the Russian propylene market more heavily dependent on polypropylene, and also drove a shift towards dependency on propylene derivative exports. Russia's polypropylene production has more than doubled since 2012 but near-term growth is in doubt due to the withdrawal of Western technology providers and contractors. Nizhnekamskneftekhim was building a new polypropylene plant with a capacity of 400 000 tons per year based on LyondellBasell's Spheripol technology, although LyondellBasell withdrew from Russia and closed both of its offices there in 2022. Another 400 000 tons per year plant based on LyondellBasell's technology was under construction at Amur.

Acrylonitrile (ACN) was for a long time the second largest application for propylene in Russia, but has declined more rapidly than cumene. The 150 000 tons per year plant owned by LUKoil-Saratovorgsintez is the only acrylonitrile plant in Russia. Russia mainly supplies export markets and a small volume of ACN is consumed locally for acrylonitrile butadiene styrene (ABS), nitrile rubber and acrylic fibre production.

Cumene accounted for around nine percent of propylene demand in 2023, increasing from the low of 2021 as demand levels as propylene become more reliant on polypropylene in Russia. All of Russia's cumene facilities are integrated with phenol production. There are currently no plans to expand cumene capacity, and therefore demand growth for propylene into cumene is expected to be limited to a recovery of operating rates at the existing plants when the global overcapacity for phenolics eases.

2-Ethylhexanol production made up four percent of the propylene market in 2023, also decreasing its market share as propylene consumption into polypropylene increased. The latest development was the start-up of SIBUR's 100 000 tons per year DOTP plant (which uses 2-ethylhexanol as a feedstock) in Perm in 2019.

Other Eastern Europe

Consumption of propylene in the CIS states excluding Russia is dominated to an even greater extent by polypropylene compared to Russia and is set to become more so as Kazakhstan Petrochemical Industries (KPI) new unit comes online. KPI's plans include a 500 000 tons per year PDH plant which will feed a polypropylene plant of the same size. This new plant is part of plans for a major new petrochemicals complex in Karabatan (Atyrau), Kazakhstan and the addition more than doubles regional capacity.

Other recent plants commissioned include SOCAR's 184 000 tons per year polypropylene plant in Sumgait, Azerbaijan in 2018, consuming local propylene from an existing plant and in Kiyanly, Turkmenistan a polypropylene plant downstream of a new gas separation and steam cracker development which was commissioned in 2018 with a capacity of 81 000 tons per year of polypropylene.

In addition to these two plants, demand is mainly from small polypropylene plants in Kazakhstan, Turkmenistan and Uzbekistan, and a similarly small acrylonitrile plant in Belarus. The polypropylene unit at Lisichansk refinery in Ukraine was idled in 2012 and remains closed despite efforts to restart production over 2017.

Propylene production in Ukraine is all for export as there are no significant derivatives plants in operation. Karpatneftekhim is reportedly developing a pilot plant for propylene oxide production and has plans for a 120 000 tons per year plant if the pilot is successful.

Figure 4.11 Eastern Europe Propylene Consumption by End Use, e-2023

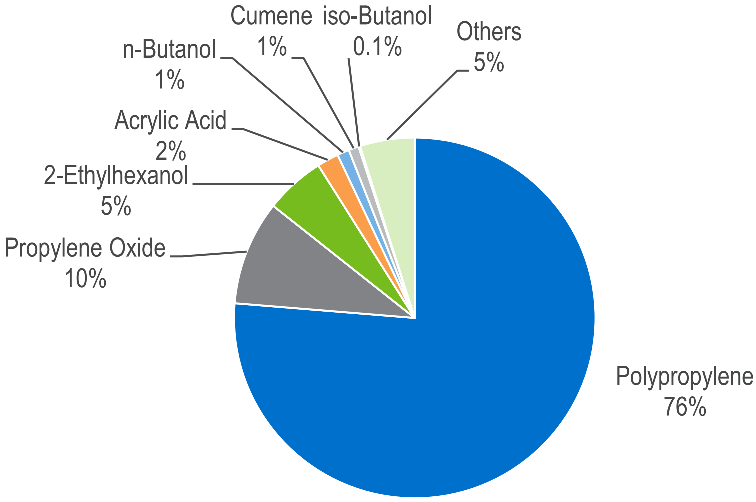


Table 4.10 Eastern Europe Propylene Consumption by End Use, e-2023

(thousand tons)

	Actual			Estimate	Forecast									Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2027	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Polypropylene	796	1 530	2 242	2 446	2 479	2 651	2 693	2 756	3 529	4 405	4 579	6 152	7 242	10.7	5.4	3.7
Acrylonitrile	269	277	139	242	239	239	290	296	334	356	349	367	394	(1.0)	4.7	0.8
Cumene	141	111	117	120	120	123	126	129	195	209	305	380	392	(1.5)	7.2	3.6
2-Ethylhexanol	83	75	88	94	97	102	108	113	107	115	104	107	111	1.2	1.8	0.2
n-Butanol	94	94	72	59	62	66	72	77	69	80	73	78	83	(4.1)	2.1	1.0
Acrylic Acid	57	52	56	59	59	59	61	63	97	105	93	92	212	0.2	7.4	4.0
Propylene Oxide	56	60	57	58	58	58	59	60	128	133	200	205	65	0.3	12.0	(3.3)
iso-Butanol	20	55	56	51	56	58	60	61	56	62	62	63	95	9.0	1.4	2.7
Isopropanol	28	30	33	27	27	27	28	28	30	32	32	33	34	(0.4)	1.5	0.7
EPDM	2	1	1	1	1	1	1	1	1	1	1	1	1	(8.5)	(1.0)	1.5
Others	140	140	150	145	144	149	155	161	176	207	239	284	322	0.3	2.8	3.1
Total	**1 685**	**2 424**	**3 011**	**3 302**	**3 343**	**3 534**	**3 651**	**3 747**	**4 721**	**5 705**	**6 036**	**7 760**	**8 951**	**6.3**	**5.2**	**3.3**

Table 4.11 Eastern Europe Propylene Consumption by Regions, e-2023

(thousand tons)

	Actual			Estimate	Forecast									Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2027	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Russia	1 444	2 133	2 495	2 480	2 535	2 728	2 835	2 913	3 467	4 395	4 733	5 231	5 294	5.0	4.9	2.1
Other Eastern Europe	241	291	516	821	808	806	817	834	1 253	1 310	1 303	2 528	3 658	11.8	6.2	5.5
Total	**1 685**	**2 424**	**3 011**	**3 302**	**3 343**	**3 534**	**3 651**	**3 747**	**4 721**	**5 705**	**6 036**	**7 760**	**8 951**	**6.3**	**5.2**	**3.3**

4.3.5.2 Supply

Russia

Supply in Russia for 2023 matched that of 2022. Capacity reportedly remained the same. SIBUR's 500 000 tons per year ZapSibNeftekhim plant in Tobolsk began commissioning, was fully operational in 2020, providing the first increase in Russian propylene capacity since the expansion of Lukoil's FCC propylene unit at Kstovo in 2016.

Steam cracking accounts for just over half of the region's propylene capacity, mainly consisting of relatively small naphtha and LPG-based steam crackers, many of which were built in the 1970s and 1980s.

SIBUR's new ZapSibNefthekhim complex in Tobolsk, Western Siberia, is the largest olefins complex in Russia and features a 1.5 million tons per year ethane/propane/butane cracker which can produce 500 000 tons per year of propylene. The complex was immediately the largest producer of olefins when it entered operation in late 2019. The US$9.5 billion complex is supplied with NGL feedstock from the Purovsky gas processing plant via a new 1 100km pipeline.

The ramp-up continued into 2021 and the combined ZapSibNeftekhim and SIBUR Tobolsk plants increased production from 732 800 tons in the first eleven months of 2020 to 1.092 million tons in the same period in 2021. There are plans for a 50 000 tons per year (eight percent) expansion of SIBUR's PDH unit at the site to a capacity of 561 000 tons per year, although this will likely be delayed or cancelled due to sanctions, as Honeywell announced in March 2022 that it was suspending its business in Russia. The regions expects to see an overall increase in capacity of 220 000 tons per year.

Nizhnekamskneftekhim (NKNH) has planned an expansion at its facilities in Nizhnekamsk with its EP-600 project as part of its investment strategy. The project centres around a 600 000 tons per year naphtha-fed steam cracker with capacity for around 300 000 tons per year of propylene, supported by Lummus technology, as well as polypropylene capacity. The cracker feedstock will largely be based on naphtha (80 percent) from the adjacent Tatneft refinery, with the remainder a mix of butane and propane. Construction of the US$3 billion project reportedly began in the third quarter of 2019 with commissioning expected in 2023, however there are no new updates. Linde was awarded the license, design, and construction contract in mid-2017 and construction of the naphtha cracker reportedly began early 2019. Linde has withdrawn from Russia following the invasion of Ukraine.

NKNH proposed expanding its complex at Nizhnekamsk further, after a technology licensing and engineering services contract was awarded to Lummus in 2021 to deliver for a series of new units to be built as part of an expansion for four new plants which includes two units — one outfitted with ethylene dimerization (DIMER) technology and the other with olefins conversion (OCT) technology—based on olefins metathesis chemistry that, combined, will produce 150 000 tons per year of polymer-grade propylene. Lummus Technology disclosed neither a value of the contract nor a timeframe for its work on the project but it is expected as early as 2024 with the construction of a 400 000 tons per year polypropylene plant at the site.

Other projects include:

- Stavrolen (a subsidiary of Lukoil) is upgrading its plant in Budennovsk with the construction of a second gas processing unit. The development program is expected to increase the ethylene and propylene capacity alongside a 40 000 tons per year increase in polypropylene production.
- The Power of Siberia pipeline system which is being developed to export gas to China includes significant midstream infrastructure including gas separation. A mixed feed (ethane and LPG) steam cracker is going ahead at Amur as part of the Amur Gas Chemical Complex, which will supply 400 000 tons of propylene. The site is adjacent to the Chinese border, and Sinopec is taking a 40 percent share in the development via a joint venture. Russian banks have agreed to provide around US$2.1 billion for the construction of the Amur Gas Chemical Complex, from the total cost estimates of US$9.1 billion. Thus far, the construction progress of the complex is on schedule, having achieved around 30 percent of the project by the end of 2021. Project completion is scheduled for 2024, but this is likely to be impacted by the Russian invasion of Ukraine. SIBUR reported that they expected a start of operations in 2025-2026 following sanctions, but it remains to be seen how this could be achieved.
- A mid-size steam cracker project is being evaluated in Irkutsk.
- In Western Russia, the Baltic Chemical Complex proposed to build nearly 3 million tons per year of ethylene capacity, but would not produce propylene.

Lukoil announced the start of a catalytic cracking complex construction project at the Perm refinery. The project is being implemented under an agreement with the Ministry of Energy of the Russian Federation. The feedstock capacity of the complex will be 1.8 million tons per year, and it will include a catalytic cracking unit. The complex is planned to be launched in 2026. There are no updates on the progress, however, as a privately owned entity, it seems Lukoil has managed to escape the EU sanctions, as of a 2023 report.

Rosneft has been considering olefins/polyolefins at Ufaorgsintez and has endorsed implementation of the pre-investment stages of the project. Selection of technological process licensors is in progress, but no further updates on the project have been announced.

Other Eastern Europe

The Kazakhstan Petrochemical Industries 500 000 tons per year was completed in mid-2022 but it is not clear if commercial operations are as yet underway. The expansion of SOCAR's existing naphtha cracker in Sumgait, Azerbaijan was also completed at the beginning of 2022.

Propylene capacity in the 'Other Eastern Europe' region was otherwise stable since it increased in 2020 with the new splitter unit at the Mazeikiai refinery in Lithuania. This was the first addition since the newly constructed Kiyanly plant in Turkmanistan began start-up in late 2018. Production from this plant was relatively slow to reach capacity.

In 2019 PKN Orlen commissioned a PPF splitter unit capable of producing 80 000 tons per year of polymer grade propylene at its Mazeikiai refinery in Lithuania. The output is nominally for the group's polypropylene plants in Central Europe, but most supply to date has been exported to Western Europe.

In 2018, Turkmengas completed its construction of an olefins and polyolefin unit in Kiyanly, with the plant officially opening in October 2018. The site's propylene capacity is understood to be 81 000 tons per year which supplies an integrated polypropylene plant. Turkmenistan also produces propylene from a 90 000 tons per year FCC unit, which supplies a polypropylene plant.

Capacity addition in recent years in 'Other Eastern Europe' include the former Lukoil subsidiary Karpatneftekhim at Kalush in Ukraine restarted steam cracker operations in 2017 under new ownership. All of the propylene is exported due to the lack of propylene derivatives at the site. The site was previously owned by LUKoil and remains dependent on Russian feedstock. The hostilities in 2022 rapidly led to the plant again being taken offline.

In Azerbaijan, Technip Energies completed an EPC for the revamp of the EP-300 steam cracker at SOCAR's Sumgait production plant. Scope also included construction of cracker furnaces licensed by Technip Energies, as well as installation of a refinery dry gas treatment unit. The capacity enhancement is equivalent to around 40 percent of prior capacity, and its implementation has increased the design capacity of the steam generator complex at the plant from 32 to 65 MW, fully allowing it to be self-sufficient in electricity supply.

In addition, SOCAR had considered a new gas processing plant and petrochemical complex on the outskirts of Baku, named as the OGPC project but this was put on hold in 2016. This OGPC project was then superseded by the GPC project, a 610 000 tons per year cracker which would consume ethane, propane and butane extracted from gas exported along the Shah Deniz pipeline to Turkey. The gas is sufficiently rich to cause pipeline slugging issues in the winter months, and SOCAR is incentivized to invest as a result of this opportunity to obtain fuel-price NGLs from the export gas. Engineering contracts were awarded to Technip in 2019, with plans to have the plant available as early as 2024. A lack of funding has however put this project on hold indefinitely, with no new announcements since 2019.

Kazakhstan Petrochemical Industries (KPI) is pursuing ambitious plans for a major new petrochemicals complex, specifically an integrated gas-to-chemicals complex in National Industrial Petrochemical Technopark in Kazakhstan's western Atyrau region. China National Chemical Engineering Co (CNCEC) joined the project in December 2015, replacing Sinopec Engineering Group as the EPC contractor. A steam cracker is included in plans for later phases, while the Phase 1 PDH unit is based on Lummus Technology LLC's proprietary CATOFIN process. The plant will convert up to 629 000 tons per year of propane from Tengiz oil field, into propylene feedstock for the complex's associated polypropylene plant. Phase two of the IGCC, which will be Kazakhstan's first integrated petrochemical complex, is proposed to produce 1.25 million tons per year of polyethylene.

In Uzbekistan, Uzbekneftegas has signed financial cooperation agreements relating to €1.1 billion to finance the expansion at Shurtan, with an increase in the design capacity of polyethylene production from 125 000 to 405 000 tons per year and the organization of a new polypropylene production with a capacity of up to 100 000 tons per year due to the deep processing of synthetic naphtha in the amount of 430 000 tons.

Polymir in Belarus runs two small crackers in Novopolotsk, with propylene capacity of 98 000 tons per year to supply its polypropylene plant. In recent years Polymir has worked on plans to expand capacity of both the ethylene and derivatives plants, but the investment has not been approved and discussions appears to be pushed back due to the current financial situation.

With cracker plans in Kazakhstan indefinitely postponed, the next expected olefins development will be in Uzbekistan. Uzbekneftegas currently operates a small gas-based cracker at Shurtan but plans to triple capacity to around 450 000 tons per year of ethylene, using synthetic naphtha from an adjacent GTL plant as feedstock. UzGTL started operation in 2022 and is yet to achieve full production. The GTL operator UzGTL is also a backer for the Shurtan expansion with the plant is expected to bring around 100 000 tons per year by 2024.

4.3.5.3 Supply, Demand and Trade

Russia

The Russian propylene market remained contracted in 2023, following growth in 2020 and 2021 which was driven by the integrated propylene/polypropylene at ZapSibNeftekhim.

The Lukoil and Angarsk Polymer Plant propylene sites at Kstovo and Angarsk respectively are the major exporters, both of which exported greater volumes in 2021 as higher production in Russia forced greater volumes into the export market. The volume was lost equally rapidly in 2022 however as EU buyers shied away from business with Russian companies. By late-2022 only China and Serbia were purchasing propylene from Russia. While there were no sanctions affecting trade with China, market conditions were extremely challenging due to massive capacity additions in China. While sales to China did increase, the volume was much lower than that lost in sales into the EU.

The shift towards oversupply and exports of polypropylene will continue to create competitive pressure, especially given the large-scale developments of propylene/polypropylene capacity in other CIS states which are currently export markets for Russian producers. These developments are likely to be hindered by the invasion of Ukraine by Russian forces, with a wave of sanctions imposed on Russian companies worldwide.

Other Eastern Europe

The remoteness of propylene supply sources in Turkmenistan and Kazakhstan makes propylene trade unlikely, and the imports into Belarus have dried up, while exports from Ukraine accounted for most of the region's propylene trade. Exports from Ukraine had been maintained due to the Karpatneftekhim heavy liquids cracker and most of the exports being shipped to Poland in recent years. Karpatneftekhim was taken offline shortly after the outbreak of hostilities, and it remains unclear when it can restart.

Longer term plans for a new propylene oxide plant there may eventually remove the surplus of propylene in Ukraine, although the entire site may not be viable without Russian feedstock.

Operating rates at SOCAR's Sumgait, Azerbaijan steam cracker were low for several years, but have increased as a result of recent investment. Elsewhere, PKN Lithuania increased its production close to capacity in quarter four 2021 and there have been continued lower oil imports to the refinery at the site of Polymir's Novopolotsk naphtha crackers in Belarus.

Figure 4.12 Eastern Europe Propylene Supply, Demand and Trade

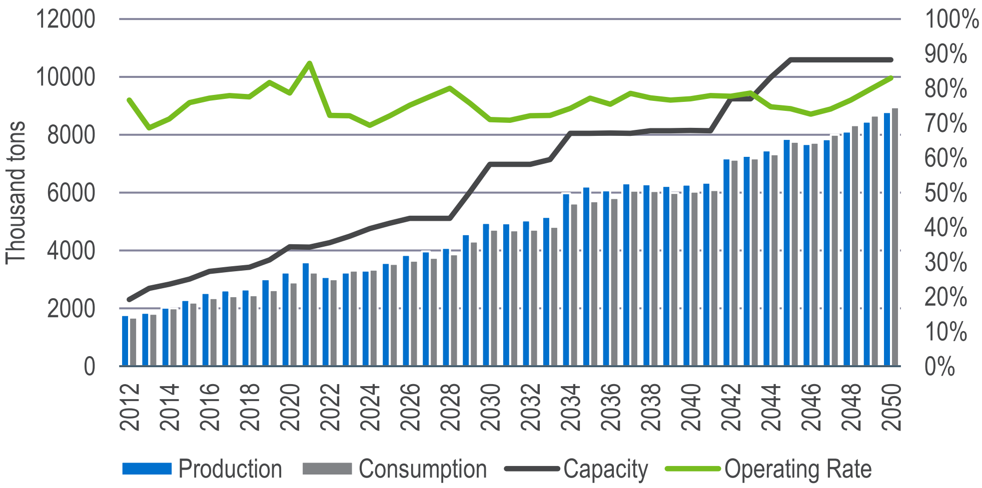


Table 4.12 Eastern Europe Propylene Supply, Demand and Trade, e-2023
(thousand tons)

	Actual			Estimate	Forecast									Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2027	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Firm Capacity	2 309	3 359	4 276	4 498	4 762	4 952	5 110	5 110	5 810	5 810	5 814	5 810	5 809			
Speculative	-	-	-	-	-	-	-	-	1 167	2 238	2 337	4 777	4 777			
Total Capacity	2 309	3 359	4 276	4 498	4 762	4 952	5 110	5 110	6 976	8 048	8 151	10 586	10 586	6.2	6.5	2.1
Operating Rate	77%	78%	72%	72%	69%	72%	75%	78%	71%	77%	77%	74%	83%			
Production	1 771	2 617	3 090	3 245	3 306	3 574	3 843	3 968	4 957	6 217	6 281	7 854	8 787	5.7	6.2	2.9
Net Export	86	194	79	(57)	(37)	40	192	221	236	512	245	95	(164)			
Consumption	1 685	2 424	3 011	3 302	3 343	3 534	3 651	3 747	4 721	5 705	6 036	7 760	8 951	6.3	5.2	3.3

4.3.6 North Africa

4.3.6.1 Consumption

North African propylene demand increased by 18 percent in 2023. The production of polypropylene accounts for all of propylene demand in the region, with all polypropylene plants located in Egypt.

The political and economic climate in Egypt remains challenging but has improved greatly since 2021 as the economy recovered from the impact of the COVID-19 pandemic. Operating rates at propylene consumers in Egypt increased in 2023 Polypropylene producers in Egypt have lost more than half of their total export volume in recent years, and also endured a near doubling of imports in 2022.

Africa’s large population, low labour costs and potential for high long term economic growth will drive derivative demand growth and enable new propylene derivative projects, with acrylic acid capacity expected to come online later in the forecast period in North Africa. Egyptian demand has the greatest potential for growth in the continent, with some currently underutilised polypropylene capacity, and major new cracker projects proposed.

Figure 4.13 North African Propylene Consumption by End-Use, e-2023

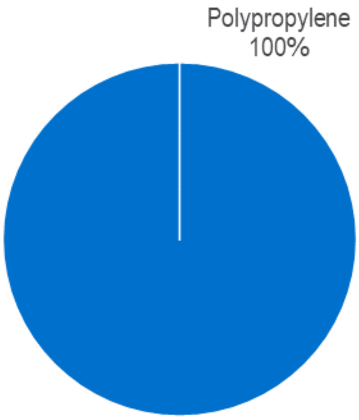


Table 4.13 North African Propylene Consumption by End-Use, e-2023
(thousand tons)

	Actual			Estimate	Forecast									Average Annual Growth Rate, %		
	2012	**2017**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2030**	**2035**	**2040**	**2045**	**2050**	**2012-2023**	**2023-2030**	**2030-2050**
Polypropylene	334	433	361	429	420	419	425	433	834	1 497	1 491	1 463	1 455	2.3	10.0	2.8
Acrylic Acid	-	-	-	-	-	-	-	-	-	23	21	21	22	-	-	-
Total	**334**	**433**	**361**	**429**	**420**	**419**	**425**	**433**	**834**	**1 520**	**1 512**	**1 484**	**1 477**	**2.3**	**10.0**	**2.9**

Table 4.14 North African Propylene Consumption by Country, e-2023
(thousand tons)

	Actual			Estimate	Forecast									Average Annual Growth Rate, %		
	2012	**2017**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2030**	**2035**	**2040**	**2045**	**2050**	**2012-2023**	**2023-2030**	**2030-2050**
Algeria	-	-	-	-	-	-	-	-	395	413	411	403	401	-	-	0.1
Egypt	334	433	361	429	420	419	425	433	439	1 107	1 101	1 080	1 076	**2.3**	0.3	4.6
Total	**334**	**433**	**361**	**429**	**420**	**419**	**425**	**433**	**834**	**1 520**	**1 512**	**1 484**	**1 477**	**2.3**	**10.0**	**2.9**

4.3.6.2 Supply

Production of propylene increased in Egypt in 2023as EEPC sought to maximise its utilisation, particularly for its polypropylene production as it imported propylene for the first time in 2021, and the company imports propylene from Saudi Arabia, Europe, and South-East Asia. Domestic production increased to over 322 000 tons per year in 2023. Sidpec also increased its operating rates at its cracker during 2023 to satisfy the increased downstream demand on the back of strong polymer markets. As Egypt has become increasingly reliant on imported propane, its ability to compete in both the local and export polypropylene markets have weakened.

Additional PDH capacity is considered likely in Egypt, with two projects currently in development:

- Egyptian producer Sidpec and Egyptian state-backed chemical holding company ECHEM are planning to develop a PDH plant in Alexandria with up to 500 000 tons per year propylene and integrated polypropylene. Feedstock and land for this project are understood to have been obtained, but final investment decision has not yet been made and EPC selection is ongoing following the completion of the pre-feed with Jacobs engineering. Process automation improvements have been implemented at the current Sidpec complex to upgrade production capabilities with the intension to support collective production at the site following the start-up of Sidpec's proposed expansion. Tentative plant start up would be 2024 to 2025.
- The Egyptian Propylene and Polypropylene Company (EPPC) currently has a 350 000 tons per year PDH unit in Port Said. In 2018 it was reported that the company plans to invest €890 million to expand the capacity of this plant. This seems less likely with no further update to the proposed investment.

ECHEM's Red Sea Refining and Petrochemical Co. (RSNRPC) is moving forward with plans to build a grassroots integrated refining and petrochemicals in Ain Sokhna, Suez Province, Egypt. The US$11.5 billion complex will include a world-scale refinery integrated steam cracker and derivatives complex, including polyethylene and polypropylene to produce 2.8 million tons of petrochemical products per year. The plan is part of Egypt's petroleum sector modernisation program, and the complex is expected to process 4 million tons per year of crude oil. Currently the team of ENPPI, Petrojet and Bechtel are working on the FEED for the petrochemical complex, and an in-principal agreement has been signed with Saudi Aramco to secure crude oil feedstock for the project. The complex is scheduled to be completed by year end 2024, according to the Ministry of Petroleum & Mineral Resources. There has also been discussion over a "GTO" gas-to-olefins complex that would include large-scale methanol and MTO in Egypt.

Carbon Holdings has proposed the Tahrir Petrochemicals project at Ain Sokhna on the Red Sea. The cracker was to produce 1.5 million tons per year of ethylene and around 700 000 tons per year of propylene. Having missed numerous financing deadlines over the past years, the project is no longer considered as active. The new ECHEM project effectively duplicates the plans and there might not be a market opportunity for multiple refining and petrochemical complexes on the Egyptian Red Sea coast.

Elsewhere in North Africa there have been discussions about a cracker complex in Algeria. Sonatrach also signed an agreement with France's TotalEnergies in 2016 to discuss the feasibility for a world-scale petrochemical complex in Arzew, Algeria. Despite limited progress reports, in mid-2022, TotalEnergies claimed to still be moving forward with the project. It reportedly includes the development of a PDH and a polypropylene production plant with a capacity of 550 000 tons per year. According to TotalEnergies, the technical design would have been completed in February 2022.

The Ras Lanuf naphtha cracker initially shut in 2011, after regional conflict, causing a shortage of feedstock for derivatives plants across the region. There were numerous announcements of attempted restarts, and the downstream RASCO polyethylene plant was brought back into use in the second half of 2019 using imported ethylene. The cracker incinerator and waste gas burner were tested in 2020 and testing continued in 2021. In January 2022 RASCO started operational testing of the cracker and by the end of the month final testing had started. In late 2022, the National Oil Corporation (NOC), authorized the reactivation of the ethylene plant, in the Gulf of Sirte, after being offline for over ten years.

4.3.6.3 Supply, Demand and Trade

There was a significant expansion in the Egyptian propylene market in 2023. Egypt's imports decreased but were lower than e.g. in 2020. African propylene trade is normally limited to Egypt which historically had a small structural import requirement which was reduced by the arrival of the ETHYDCO cracker. Much was met by increased domestic production.

EPPC's 350 000 tons per year polypropylene facility has generally imported propylene from Saudi Arabia, Europe, and South-East Asia.

Propylene demand growth in the region is expected to outpace production growth over the forecast as new polypropylene capacity comes online in the region. Production of propylene will increase significantly over the next ten years as new capacity is expected to come online in the region.

Figure 4.14 North Africa Propylene Supply, Demand and Trade

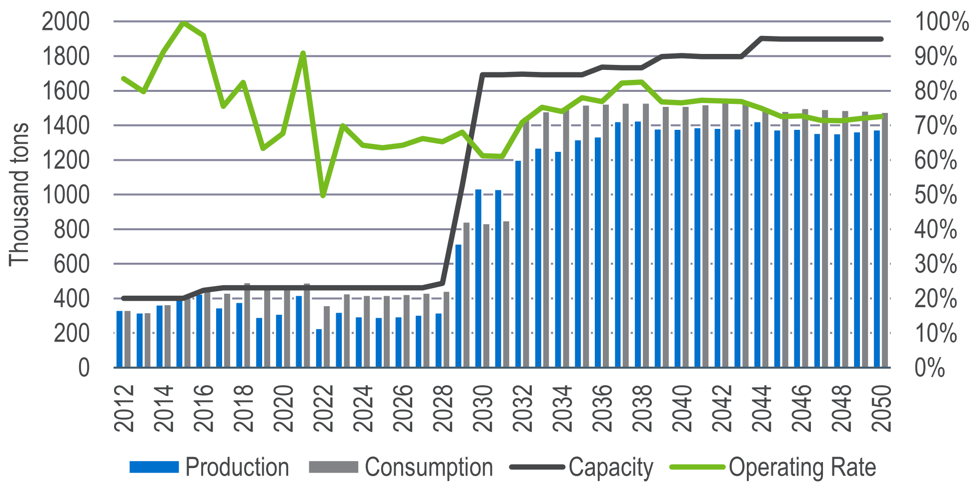


Table 4.15 North Africa Propylene Supply, Demand and Trade, e-2023
(thousand tons)

	Actual			Estimate	Forecast									Average Annual Growth Rate, %		
	2012	**2017**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2030**	**2035**	**2040**	**2045**	**2050**	**2012-2023**	**2023-2030**	**2030-2050**
Firm Capacity	400	461	461	461	461	461	461	461	461	461	461	461	461			
Speculative	-	-	-	-	-	-	-	-	1,231	1,231	1,341	1,437	1,437			
Total Capacity	400	461	461	461	461	461	461	461	1,692	1,692	1,802	1,898	1,898	1.3	20.4	0.6
Operating Rate	84%	75%	50%	70%	64%	64%	64%	66%	61%	78%	77%	73%	73%			
Production	334	348	229	322	296	293	296	305	1,036	1,320	1,379	1,377	1,376	(0.3)	18.2	1.4
Net Export	-	(85)	(132)	(107)	(124)	(126)	(129)	(128)	202	(200)	(133)	(106)	(101)			
Consumption	334	433	361	429	420	419	425	433	834	1,520	1,512	1,483	1,477	2.3	10.0	2.9

4.3.7 Middle East (excluding Turkey)

4.3.7.1 Consumption

Propylene consumption in the Middle East (excluding Turkey) decreased by approximately six percent in 2023 compared to 2022. There were no capacity expansions on other derivatives and consumption changes in 2023 were therefore solely an effect of the linking to polypropylene production. Production of most propylene derivatives in the Middle East is heavily dependent on exports, and has therefore come under pressure from massive capacity development of propylene and derivatives in East Asia. China had accrued large imports requirements for polypropylene and other major derivatives such as oxo-alcohols and phenol, providing a strong investment case for local capacity to displace imports. China's net imports of most derivatives have dropped sharply over the past two years, and it has in some cases started exporting substantial amounts. While still a net importer, China exported around 1.3 million tons of polypropylene in 2022, further increasing competitive pressure in alternative markets for Middle Eastern polypropylene exports.

The dominant polypropylene sector was essentially flat since 2016 until the 300 000 tons per year polypropylene plant at LPIC's cracker complex in Sohar, Oman started-up in 2021. Despite this there was a fall in propylene consumption into polypropylene of almost six percent during 2023. Almost all of China's export volume was homopolymer, which is the main focus of Middle Eastern exports, and this created a very significant increase in competitive pressure in export markets.

Growth between 2016 and 2018 came from new smaller derivatives plants in Saudi Arabia including Petro-Rabigh's new cumene plant and the 330 000 tons per year Sadara Petrochemicals propylene oxide unit. In 2019 production was steadier, with a marginal increase in the principal demand segment of polypropylene and a larger increase in small volume acrylonitrile and EPDM demand. In 2020 consumption declined with the pandemic drastically impacting supply chains.

Capacity growth in Saudi Arabia is set for a revival as a result of investments by Advanced Petrochemicals through its subsidiary Advanced Global Investment (AGIC). The company is a long-standing operator of a PDH/polypropylene complex and has now received a feedstock allocation for both a larger new PDH unit and a steam cracker, both of which will supply large-scale polypropylene plants. The PDH unit will also supply a new isopropanol plant. INEOS also plans its first major investment in the Middle East in Saudi Arabia, which will include a 425 000 tons per year acrylonitrile plant downstream of the planned Amiral steam cracker. While the partners in the Amiral steam cracker reached FID in 2022, INEOS has yet to do so regarding the acrylonitrile plant.

The region is a major net exporter of polypropylene, and its propylene consumption is thus driven by derivative capacity growth and the health of the derivative export markets. Saudi Arabia was the leading consumer of propylene in 2023, with a 59 percent market share. The 'Other Middle East' region, mainly represented by United Arab Emirates and Oman, accounted for a 25 percent market share, increasing by approximately three percent from 2022. The change in consumption and regional growth has been a result of new capacity in 'Other Middle East' from the United Arab Emirates, where additional new propylene capacity came onstream again in 2022, and Oman where capacity came online during 2021.

Polypropylene accounts for just under 90 percent of demand, with smaller other industries such as oxo-alcohols, propylene oxide, cumene, acrylonitrile and acrylic acid all comparatively small and mostly restricted to Saudi Arabia. The outlook for demand growth is limited by supply, but the prospects are brighter than they have been for many years, largely as a result of new PDH projects in Iran and Saudi Arabia.

Iran has been a relatively small consumer of propylene over the last decade, particularly in comparison to ethylene consumption. Feedstock in Iran is heavily based on ethane, so propylene output from crackers is low compared to regions that crack heavier feeds. There is currently no refinery FCC propylene in Iran and

PDH capacity is only in the development stage. Therefore, steam cracking and imports remain the only sources of propylene. The lack of domestic supply has restricted propylene demand growth to date with only small supply increases during 2021; however, PDH projects have the potential to significantly increase propylene availability and these projects will drive domestic consumption growth in the mid-term.

As propylene was often short in the Middle East, major developments in consumption required new sources of supply. The market was driven by upstream investments in refinery FCC, metathesis and propane dehydrogenation capacity in recent years, and most major developments have been integrated with polypropylene. The latest major polypropylene development by Borouge in the United Arab Emirates, is based on propylene which was previously exported. The 500 000 tons per year Takreer FCC propylene plant came online in 2018 without polypropylene. Borouge's new polypropylene plant (PP5) brings a further 500 000 tons per year of polypropylene capacity to the region, absorbing most of the surplus propylene in the UAE.

Sadara Chemical's 400 000 tons per year propylene oxide plant in Al Jubail, Saudi Arabia approximately tripled propylene demand into this application when the plant started in 2017. The only other producer in the Middle East is Petro Rabigh, with 200 000 tons per year of capacity at its facility in Rabigh, Saudi Arabia. Sadara Chemical has signed an agreement to supply ethylene oxide and propylene oxide to SADIG-ILCO's future chemical manufacturing facility in Jubail's PlasChem Park. This involved the construction of a pipeline between the facilities and mechanical completion of the pipeline and distribution centre for PlasChem Park has been completed.

Companies in Iran are considering new acrylonitrile capacity over the next few years. Arg Petrochemical is developing plans for a 100 000 tons per year acrylonitrile plant to be located at Mahshahr, Bandar Imam although this may suffer from the slow progress or postponement of the Salman-e-Farsi PDH unit. These plans were originally approved in 1996 and have not progressed.

Cumene accounted for two percent of propylene demand in 2021, having recently experienced an uptick in demand in recent years with the ramp-up of Petro Rabigh's 375 000 tons per year cumene facility which started-up in mid-2017. Saudi Kayan Petrochemical in Al Jubail owns the region's only other cumene unit, with a capacity of 290 000 tons per year integrated with a phenol facility.

Acrylic acid accounts for a small proportion of propylene demand, with the first acrylic acid capacity entering commercial operations in 2014. The plant belongs to Saudi Acrylic Polymer and produces glacial acrylic acid and butyl acrylate at the same site. In Iran, Ofogh Polymer Company is developing plans for an 80 000 tons per year acrylic acid plant to be located at Mahshahr, Bandar Imam; however, no outward updates have been provided for this project. This will be to support new acrylate esters and super absorbent polymer capacity. Although other acrylic acid projects have been floated, such as those by Petro Rabigh and Dammam 7 Petrochemical, none have progressed and no further acrylic acid plants are planned.

There is currently no market for propylene in either Qatar or Iraq, but both countries are expected to develop propylene supply and derivatives in the longer term.

Figure 4.15 Middle East (excluding Turkey) Propylene Consumption by End-Use, e-2023

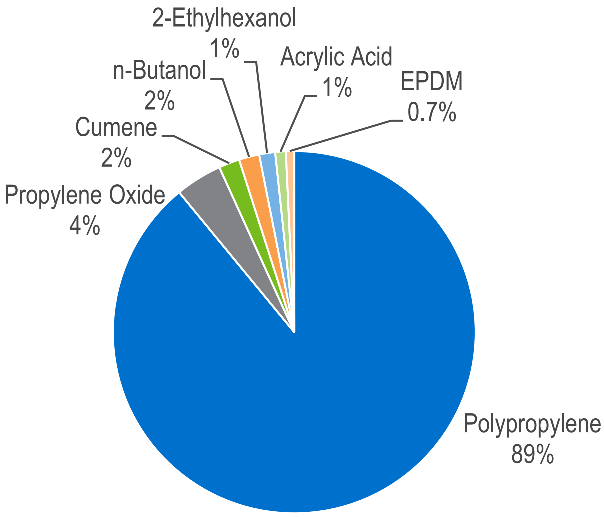


Table 4.16 Middle East (excluding Turkey) Propylene Consumption by End-Use, e-2023

(thousand tons)

	Actual			Estimate	Forecast									Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2027	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Polypropylene	6 237	8 438	9 023	8 485	8 384	9 022	9 133	9 732	11 542	14 609	16 954	19 397	21 229	2.8	4.5	3.1
Propylene Oxide	167	254	417	397	372	363	365	377	579	881	891	1 082	1 245	8.2	5.5	3.9
Cumene	103	130	210	177	178	181	184	188	186	278	389	475	554	5.1	0.7	5.6
n-Butanol	-	187	188	173	177	181	187	192	267	289	332	374	386	-	6.4	1.9
2-Ethylhexanol	129	130	132	135	138	142	147	151	222	230	251	285	284	0.4	7.4	1.2
Acrylonitrile	-	-	-	-	-	-	-	-	369	394	386	408	439	-	-	0.9
Acrylic Acid	-	97	90	89	91	93	96	98	172	180	208	303	406	-	9.8	4.4
EPDM	-	16	80	69	71	74	77	74	80	101	100	117	145	-	2.2	3.0
iso-Butanol	3	3	3	2	2	3	3	3	10	11	17	21	21	(2.9)	23.3	3.7
Isopropanol	-	-	-	-	-	37	38	39	40	42	71	74	81	-	-	3.6
Total	**6 639**	**9 254**	**10 143**	**9 528**	**9 413**	**10 096**	**10 229**	**10 854**	**13 468**	**17 016**	**19 599**	**22 536**	**24 790**	**3.3**	**5.1**	**3.1**

Table 4.17 Middle East (excluding Turkey) Propylene Consumption by Country, e-2023

(thousand tons)

	Actual			Estimate	Forecast									Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2027	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Iran	642	907	858	964	943	1 021	1 043	1 514	1 780	2 648	2 871	3 547	4 120	3.8	9.2	4.3
Iraq	-	-	-	-	-	-	-	-	-	-	631	1 233	1 214	-	-	-
Israel	367	347	270	370	362	362	366	373	464	483	481	475	473	0.1	3.3	0.1
Kuwait	131	122	139	127	127	126	127	130	407	888	894	878	883	(0.3)	18.1	3.9
Qatar	-	-	-	-	-	-	-	-	-	-	-	785	1 134	-	-	-
Saudi Arabia	4 621	6 052	6 325	5 647	5 561	6 227	6 323	6 431	7 778	9 307	10 068	11 039	12 208	1.8	4.7	2.3
Other Middle East	877	1 826	2 551	2 420	2 420	2 361	2 369	2 406	3 038	3 689	4 654	4 579	4 758	9.7	3.3	2.3
Total	**6 638**	**9 254**	**10 143**	**9 528**	**9 413**	**10 096**	**10 229**	**10 854**	**13 468**	**17 016**	**19 599**	**22 536**	**24 790**	**3.3**	**5.1**	**3.1**

4.3.7.2 Supply

Propylene capacity addition in the Middle East has slowed following a prior wave of major additions. There were no new crackers since 2016 until the new mid-sized LPIC (LIWA Plastics) cracker in Oman entered the market in 2021. The cracker produces 300 000 tons per year of propylene and this led to capacity increasing by three percent in 2021. Prior to this propylene addition included a new 500 000 tons per year PDH unit at the Takreer refinery in Abu Dhabi, which was commissioned in 2018. This followed an increase in propylene recovery at the same refinery's FCC unit from 600 000 to 1.1 million tons per year in 2015.

The prospect of a step-out development in Saudi Arabia as part of "crude oil-to-chemicals" (COTC) complex is now back on the table, with Saudi Aramco now selecting Ras Al-Khair as its planned site, although no details on scale, technology or timeline. The Amiral cracker in Saudi Arabia will consume liquid and NGL feedstocks and produce substantial quantities of propylene, while the new crackers planned in Abu Dhabi and Qatar will both be pure ethane based. PDH plants will remain a significant growth platform in Saudi Arabia in the near term.

Liquids cracking economics are challenging in the Middle East, and recent projects have tended towards lighter feed. Plans for two mixed feed crackers (in Qatar) were abandoned as the required feedstock subsidy made them unattractive from a national value perspective, and an ethane cracker is expected to be built instead. Saudi Arabia and the United Arab Emirates have driven propylene production growth and the recent developments have consolidated their leading positions.

Saudi Arabia

In 2018 Saudi Aramco and SABIC signed a contract with the EPC contractor Wood Group to complete a feasibility study for a major "crude oil to chemicals" (COTC) complex in Yanbu. The associated refinery has a planned capacity of 400 000 barrels per day, capable of producing significant quantities of ethylene, propylene, and butadiene. Ras Al-Khair has now been selected as the site for a major COTC development, but it is not clear how closely the design will follow the earlier designs explored with Wood Group.

Saudi Aramco and TotalEnergies confirmed the Amiral project in 2022, which includes a mixed feed steam cracker in Al Jubail, with 500 000 tons per year of propylene that could be available as early as 2026. FEED and pre-FEED were awarded to Technip following feasibility studies with Jacobs Engineering in 2018 and licences with Lummus have also been agreed. Feedstock would be from the existing SATORP joint venture refinery between the partners. Solicitations of interest were issued during 2021 and a final investment decision was made in quarter four of 2022. The project represents an investment of around US$11 billion, of which US$4 billion will be funded through equity by Aramco (62.5 percent) and TotalEnergies (37.5 percent). Its construction is scheduled to begin during the first quarter of 2024 with commercial operation targeted to start in 2027.

A joint venture between SK Gas and AGIC (Advanced Global Investment Company) under the name Advanced Polyolefins Industry Co. (APOC) have rapidly progressed plans for a large-scale PDH complex at Al Jubail which targets 840 000 tons per year of propylene. Samsung Engineering announced in a statement that it was awarded the EPC contract for the project. Work is underway and mechanical completion is expected inQ1 2024. 800 000 tons per year of propylene is earmarked for two polypropylene plants, and the remainder may serve an isopropanol plant. This is the first new PDH project to receive approval and feedstock allocation for many years in Saudi Arabia, enabled partly by the addition of supply for what would be the first isopropanol plant in the Kingdom. The financial close for the financing was announced in quarter four of 2022. The project has reportedly already completed 45 percent of EPC activities. While the sponsor has proposed to commence operations in early 2024 this seems ambitious, and the project is included in the forecast from the beginning of 2025.

In another project AGIC has received approval from the Ministry of Energy for the allocation of feedstock to supply its proposed petrochemical complex in Jubail Industrial City. The complex will include a mixed-feed steam cracker and will produce 1.15 million tons per year ethylene, 850 000 tons per year propylene and 400 000 tons per year of aromatics, fuels, and their derivatives. Start-up is scheduled for the fourth quarter of 2025, however there are no new announcement since this was first reported in 2021.

United Arab Emirates

Propylene in the UAE is generated through the Borouge petrochemical complex, as well as both FCC recovery and propane dehydrogenation technology at the Takreer refinery, which started production of a new PDH plant in 2018. A unique approach is used to produce propylene at the Borouge II complex since the steam cracker is entirely ethane based. The process dimerises a proportion of the ethylene to butene, which is in turn fed into the metathesis plant along with more ethylene.

Borouge made a final investment decision in November 2021 to move forward with the planned US$6.2 billion Borouge 4 polyolefin complex. The planned US$6.2 billion Borouge 4 polyolefin complex has reached the next step of development, in July 2022, with the construction of the infrastructure, which includes the utility system, roadworks and associated civil works of the complex. The project will house the new 1.5 million tons per year ethane cracker, two polyethylene plants based on Borealis' proprietary Borstar technology, and the cross-linked polyethylene plant to produce 1.4 million tons per year of polyethylene. Plans indicated two large refinery-integrated steam crackers which could together produce around one million tons per year of propylene; however, these are no longer included in plans for the complex.

ADNOC has announced the discovery of gas off Abu Dhabi, with interim results from the first exploration well indicating between 1.5 and two trillion standard cubic feet of raw gas in place. This follows from the discovery of up to one billion barrels of oil equivalent announced in December 2021. Awards have been announced for a new record investment in a drilling programme during February 2022. With the discovery of significant natural resources and investment into drilling, there is potential for further investment into crude to chemical complexes in the region.

Iran

Progress on projects in Iran has historically been slow, hampered by feedstock availability and power outages etc. which have resulted from the inability to purchase machinery and spare parts due to sanctions. Ongoing worries regarding Iran's nuclear program suggest an immediate lifting of sanctions is unlikely despite efforts by the new Biden administration.

Plants believed to be under construction in Iran are:

- Ilam Petrochemical, Iran, a 458 000 tons per year ethane/propane cracker with capacity for 124 000 tons per year of propylene. The project was due to start production by 2020, however the project has been further delayed, with the prospective start-up date to be in 2024. This plant was targeted by sanctions in June 2019, but is understood to have been completed in 2022.
- Gachsaran Petrochemical, Iran, 1.09 million tons per year predominantly ethane-fed cracker with capacity of up to 90 000 tons per year of propylene for Gachsaran in 2023. Its latest status is not clear.
- Dehloran Petrochemical cracker with a capacity of 622 000 tons of ethylene and 130 000 tons per year propylene. Progress is unclear at this stage with associated petroleum gases from oilfields in Ilam expected to supply the petrochemical plant with natural gas.
- Salman-e-Farsi, Iran, 450 000 tons per year PDH plant for Mahshahr. This plant was originally due to be commissioned in 2020 but has seen limited progress since 2017. The plant will use 560 000 tons per year of propane as feedstock, which will be provided by Bandar Imam Petrochemical Co.

There has been limited announcements on the progress however it was reported that the plant should launch in quarter three of 2023. An update on this is not yet available.

Additional projects proposed in Iran may add significant capacity in the future; however, these have all seen limited development in the wake of new sanctions. An additional 450 000 tons per year PDH plant was planned Mehr Petro Kimia in Bandar Assaluyeh by 2022 which has now been pushed to 2024. The project has also seen limited progress since the reintroduction of sanctions and can no longer be considered as a firm plan.

Oman

Liwa Plastic Industries Project was the latest project to come online in Oman with the project being inaugurated in December 2021. The steam cracker has an ethylene capacity of 838 000 tons per year and 300 000 tons per year of propylene, raising the total production of both products in the country to 1.4 million tons per year, and is located in Sohar, Oman. EPC contracts were awarded to the GS Engineering and Construction and Mitsui joint venture for NGL extraction, to Punj Lloyd for the pipeline, to the CB&I and CTCI Corporation joint venture for the steam cracker and utilities and to Tecnimont for the plastics units. The facility, which had been expected to come onstream in 2018, ramped up to full capacity throughout 2022 was ramping up to full capacity during 2022. It maintained full production in 2023.

Future capacity in Oman may be boosted further in the future, as Duqm Refinery & Petrochemical Industries Co. LLC (DRPIC) and Kuwait Petroleum International (KPI) joint venture, now rebranded as OQ8 awarded a contract to Lummus Technology LLC to license technology for a series of new units as the petrochemical portion of DRPIC's long-planned 230 000 barrel per day integrated refining complex under construction in Duqm. As of November 2022, 95 percent of the project was reported to be complete, with an expected start date of commercial operations in late 2023. No update has been provided of the expected start of commercial operations.

Kuwait

A 615 000 barrel per day refinery in Al Zour state began construction in 2016 and boosted the country's refining capacity by 66 percent. The project is from the Kuwait Petroleum Company (KPC), has completed construction and commissioning reported in quarter one of 2023. The petrochemical project has yet to be fully defined, but there have been discussions for a product slate including ethylene, ethylene glycol, HDPE, LLDPE, polypropylene, polyethylene terephthalate and purified terephthalic acid. Al Zour will be the largest refinery in the Middle East once complete and will increase Kuwait's total refining capacity to 1.415 million barrels per day.

4.3.7.3 Supply, Demand and Trade

Although historically a net exporter of propylene, the Middle East trade position reversed in 2022 as demand increased for downstream polypropylene capacity expansions while operating rates dropped slightly from 2021. This trade position was maintained in 2023. Regional propylene capacity has largely been developed along with derivatives; and exports have generally been of the surplus monomer, particularly when margins on polypropylene were low. Net trade was almost balanced in 2023. Middle Eastern propylene exports are mainly to China, Belgium, and a host of other European and Asian countries. The UAE has run with a structural surplus of propylene, although most of this was absorbed by the PP5 polypropylene project that was commissioned in early 2022, and exports dropped significantly as a result.

Exports from the UAE have mainly been to China, Belgium, Saudi Arabia, and India. Derivative margins had increased prior to 2019, which encouraged domestic consumption, but in 2019 exports became more attractive in many Middle Eastern markets. The opposite occurred in 2020 with margins falling, but production cutbacks resulted in lower production to reduce exports. In 2021 derivative margins increased in the first half of the year before falling significantly, particularly in Asia, which promoted exports into Western Europe. 2022 and 2023 was a challenging set of years all round, particularly for those companies focussed on China.

Operating rates increased fractionally during 2023 over 2022 despite the new capacity addition from Liwa Plastic Industries Project not reaching full operating rates during the year, and turnarounds including SEPC's PDH plant. The strengthening global economy has previously supported demand growth in the Middle East conditions; it will remain challenging in 2024 and thereafter as oil prices have eased, supporting naphtha-based olefins production in other regions, and recessionary fears and high inflation continue to suppress demand.

The ethane/propane crackers and the PDH units in Saudi Arabia are competitive and generally operate at high rates. The market-based pricing for propane did not significantly impact competitiveness, and the proposed increase in ethane prices in late-2022, and subsequent annual reviews may actually encourage propane cracking, and thus result in some additional propylene supply.

Figure 4.16 Middle East (excluding Turkey) Propylene Supply, Demand and Trade

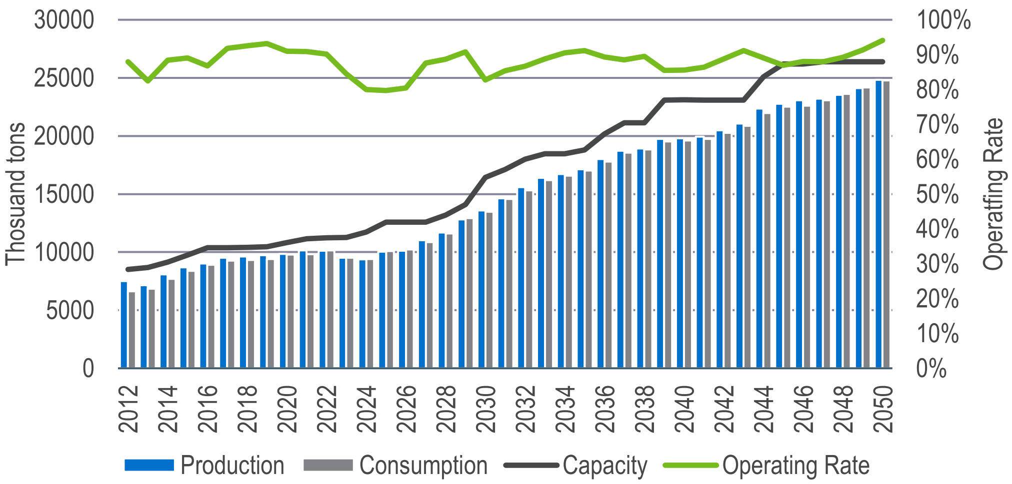


Table 4.18 Middle East (excluding Turkey) Propylene Supply, Demand and Trade, e-2023
(thousand tons)

	Actual			Estimate	Forecast									Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2027	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Firm Capacity	8 521	10 371	11 221	11 258	11 725	12 590	12 590	12 590	13 118	13 118	13 126	13 118	13 119			
Speculative	-	-	-	-	-	-	-	-	3 304	5 678	9 995	13 070	13 270			
Total Capacity	8 521	10 371	11 221	11 258	11 725	12 590	12 590	12 590	16 422	18 796	23 122	26 188	26 389	2.6	5.5	2.4
Operating Rate	88%	92%	90%	84%	80%	80%	80%	88%	83%	91%	86%	87%	94%			
Production	7 494	9 519	10 120	9 506	9 374	10 037	10 124	11 029	13 588	17 144	19 789	22 774	24 832	2.2	5.2	3.1
Net Export	856	265	(24)	(21)	(39)	(59)	(104)	174	120	128	190	238	41			
Consumption	6 639	9 254	10 143	9 527	9 413	10 096	10 228	10 855	13 467	17 016	19 599	22 536	24 790	3.3	5.1	3.1

4.3.8 North-East Asia

4.3.8.1 Consumption

Total propylene consumption in North-East Asia reached 60.5 million tons in 2023, a growth of three percent from 2022. Economic recovery efforts drove derivative demand growth in almost all countries, although demand overall was hit by high energy and food prices. China was still under the zero COVID-19 policy that restricted population movement and have suppressed derivative demand growth in the country. New plant start-ups were the main driver of propylene consumption growth. New capacity for polypropylene, propylene oxide, acrylonitrile, cumene/phenol, acrylic acid, oxo-alcohols, was the main driver for demand growth.

Global uncertainties limited the growth of polypropylene production in China, as a significant element of the polypropylene consumed in China is subsequently exported as manufactured goods.

Polypropylene dominates propylene demand in North-East Asia, accounting for 64 percent of total propylene demand. The region has achieved dominance of the global fibre and manufacturing industries as a result of low labour costs and the unrestrictive business environment in many countries. Growth will continue, driven by ongoing investment in polypropylene capacity, and the relative competitiveness of capital costs in Asia. The scale of capacity development in China is far beyond forecasts for consumption growth, as capacity is set to increase to 63 million tons per year by 2027.

China's polypropylene demand and appetite for imports is the key factor driving the Asia Pacific propylene market. The development of such large volumes of polypropylene capacity in China is bringing change to the global market, intensifying competition in other regional polypropylene markets. The new polypropylene plants in China have licensed a wide variety of technology from global technology licensors, and look set to pose a considerable challenge to the incumbent overseas polypropylene suppliers. The capacity growth was sufficient to drop China's polypropylene net import. This greatly increased competitive pressure in the region, impacting both exporting regions such as the Middle East, and other regional producers such as India. There have been some concerns over ash content in polyolefins produced by methanol-to-olefins (MTO), but this does not appear to be a major issue for the new Chinese producers.

Figure 4.17 North-East Asia Propylene Consumption by End-Use, e-2023

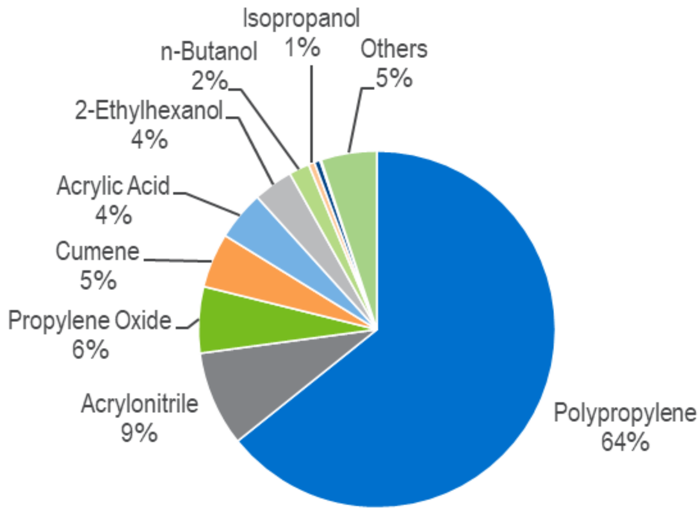


Table 4.19 North-East Asia Propylene Consumption by End-Use, e-2023

(thousand tons)

	Actual			Estimate	Forecast									Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2027	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Polypropylene	18 247	27 318	38 125	38 855	40 566	41 380	42 794	43 903	45 071	49 826	53 895	59 116	65 241	7.1	2.1	1.9
Acrylonitrile	3 020	3 919	4 858	5 212	5 563	5 814	6 135	6 431	6 260	7 095	7 827	9 186	10 170	5.1	2.7	2.5
Propylene Oxide	1 859	2 660	3 213	3 632	3 985	4 182	4 471	4 707	5 051	5 824	6 800	7 955	9 023	6.3	4.8	2.9
Cumene	1 804	2 389	2 733	2 988	3 115	3 241	3 355	3 500	3 687	4 206	4 581	5 248	5 916	4.7	3.0	2.4
Acrylic Acid	1 477	2 209	2 636	2 710	2 803	2 929	3 090	3 270	3 498	4 084	4 789	5 497	6 163	5.7	3.7	2.9
2-Ethylhexanol	1 165	1 852	2 126	2 170	2 215	2 285	2 369	2 451	2 530	2 818	2 871	3 026	3 207	5.8	2.2	1.2
n-Butanol	632	928	984	1 121	1 162	1 209	1 264	1 336	1 369	1 512	1 543	1 646	1 783	5.4	2.9	1.3
Isopropanol	288	300	336	339	338	339	352	369	383	423	411	431	456	1.5	1.7	0.9
EPDM	162	284	314	318	324	336	351	406	439	514	552	661	719	6.3	4.7	2.5
iso-Butanol	70	58	74	72	75	77	80	83	94	105	112	122	134	0.2	3.9	1.8
Others	1 375	2 995	3 059	3 056	3 068	3 103	3 154	3 210	3 273	3 439	3 644	3 997	4 296	7.5	1.0	1.4
Total	**30 099**	**44 909**	**58 459**	**60 472**	**63 213**	**64 896**	**67 415**	**69 666**	**71 654**	**79 846**	**87 025**	**96 886**	**107 109**	**6.5**	**2.5**	**2.0**

Table 4.20 North-East Asia Propylene Consumption by Country, e-2023

(thousand tons)

	Actual			Estimate	Forecast									Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2027	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
China	16 799	30 048	43 272	44 996	47 522	49 149	51 398	53 268	55 258	62 582	68 993	78 661	87 958	9.4	3.0	2.4
Japan	4 933	5 001	4 210	4 277	4 370	4 379	4 456	4 566	4 559	4 778	4 738	4 762	4 904	(1.3)	0.9	0.4
South Korea	5 615	6 744	7 890	8 279	8 405	8 444	8 586	8 785	8 791	9 291	10 136	10 269	10 972	3.6	0.9	1.1
Taiwan	2 752	3 116	3 088	2 920	2 915	2 925	2 975	3 047	3 047	3 195	3 159	3 194	3 275	0.5	0.6	0.4
Total	30 099	44 909	58 459	60 472	63 213	64 896	67 415	69 666	71 654	79 846	87 025	96 886	107 109	**6.5**	**2.5**	**2.0**

China

China is the largest propylene consumer in Asia Pacific, accounting for near 60 percent of regional propylene demand in 2023 and nearly three quarters of demand in North-East Asia. The growth in Chinese propylene demand has been driven by the intensive capacity addition of downstream derivatives in recent years, and the prevailing low propylene prices relative to ethylene. This has accelerated polypropylene growth ahead of most other derivatives, partly by making it more competitive against HDPE.

Polypropylene accounts for an increasing share of nearly 70 percent of total propylene consumption, broadly in line with the global average. Polypropylene capacity grew at near 13 percent annually between 2019 and 2022, reaching 53.5 million tons per year in 2023. Capacity growth is to accelerate further in the near future, reaching 60 million tons per year by 2025. With the global health emergency caused by COVID-19, polypropylene consumption into fibre to produce masks and personal protective equipment surged in 2020 and a lot of production lines have switched to produce fibre grade polypropylene for non-woven fabric and melt blowing layer. However, the consumption into this sector has come down to a more normal level since 2021-2022. Injection moulding is the largest sector for polypropylene consumption in China and has been growing well with the support of exports for finished products.

For upstream integration of polypropylene, MTO/MTP has been driven with its ability to transform stranded coal into high value products which can be economically shipped to consumers in the coastal areas of China. Polypropylene is readily transported in freight containers over long distances in China by road or rail and has therefore become the derivative of choice for most MTO/MTP developments. With pressure from environmental perspectives and low crude oil prices, some projects have been delayed or reconsidered.

Recent and ongoing polypropylene developments integrated with MTO/MTP capacity include the following:

- Shaanxi Yanchang China Coal Yulin Energy and Chemical added a new polypropylene line with 400 000 tons per year capacity at the end of 2020.
- Tianjin Bohai Chemical with 300 000 tons per year propylene capacity integrated with MTO complex successfully started up in 2022 after several delays.
- Huating Zhongxu Coal Chemical has completed construction of a new 200 000 tons per year polypropylene plant, integrated with upstream MTP plant. The plant started up in 2022 but the operation has not been stable.
- Qinghai Damei Coal Industry has completed construction for 400 000 tons per year polypropylene plant but the start-up time remains unclear.
- Ningxia Baofeng Energy is constructing a new polypropylene plant with 300 000 tons per year capacity, integrated with upstream MTO plant; production at the new facility was launched by the end of September 2023.
- Shanxi Coke and Sinopec Bijie had plans to build new MTO plants with propylene capacities but the projects have been cancelled.

There have been more polypropylene developments integrated with steam cracker propylene:

- Zhejiang Petrochemical has planned two 450 000 tons per year polypropylene plants integrated with its naphtha/gasoil based steam cracker in two phases. The first phase with one 450 000 tons per year polypropylene plant has already started up in the beginning of 2020. Other than the refineries, propylene can also be supplied from the company's two 600 000 tons per year PDH units in two phases.
- Sinopec Zhanjiang started two polypropylene plants with 350 000 tons per year and 200 000 tons per year capacity respectively, integrated with the upstream mixed feed steam cracker in September 2020.

- Liaoning Bora started up two polypropylene plants with 400 000 tons per year and 200 000 tons per year capacity respectively, integrated with the upstream gas cracker in September 2020.
- Wanhua Chemicals added 300 000 tons per year polypropylene capacity, integrated with the upstream gas cracker by the end of 2020.
- Hainan Petroleum Refining Chemical is building two polypropylene plants with 200 000 tons per year and 250 000 tons per year capacity respectively, integrated with the upstream steam cracker, aiming to start in the third quarter of 2021. The 200 000 tons per year plant is claimed to have started in December 2022. So far NexantECA have not seen confirmation that the 250 000 tons per year facility has started up.
- Sinochem Quanzhou started up a 350 000 tons per year polypropylene plant integrated with naphtha/gasoil steam cracker in September 2020.
- Gulei Refinery started up 350 000 tons per year polypropylene capacity integrated with its new steam cracker in 2021.
- Zhejiang Petrochemical started up another 900 000 tons per year polypropylene plant, doubling the capacity to achieve 1.8 million tons per year in 2021.
- Guangdong Petrochemical, which is a subsidiary of PetroChina, started up 500 000 tons per year of polypropylene capacity in February 2023. It planned to add another 200 000 tons per year polypropylene capacity by the end of 2023, but the start-up was slightly delayed and is now expected in 2024.

Recent and ongoing polypropylene developments integrated with PDH units include:

- Dongguan Juzhengyuan started up 600 000 tons per year polypropylene plant integrated with PDH unit with the same scale in the four quarter of 2019. It planned to double the 600 000 tons per year polypropylene capacity and upstream propylene capacity in 2023. So far NexantECA have not seen confirmation that this facility has started up.
- Oriental Energy added two polypropylene lines with 800 000 tons per year capacity by the end of 2020, integrated with upstream PDH units.
- Jinneng Science and Technology started up the first phase 450 000 tons per year polypropylene plant integrated with a 900 000 tons per year PDH unit in 2021.
- Formosa Plastics expanded its polypropylene capacity by 70 000 tons per year to 520 000 tons per year in the second half of 2022, integrated with the start-up of a new PDH unit.
- Grand Pacific is planning to add 450 000 tons per year polypropylene capacity with upstream 600 000 tons per year PDH unit in Quanzhou, Fujian. The complex is expected to commence commercial operations in 2025.
- Ningbo Kingfa is planning to add 800 000 tons per year polypropylene capacity with a new 600 000 tons per year PDH unit in Ningbo, Zhejiang by the end of 2023. The facility started in 2023 but was shutdown for maintenance in December 2023. On the site, there is also an existing PDH unit with the same scale in operation.
- Wanhua Chemicals is planning to construct a 300 000 tons per year polypropylene plant with upstream 900 000 tons per year PDH unit in Yantai, Shandong in 2024.

Propylene consumption into propylene oxide had positive demand growth in 2023 at over 13 percent due to start-ups of new plants. Propylene oxide accounted for near six percent of total propylene demand in China in 2023. Polyurethanes and polyether polyols remain the main drivers for propylene oxide consumption in China with increasing volumes of exports observed. Propylene oxide capacity has increased by over 700 000 tons per year, since 2021 and the wave of new additions will continue in the near future. Details of recent and ongoing projects include:

- Sinochem Quanzhou started up a new POSM plant with 200 000 tons per year propylene oxide capacity integrated upstream with a naphtha/gasoil-based steam cracker in the first quarter of 2021.
- CSPC started up a POSM unit with 300 000 tons per year propylene oxide capacity in the first half of 2021.
- Wanhua Chemicals started up a new POSM plant with 300 000 tons per year propylene oxide capacity based on own proven technology, integrated with the new gas cracker in the end of 2021.
- Ningbo ZRCC Lyondell Chemical, a joint venture between Sinopec and LyondellBasell started up a POSM plant with 275 000 tons per year propylene oxide capacity in early 2022.
- Sinopec Tianjin started up a cumene oxidation plant with 150 000 tons per year propylene oxide capacity in the second quarter of 2022.
- Tianjin Bohai Chemical started up a new POSM plant with 200 000 tons per year propylene oxide capacity and 450 000 tons per year of styrene capacity in the third quarter of 2022.
- Jiangsu Yida Chemical started normal operation for its 150 000 tons per year HPPO plant in the fourth quarter of 2022 in Taixing, Jiangsu.

In the future, Qixiang Tengda, Zhenhua Oil, Tianchen New Materials, Shandong Jincheng Petrochemical, Zhejiang Petrochemical, Wanhua Chemicals and Shenghong Group are expected to add more than two million tons per year propylene oxide capacity in 2023-2024. The development of local Chinese acrylonitrile technology has transformed the global market. Propylene consumed in acrylonitrile accounted for more than seven percent of total demand in 2023. After a relatively flat period of capacity development in 2017-2018, a few new projects have been developed. Recent and ongoing developments include:

- Zhejiang Petrochemical started up a complex integrated with upstream naphtha/gasoil steam cracker. The first phase of this complex includes capacity of 260 000 tons per year acrylonitrile which started up in the middle of 2020. The second phase project with another 260 000 tons per year acrylonitrile capacity was started up in August 2021.
- Shandong Keluer doubled their existing 130 000 tons per year capacity in Dongying, Shandong in November 2021.
- Jiangsu Sailboat constructed its third phase acrylonitrile plant, which brought another 260 000 tons per year acrylonitrile capacity in late 2021.
- Lihuayi Group started up a 260 000 tons per year acrylonitrile plant in Dongying, Shandong in the beginning 2022.
- Tianchen Qixiang started up a new acrylonitrile plant with 130 000 tons per year capacity in Zibo, Shandong in Q1 2022.
- Kingfa Group has become the main shareholder for Liaoning Bora New Materials after acquiring more than 51 percent share. They finished construction for the integrated project with 600 000 tons per year propylene from PDH unit, 260 000 tons per year acrylonitrile capacity, 100 000 tons per year MMA and 600 000 tons per year ABS in October 2022.
- Jilin Petrochemical started up a 130 000 tons per year acrylonitrile plant in Jieyang, Guangdong in February 2023.

- CNOOC Dongfang started up its new 200 000 tons per year ACN plant in February 2023.
- Sinopec announced plans to construct a 400 000 tons per year ACN plant in Ningbo in Zhejiang province. Sinopec's subsidiary Zhenhai Refining & Chemical Co will provide feedstock propylene.
- Jilin Petrochemical commenced construction of a new cracker in Jilin province, China. The facility will include a new 260 000 tons per year ACN plant.
- Sinochem Quanzhou Petrochemical started up the new naphtha/gasoil steam cracker in late 2020, but the construction of their 260 000 tons per year acrylonitrile capacity has been delayed.

China’s rapid expansion of oxo-alcohol capacity is affecting volumes of oxo-alcohols and their derivatives exported from several other regions. The oxo-alcohols (2-ethylhexanol and butanols) accounted for more than five percent of total propylene consumption in China in 2023. Capacity development has been stagnant in recent years. 2-ethylhexanol capacity reached 2.4 million tons per year while butanols capacity increased to near 2.6 million tons per year in 2019 and both remained flat in 2020-2023. Recent developments include:

- CSPC, the joint venture of CNOOC and Shell, started a complex with 250 000 tons per year capacity for oxo-alcohols in the beginning of 2018.
- Hualu Hengsheng added 100 000 tons per year oxo-alcohols capacity in the first half of 2018.
- Jiangsu Huachang Chemical expanded its oxo-alcohols capacity by 80 000 tons per year in the second half of 2018.
- Shaanxi Yanchang Yan’an Nenghua added 200 000 tons per year oxo-alcohols capacity by the end of 2018.
- In 2023, PetroChina Guangdong and Huayi Group are both adding oxo-alcohols capacity by 330 000 tons per year and 300 000 tons per year respectively, in Jieyang Guangdong and Qinzhou, Guangxi.

Accounting for about four percent of total propylene demand in 2023, propylene consumption into acrylic acid is being driven by superabsorbent polymers and acrylate esters. Capacity for acrylic acid in China was 4 million tons per year for.

Key developments include:

- Bohai Oriental Chemical constructed a new complex which includes 40 000 tons per year acrylic acid integrated with 40 000 tons per year butyl acrylate.
- Huayi Group started up a new complex with 200 000 tons per year acrylic acid capacity in the end of 2022. A 750 000 tons per year PDH unit and a 200 000 tons per year butyl acrylate plant are integrated with the project.
- In 2021, Zhejiang Satellite added additional of 180 000 tons per year of acrylic acid capacity, with another 180 000 tons per year capacity to be added in 2023.
- Lanwan New Materials and Shandong Sanyue are planning to add 200 000 tons per year and 800 000 tons per year acrylic acid capacities with downstream integration in 2023-2024.
- Wanhua Chemicals, BASF Guangdong, Hengli Petrochemical have plans to add more acrylic acid capacities with upstream and downstream integration after 2024.

Accounting for near three percent of total propylene demand, demand into cumene has been supported by the development of phenol, and downstream bisphenol A (for polycarbonate and epoxy resins) as well as phenolic resin. Cumene capacity reached 5.2 million tons per year in 2023, , driving a significant increase in propylene consumption into cumene.

Recent developments include:

- Zhejiang Petrochemical started a 550 000 tons per year cumene plant in Zhoushan, Zhejiang, integrated with downstream phenol/acetone, BPA and polycarbonate plants in 2020. They have built another plant to double the capacity for cumene/phenol/acetone/BPA in 2022.
- Jiangsu Ruiheng New Materials, which is a subsidiary of Sinochem International, started up a 550 000 tons per year cumene plant with downstream phenol/acetone/BPA capacities and a PDH unit in Lianyungang, Jiangsu in the second half of 2022.
- Wanhua Chemicals constructed 480 000 tons per year BPA capacity to supply downstream polycarbonate units in end 2022. They have also built 530 000 tons per year cumene capacity and the integrated phenol/acetone capacity to supply raw materials to the BPA unit.
- Huayi Group has built a new complex which includes a 750 000 tons per year propane dehydrogenation (PDH) plant at Qinzhou, Guangxi province. A 230 000 tons per year cumene plant, 280 000 tons per year phenol/acetone plant with near 180 000 tons per year phenol capacity, and 200 000 tons per year BPA plant have started up by March 2023.
- Haiwan Petrochemical is constructing a cumene/phenol/acetone/BPA plant unit to be onstream in Qingdao, Shandong in 2023. The plant will include a 180 000 tons per year BPA unit, a 200 000/120 000 tons per year phenol/acetone unit and a 300 000 tons per year cumene unit.

China's propylene consumption development has benefited from the fast development of downstream capacity, which has enabled local producers to displace derivative imports. Future demand growth will depend more on the competitiveness of the new propylene supply and growth in the derivatives markets. The developments in almost all derivatives are having a major effect on global trade flows, creating additional competitive pressure against overseas suppliers. The situation is less problematic in products such as cumene where the multinational producers such as FCFC and CEPSA Quimica are themselves developing capacity in China and can therefore rebalance the supply within their own marketing organisations. The situation is markedly different for polypropylene however, with numerous new players in the market diluting the market share of the established players.

Japan

Propylene demand in Japan increased by 1.5 percent , up to 4.3 million tons in 2023. With an absence of capacity development, Japan is the fourth largest propylene consuming country in Asia, surpassed by India in 2017. Production of all propylene derivatives decreased as the GDP of the country also slowed from 2021. Japan struggled with high inflation and interest rates that affects the manufacturing sector and consumer spending in the country. Exports were interrupted following Russia Ukraine conflict causing economic turmoil. Feedstock costs increase also affected production as suppliers struggle to make margins in a slow end market demand. 2021 was an economic recovery year for Japan as the pandemic subsided and government spending rejuvenate the economy. Most derivative production mainly supported export markets which recovered during 2021. In 2020, limitations in export markets together with low domestic demand reduced propylene demand by eight percent. Although some downstream applications were not affected by COVID-19, domestic production declined along with muted international markets. Domestic demand for propylene derivatives is mature, and propylene consumption had been stable before the COVID-19 pandemic. Japanese propylene derivative capacity faced closures due to high energy, labour and feedstock costs. In particular, capacity that was intended for export was rationalized as some producers were unable to compete in global markets. As a result, the Japanese downstream polypropylene producers refocused on the domestic market or changed to higher value niche materials.

Demand into polypropylene remained flat in 2023 relative to 2022. Manufacturing industries also suffered with output decreasing from slow export demand especially exports to China. Polypropylene production declined in 2023 along with domestic demand. Production of some other propylene derivatives also dropped with the similar cause. Propylene consumption in Japan slightly recovered in 2019, boosted by polypropylene production to support international requirements mainly from China and Vietnam. Propylene consumption into cumene fell sharply and even phenol production became better. JX Nippon Oil & Energy permanently shut down its cumene facility in early 2019 and this unit has no downstream phenol integrated with it. This resulted in sharp decline in cumene exports. Most of the downstream production was affected by country's natural disasters throughout the year. Polypropylene production went down by almost ten percent. Japanese reform of the propylene derivative markets appears to have run its course, with no further capacity closures announced. As a result, propylene consumption will remain relatively flat after the expected recovery year in the forecast period.

South Korea

Propylene demand in South Korea reached 8.3 million tons in 2023, following almost five percent growth from 2022. The main growth contribution came from commercial operations of new petrochemical complexes which include polypropylene units. Hanwha Total, Hyundai Chemical, and SK Advanced Co added polypropylene capacity in late 2021 and fully operational in 2022, bringing additional 900 000 tons in 2022. Polypropylene capacity reached 6.2 million tons in 2022 to reflect full-year capacity by those producers. Hanwha Total added 400 000 tons per year of polypropylene capacity in May 2021. SK Advanced Co started a new polypropylene unit with capacity of 400 000 tons per year in March 2021. Hyundai Chemical began commercial operation at polypropylene units with capacity of 500 000 tons per year in December 2021. These contributed to 1.3 million tons capacity added. For other major derivatives including propylene oxide, acrylonitrile, cumene, and acrylic acid, production recovered close to pre-pandemic levels.

Propylene demand in South Korea expanded in all derivatives except 2-Ethyl hexanol and butanols. in 2023. South Korea was able to push export volumes into China despite the slow-down of market consumption in the expense in lower volume of exports into China from other countries. Polypropylene production was able to remain stable amid COVID-19 outbreak because the development of protective applications against COVID-19. Polypropylene production growth was halted in 2019 after growing by five percent due to combinations of Hyosung units starting in 2017 ramping up production, new integrated propylene-polypropylene unit by S-Oil coming online in late-2018, and demand for export markets. For other derivatives, LG Chem expanded propylene-based isopropanol capacity in late-2019 and fully utilized in 2020, supported by the surge demand during COVID-19. Tong Suh Petrochemical debottlenecked its acrylonitrile plant in mid-2020, increasing capacity by another 25 000 tons per year. However, this failed to bring propylene demand up because COVID-19 muted acrylonitrile downstream demand, consequently resulted in lower acrylonitrile production. South Korea used to export majority of country's polypropylene production to China but now producers have increased more sales channels to many countries, reducing dependency on China's market. South Korea will continue increasing integrated propylene and polypropylene capacity through stream cracker expansion in 2022 and 2023. Apart from polypropylene, Lotte Chemical and GS Energy plans to set up a new integrated phenol-BPA unit which is expected to come online by late 2023. These developments will support the demand of propylene in the near term. Further than that, propylene demand is expected to remain relatively stable in the medium term. Downstream production is highly dependent on export markets and there will be capacity addition in several current destinations including China, South-East Asia, India, and the United States.

Taiwan

Demand in Taiwan decreased to 2.9 million tons in 20232. Similar to South Korea, downstream production in Taiwan relies heavily on export markets. The decrease of international trade has pushed down on derivative production and thus propylene demand.

Major propylene derivatives in Taiwan include polypropylene, acrylonitrile, and cumene/phenol. These collectively accounted for 75 percent of propylene consumption in Taiwan. Despite a recovery in demand in 2021 as the pandemic subsided, export markets remained flat. Propylene consumption Taiwan remained flat in 2020 as the country was able to control the COVID-19 outbreak in a short period. However, the export markets became lower in some propylene derivatives which are not tied to the application promoted during pandemic era. These included acrylonitrile, phenol, and oxo-alcohol. Polypropylene production recovered in 2020 after contraction in 2019. Taiwan's propylene market experienced contraction in 2019, mainly caused by lower production of phenol. Polypropylene accounts for more than 40 percent of the propylene market in Taiwan with around half of the production being exported, principally to China. Several Taiwanese polypropylene producers have long-term contracts or are integrated downstream in China and can compete on quality. Therefore, polypropylene production in Taiwan will remain high to support export markets. There is no capacity addition for all propylene derivatives projected in Taiwan. Propylene consumption in Taiwan will stay flat in the near-term due to an absence of new derivative capacity developments.

4.3.8.2 Supply

China

China is the largest propylene producer in Asia Pacific, accounting for near 55 percent of regional capacity in 2022. After China's expansion of propylene capacity from MTO/MTP then PDH units, several new major steam cracker projects are now contributing to the majority of propylene capacity growth. Growth in FCC propylene is comparatively small but is ongoing. More important however is the increase in crude oil import licences granted to independent Chinese refiners in 2018, allowing higher throughput at their predominantly FCC-based refineries. In 2019-2023, China's propylene capacity has been growing at an average rate of about 11 percent per year, reaching 53.5 million tons per year in 2023. The outlook for the next three years will still be dominated by capacity from steam cracking, followed by PDH projects. There is much less activity on MTO due to both emissions legislation and high coal prices.

Naphtha/gasoil crackers and refinery FCC units have historically been the main sources of propylene supply in China. The growth in FCC development ceased as hydrocracking became the preferred upgrading solution for new refineries. This spawned a generation of new large-scale refinery-based steam crackers which consume the hydrocracker bottoms (hydrowax) as well as naphtha. Oversupply in the refinery sector, and poor returns from liquids-based steam cracking once stalled the development of new steam cracker projects, but several new refinery/cracker developments are now getting into the market. The previous supply gap for *para*-xylene in China created a requirement for heavy naphtha for reforming. Entrants such as Hengli Group are downstream polyester companies which are building refineries principally to produce *para*-xylene, and consume the light naphtha and other fractions in steam crackers, which in turn are oriented towards MEG, which is the other raw material required for PET.

Propane dehydrogenation (PDH) capacity has been focused in coastal areas which have competitive access to propane imports, much of which will come from the United States. The bulk of the methanol-based propylene developments are in inland, coal-rich areas. Some methanol-based plants also chose coastal locations however, as using purchased methanol avoided the restrictive permitting procedures which affect oil and coal-based chemicals developments in China. This strategy has however been greatly undermined by the drop in crude oil prices, as methanol prices have been comparatively robust.

Propylene capacity from MTO/MTP doubled to 9 million tons per year over 2015-2020, although the remaining projects in the pipeline will add nearly 700 000 tons per year more. Yanchang Petroleum Yan'an Nenghua started up a new MTO in 2018, followed by Jiutai Energy in the first quarter of 2019. Zhong'an United added 350 000 tons per year propylene capacity in the middle of 2019. Shaanxi Yanchang China Coal start their plant in 2020. Tianjin Bohai also started up the MTO plant in 2022 despite delays. Within the same year, Hami Hengyou started up a MTP plant which uses methanol and light hydrocarbon as raw material to produce propylene. The start-up time for Qinghai Damei remains uncertain but Ningxia Baofeng is going to start an MTO plant by the end of 2023.

Propylene capacity from PDH is likely to double from 7.5 million tons per year for 2020 to more than 16 million tons by 2024, with new capacity including the second phase project of Zhejiang Petrochemical, Jinneng Science and Technology and Ningxia Runfeng which started up in 2021, capacity additions from Formosa Plastics, and Liaoning Kingfa in 2022, as well as projects for Oriental Energy, Jiangsu Ruiheng, Grand Pacific, Dongguan Juzhengyuan, Ningbo Kingfa and Huayi Group in 2023. Wanhua Chemicals is also expected to start up a new PDH unit with 900 000 tons per year capacity in Yantai, Shandong in 2024.

After a pause in refinery capacity development, there are now several new projects underway. There is very little FCC or DCC capacity associated with these refineries, but there are considerable quantities of propylene expected from the steam crackers associated with them. The new steam cracker propylene supplies will greatly outweigh the volume of propylene lost from the increased usage of NGL feed at crackers which previously consumed only liquid feedstock. While the new gas-based crackers such as that of SP Chemicals bring a reduced proportion of propylene supply relative to ethylene, their share of new ethylene supply is small relative to the newly announced liquids crackers. New and very large-scale ethane crackers have originally been planned, but were decided to switch to higher flexibility as using mix light feedstocks, as it is unclear whether or not there will be sufficient surplus ethane available in the United States to supply all of the originally proposed capacity in China. These projects include SP Chemicals, Zhejiang Satellite and Ningbo Huatai.

The differential between naphtha and LPG prices is driving more LPG usage at steam crackers in China, which have on aggregate the heaviest feedstock slate of any country in the world. The hydrowax element of their feedstock can be regarded as advantaged, while the naphtha element is not. CNOOC is procuring LPG for its new CSPC joint venture mixed feed cracker at Huizhou, while Sinopec is procuring LPG which can be used at a number of its existing plants, or indeed sold to other consumers. Increasing numbers of crackers in China are consuming a proportion of LPG into their feedstock mix to obtain more feedstock flexibility. The plants include such as the Sinopec affiliates Secco, and Zhenhai Refining, Guangzhou Petrochemical, Maoming Petrochemical, Wuhan Petrochemical, Shanghai Petrochemical, Qilu Petrochemical, CSPC, as well as Dushanzi Refining under PetroChina.

The recent major refinery propylene development were for Hengli Group and Zhejiang Petrochemical which started mixed-feed crackers at the beginning of 2020. Liaoning Bora Petrochemical, Sinochem Quanzhou, Sinopec Zhanjiang and Wanhua Chemicals also added a total of more than 1.7 million tons per year propylene capacities within the same year. The second phase of Zhejiang Petrochemical, Ningbo Huatai, Shandong Shouguang Luqing, Gulei Refinery collectively added near 1.5 million tons per year new propylene capacity in 2021. In 2022, Zhenhai Refining and Shenghong Group added new capacities with a total of more than 1.2 million tons to the market. Sinopec Hainan Petrochemical, Sanjiang Chemical and PetroChina Guangdong will develop more than 1.5 million tons per year new propylene capacity by the end of 2023.

Other than above projects, there are a few projects which have been considered firm and will add more new capacities in 2024-2027, including the joint venture of Saudi Aramco and NORINCO in Panjin, Liaoning, ExxonMobil in Huizhou, Guangdong, BASF in Zhanjiang, Guangdong, Yulong Petrochemical, and the joint venture of Gulei Refinery and SABIC. On the other hand, Sinopec is also looking into further investments after the expansion to Zhenhai Refining, completion of Hainan Petroleum and the new project for Yangzi Petrochemical. Future plans are related to Sinopec sites in Yueyang of Hunan province, Luoyang of Henan province, and the possible second phase of Gulei Reginery in Zhangzhou of Fujian province. However, with most of the mentioned in progress/commercialised, some shutdowns of old and uncompetitive plants are also expected in the future.

Japan

Japanese propylene capacity has decreased significantly in recent years as part of the ongoing consolidation in the country’s petrochemical industry. Due to the high energy and labour costs and the age of the equipment, some of Japan’s capacity base is severely challenged in terms of competitiveness. 2022 proved to be especially tough as costs of production had spiked and increased competition in the export market. Efforts are ongoing to rationalise both the petrochemicals and refining industries. Several joint ventures have been formed, both reducing the number of competitors and leading to the closure of laggard plants. In September 2017, Mitsui and Idemitsu Petrochemical modified their crackers in order to increase the propane processing capacity. Both companies are located close to LPG import facilities and can switch a proportion of their feedstock to whichever is priced most attractively. This decreases propylene output at these plants, although the nameplate capacity (effectively of the propylene section of the plant) remained unchanged. Idemitsu also widened LPG use at its cracker at Chiba. These increased ethylene yield but lowered other by-products in 2018. Mitsui has increased propane processing capacity to 40 percent at its steam cracker in Osaka during 2023. This will further reduce propylene yield but will not change propylene capacity. In 2022, ENEOS was forced to shut down its plant in Kawasaki and Sendai due to an earthquake which affected the supply output of Japan. In the forecast period, Japanese propylene production is expected to continue to decline as a result of further capacity rationalization and an ongoing shift to lighter cracker feedstock.

South Korea

Producers in South Korea continue to add only modest propylene capacity to support the country's already leading export position for propylene and its key derivatives. Capacity in South Korea increased in 2023 with several crackers coming onstream. Full year production of new capacities in 2023 led to major increase of South Korean exports of propylene and reduction in overall operating rate. GS Caltex started its new mixed-feed stream cracker in mid-2021 which boosted propylene supply by around 430 000 tons per years. LG Chem started the third steam cracker in South Korea at Yeosu in mid-2021 using naphtha and LPG as main feedstock, with new propylene capacity is estimated at 450 000 tons per year. Hyundai Chemical, a joint venture between Lotte Chemical and Hyundai Oilbank, started up a new heavy feed-based petrochemical complex in Daesan in the end of 2021. The complex is able to produce up to 540 000 tons of propylene and this is mainly for internal polypropylene capacity. In 2020, Hanwha Total expanded the LPG cracking capacity in mid-2020, increasing propylene capacity by 50 000 tons per year. YNCC also expanded its naphtha-based cracker which boosted propylene supply by around 170 000 tons per year in the third quarter of 2020. In 2019, Hanwha Total completed an expansion of its steam cracker by adding an LPG cracking unit. This added propylene supply of around 130 000 tons per year.

Other developments include Korean Petrochemical which expanded its ethylene cracker capacity another 50 000 tons by in 2022. Further development came from S-Oil with a final decision confirmed on the Shaheen project (including a refinery and liquids cracker) in early 2023. The project is expected to be completed in 2026.

Taiwan

Taiwan's market consists of two propylene suppliers, Formosa Petrochemical Corporation (FPCC) and the state-owned China Petrochemical Corporation (CPC). The development of the Mailiao petrochemical complex by FPCC began in the late 1990s and then between 2006 and 2008 the company boosted Taiwan's total capacity by 50 percent. During this period FPCC brought on a metathesis plant and a naphtha-based steam cracker as well as expanding capacity at its existing fluid catalytic crackers, helping Taiwan shift from being a net importer to a net exporter. The most recent development is CPC's scrap and build project, which began in 2009. The new naphtha-based steam cracker with an olefins conversion unit employing ABB Lummus' technology added almost 300 000 tons per year to the existing capacity since its commissioning in late 2013. The new unit at Linyuan was followed by a metathesis plant in mid-2015. CPC permanently shut down its Kaohsiung refinery and petrochemical complex with 500 000 tons per year propylene capacity in December 2015. CPC now produces only at Linyuan and Dalin. There has not yet been any announcement of future plant development as competition in the region intensifies and new supply in the medium term outpaced global demand growth.

4.3.8.3 Supply, Demand and Trade

North-East Asian propylene operating rates dropped as new capacities in the region started operation in 2023. Despite an increase in demand, it was offset by a ten percent capacity addition, but producers were unable to ramp up production as the demand increase was not able to absorb all of the new supply. Geopolitical and global economic issues led to extremely high prices of feedstocks and choked growth in end market demand in 2023. This led to propylene producers to lower their operating rates.

Propylene output from refineries recovered in 2023 as the lift in travel restrictions started to promote demand for refined products. Gas-based crackers became more competitive in 2023 after the oil price recovery while this demoted the competitiveness of naphtha-based crackers. Operating rates remained lower in 2023 supported by an increase in propylene capacity additions. Several producers conducted turnarounds during the period of low margins at the peak of the COVID-19 pandemic. Low crude oil prices resulted in higher heavy feedstock portion to flexible crackers which resulted in lower production by olefin conversion units. Overall operating rates were slightly dropped but remained at around 80 percent in 2023. Several mixed-fed steam crackers in North-Eastern countries employed more gas than heavy feedstock through 2018-2019. Outside China only a few polypropylene units were brought online in 20 in the period 2020- 2023. Despite the continued attractiveness of lighter feedstock for steam cracking, the overall effect on supply was minimal, and propylene prices remained low. PDH margins remained modestly attractive through 2023 , as did fully integrated coal-based MTO, encouraging high operating rates for those plants. The substantial combined metathesis capacity in Japan, South Korea and Taiwan has effectively become the swing propylene source in Asia.

Trade tends to be more opportunistic and there are no contracts with suppliers from outside the region of the type that are in place on ethylene. Prior to 2020, almost all of volume came from the Middle East. In 2020, the United States exported moderate volumes of propylene into Asian countries mainly Taiwan and China. Exports outside the region have historically been small and tend to be occasional lots to South America or Europe. In 2021, imported volumes of propylene from the United States almost vanished as the region faced production issues in petrochemical complexes in gulf coast. Asia instead exported propylene to the United States and also South America and Western Europe. This turned the region as the net propylene exporter in 2021. Though volumes of US propylene re-emerged in 2022, as complexes were able to resume operation, the quantity is still small with higher competition in Asia, and remained so in 2023. Trading activity within the region was slow as global economic impacted buying incentives and suppliers were aware of feedstock cost hike during the year.

Exports of propylene from Japan swiftly recovered in 2019 due to declining margins on metathesis, capacity rationalisation, and shifting to lighter cracker feedstocks. Low crude oil prices, turnarounds, and demand resulted in lower propylene exports by Japan in 2020. Exports of propylene by Japan declined further in 2021 as new supply was developed in major destinations. Japan mainly exports propylene to North-East Asian neighbours including China, South Korea, and Taiwan while also importing some propylene from South Korea. The majority of exports are destined for China, accounting for almost 80 percent of total exports by Japan. Capacity expansion in China reduced propylene requirement from Japan during 2020-2022 and more intensive competition from South Korean suppliers. Export to South Korea also declined due to the commercialisation of new stream crackers.

South Korea and Japan are the region's leading propylene exporters. In 2023, net exports from South Korea increased to over 1.3 million tons in 2023, from 1.2 million tons in 2022. An increase in new petrochemical complexes in South Korea resulted in higher propylene capacity surplus, but due to slow markets and thin operation margins suppliers opted to reduce operating rates.

Japan's propylene supply has been curtailed due to low margins on OCU units. Much of the excess propylene capacity in the key exporting countries of Japan and South Korea is based on metathesis, and the operating rates of these plants declined in 2020 as low crude oil prices promoted heavier feedstock for crackers, resulted in higher supply of propylene. Despite a better price ratio of propylene to ethylene in 2020, metathesis operators could not exploit the opportunity due to excess supply and low demand in the market.

Taiwan is a net propylene exporter with the main volume destined for subsidiaries in China. Exports from Taiwan have remained stable through 2018-2019, partly due to cracker and FCC turnarounds. Propylene exports by Taiwan sharply reduced in 2020 due to turnarounds and lower requirement in China. Propylene exports recovered due to an absence of turnarounds in 2021. Exports to China rebounded but not to the level prior to pandemic outbreak. Taiwan's propylene net exports in 2023 were similar in volume as in 2022, at 400 000 tons.

Figure 4.18 North-East Asia Propylene Supply, Demand and Trade

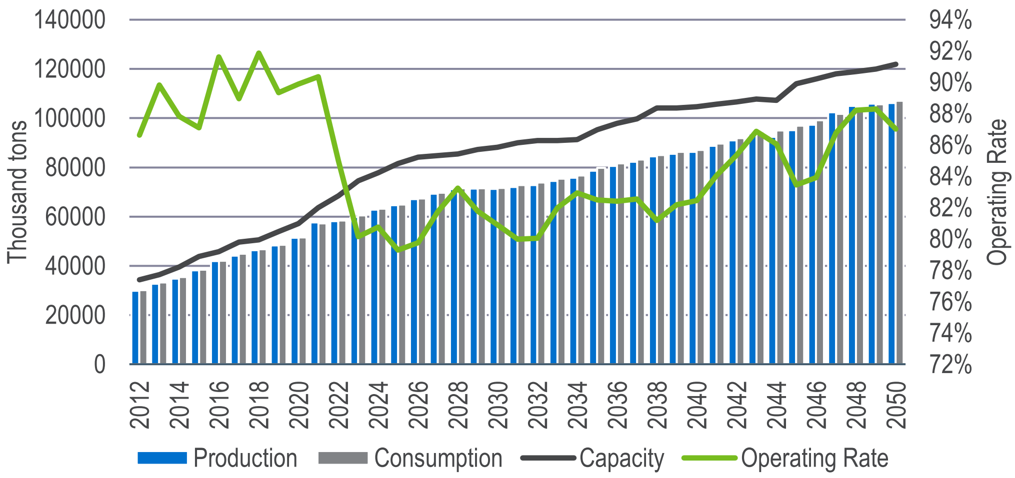


Table 4.21 North-East Asia Propylene Supply, Demand and Trade, e-2023

(thousand tons)

	Actual			Estimate	Forecast									Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2027	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Firm Capacity	34 400	49 583	68 623	74 953	78 369	81 093	82 566	82 566	82 566	82 566	82 566	82 566	82 566			
Speculative	-	-	(131)	(386)	(588)	480	1 550	2 278	5 554	12 718	22 129	31 416	39 395			
Total Capacity	34 400	49 583	68 492	74 567	77 781	81 572	84 115	84 844	88 120	95 284	104 695	113 982	121 961	7.3	2.4	1.6
Operating Rate	87%	89%	85%	80%	81%	79%	80%	82%	81%	82%	82%	83%	87%			
Production	29 802	44 105	58 208	59 768	62 815	64 684	67 094	69 361	71 291	78 597	86 315	95 121	106 124	6.5	2.6	2.0
Net Export	(296)	(804)	(251)	(704)	(398)	(212)	(321)	(305)	(364)	(1 249)	(710)	(1 765)	(984)			
Consumption	30 099	44 909	58 459	60 472	63 213	64 896	67 415	69 666	71 654	79 846	87 025	96 886	107 109	6.5	2.5	2.0

4.3.9 South-East Asia

4.3.9.1 Consumption

Propylene consumption in South-East Asia reached 8.7 million tons in 2023, following a net growth of over 15 percent from 2021. Thailand and Singapore are the two leading propylene consuming countries in South-East Asia, collectively representing two-thirds of propylene demand in South-East Asia while the countries providing most growth were Malaysia, Philippines, and Vietnam in 2023. Malaysia's PETRONAS operated its petrochemical complex only for a short period in 2020 before a blast resulted in long shutdown for repairs and inspection. The complex remained closed through 2021 and resumed its operation in 2022. Once the complex operation is restarted, propylene demand was sharply boosted. The largest derivative is polypropylene accounting for around three quarters of propylene demand, followed by propylene oxide and cumene/phenol while other derivatives are quite small.

Figure 4.19 South-East Asia Propylene Consumption by End-Use, e-2023

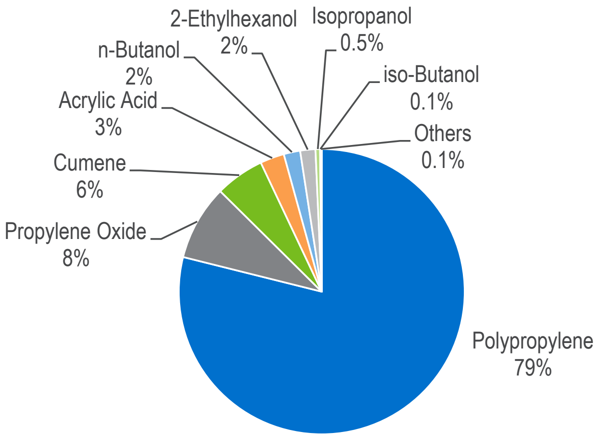


Table 4.22 South-East Asia Propylene Consumption by End-Use, e-2023
(thousand tons)

	Actual			Estimate	Forecast									Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2027	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Polypropylene	4 091	4 787	6 340	6 873	7 025	7 204	7 633	8 020	8 612	9 721	11 260	11 023	11 846	4.8	3.3	1.6
Propylene Oxide	567	622	712	743	749	750	761	768	737	771	855	877	919	2.5	(0.1)	1.1
Cumene	246	551	541	484	484	491	498	507	598	630	710	781	805	6.4	3.1	1.5
Acrylic Acid	180	232	244	238	295	299	305	314	339	499	454	486	537	2.6	5.2	2.3
n-Butanol	223	220	167	162	165	169	176	183	196	214	242	274	309	(2.9)	2.8	2.3
2-Ethylhexanol	180	154	145	150	153	158	163	168	178	186	186	182	187	(1.6)	2.5	0.2
Isopropanol	50	44	28	44	45	44	45	46	47	50	49	50	52	(1.0)	0.9	0.5
iso-Butanol	9	9	7	8	8	8	8	9	11	12	16	20	23	(1.0)	4.9	3.9
Others	8	8	9	9	9	9	9	9	10	10	10	11	11	1.5	1.6	0.6
Total	**5 552**	**6 627**	**8 193**	**8 710**	**8 932**	**9 133**	**9 599**	**10 024**	**10 727**	**12 093**	**13 783**	**13 705**	**14 689**	**4.2**	**3.0**	**1.6**

Table 4.23 South-East Asia Propylene Consumption by Country, e-2023
(thousand tons)

	Actual			Estimate	Forecast									Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2027	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Indonesia	740	858	952	953	977	1 193	1 545	1 859	2 409	2 564	3 189	3 124	3 453	2.3	14.2	1.8
Malaysia	742	741	1 016	1 539	1 564	1 565	1 596	1 607	1 737	1 826	1 832	1 835	1 890	6.9	1.7	0.4
Philippines	172	283	325	313	314	310	319	323	333	351	348	338	336	5.6	0.9	0.0
Singapore	1 728	2 122	2 069	2 003	1 991	1 992	2 023	2 058	2 055	2 149	2 114	2 087	2 107	1.3	0.4	0.1
Thailand	2 037	2 484	2 841	2 781	2 796	2 787	2 822	2 871	2 884	3 066	3 604	3 649	4 061	2.9	0.5	1.7
Vietnam	133	139	991	1 122	1 291	1 287	1 294	1 305	1 310	2 137	2 696	2 671	2 841	21.4	2.2	3.9
Total	**5 552**	**6 627**	**8 193**	**8 710**	**8 932**	**9 133**	**9 599**	**10 024**	**10 727**	**12 093**	**13 783**	**13 705**	**14 689**	**4.2**	**3.0**	**1.6**

Indonesia

Domestic consumption failed to support any propylene demand increase in Indonesia in 2023. Indonesia's propylene market is dominated by polypropylene, accounting for around 80 percent of demand. End markets were slow as the manufacturing sector in the country struggled to capture demand. Consumers limited their spending as economic uncertainty looms with inflation rate spike. Disruption in the global trade and economic uncertainties have discouraged consumer spending. Suppliers also struggled to maintain operation rates for end derivatives as feedstock cost outpaced end market prices squeezing margins thin. In 2023, propylene consumption remained flat along with polypropylene production. Domestic polypropylene demand recovered sharply with improved economic growth post-pandemic; however, polypropylene producers including Chandra Asri Petrochemical and Pertamina faced production issues during 2021. Pertamina had a fire during March 2021 causing feedstock issues at the polypropylene unit. Chandra Asri Petrochemical's cracker encountered a technical glitch in January 2021, which also caused feedstock disruption to the polypropylene units. Chandra Asri Petrochemical and Pertamina (through Polytama Propindo) are the two major polypropylene producers in the country. Polypropylene production recovered in 2020 after falling sharply in 2019 as Chandra Asri conducted turnarounds and expanded polypropylene capacity by another 80 000 tons per year in 2019. Polytama Propindo also expanded polypropylene capacity by another 60 000 tons per year to 300 000 tons per year in total in the end of 2019. The COVID-19 outbreak capped production growth as it promoted polypropylene demand in some applications while reduced demand of other applications particularly the ones linked to durable items.

The polyolefin market in Indonesia is highly geared towards polypropylene, which accounted for more than 50 percent of overall polyolefin demand in the recent years. The versatility of polypropylene has led to high growth in the manufacturing of a wide range of products in Indonesia including housewares, food packaging, electronics, and automotive components. Polypropylene will remain the major driver for propylene demand in Indonesia. Lotte Chemical Titan has already started construction of a petrochemical complex with integrated propylene and polypropylene which will add 250 000 tons per year of polypropylene capacity. Chandra Asri Petrochemical also plans for the second petrochemical complex which includes polypropylene unit with capacity of 450 000 tons per year. Several announcements of refineries and steam crackers are made in Indonesia and polypropylene units are expected to be integrated in the complexes. Indonesia's propylene derivative demand is supported by continued high population growth, a large consumption base and high forecast GDP growth. As a result, it is expected that propylene demand will grow above GDP in the forecast period.

Malaysia

Sixty percent of Malaysian propylene demand was for polypropylene production, followed by oxo-alcohols and acrylic acid. Unlike the situation in Indonesia, domestic polypropylene demand recovered sharply and polypropylene production in Malaysia was able to meet demand. Resumption of PETRONAS's complex in 2022 after maintenance boosted polypropylene production. Malaysia's propylene consumption contracted in 2021 as a result of sharp decline in acrylic acid production and the on-going shutdown of the RAPID complex. Demand into polypropylene decreased slightly in 2020 as a result of short-lived production by Petronas's RAPID (Refinery and Petrochemical integrated development) complex before experiencing the blast. Propylene consumption will increase significantly during the next few years. Polypropylene capacity from RAPID is 900 000 tons per year in total which will more than double propylene demand in the country. Surplus propylene from RAPID complex is also expected to promote other propylene derivative investments. BASF expressed an interest to increase acrylic acid and acrylates capacity in Malaysia. This will further boost domestic propylene demand.

Philippines

Polypropylene is the country's only propylene derivative. JG Summit Petrochemical significantly expanded its stream cracker and polypropylene plant into operation in March 2021. This increased polypropylene capacity by 110 000 tons per year. Despite unstable production during the early stage, the country's production volume increased by eight percent. Operability was maintained throughout 2022, significantly increasing propylene consumption within the country. In 2023, production of propylene by over 30 percent over 2021. In 2020, polypropylene production remained in an upward trend despite the pandemic outbreak as there were no long turnarounds. In 2019, JG Summit conducted 2-month long turnarounds at its steam cracker in Batagas, affecting both olefins and polyolefins. There were several issues limiting polypropylene production in Philippines through 2019 including earthquake, port congestion, and pressures from economic downturn. These contributed to sharp fall in propylene demand. Once JG Summit achieved stable operation, propylene demand is expected to increase further. Petron is also expected to increase polypropylene capacity by another 75 000 tons which will further increase propylene demand in the medium term. Apart from those, propylene demand is expected to remain stable with no anticipated propylene derivative capacity development.

Singapore

Polypropylene accounted for around two-thirds of total propylene demand in 2023. Almost the entire volume of polypropylene produced is for the export market. International trade continued to be a barrier in 2023 due to competition from China, and polypropylene export from Singapore decreased significantly.

Apart from polypropylene, propylene is consumed into propylene oxide, cumene/phenol, and alcohols. Demand into oxo-alcohols vanished in 2021 as Eastman terminated production of 2-EH and butanols. However, this contributed to minimal propylene demand reduction. Lower export opportunities caused by global pandemic outbreak resulted in sharply lower propylene demand in 2020. Propylene demand in 2019 remained stable as a compensation of lower propylene oxide production and higher cumene exports while polypropylene production and other derivative productions were flat. Propylene consumption in Singapore will stay flat in the medium term as there are no derivative expansions planned while propylene derivative production is expected to be expanded in other countries. The export competition will be tough, and this will limit propylene demand growth in Singapore.

Thailand

In Thailand, polypropylene accounted for around 75 percent of total propylene demand in 2023. The remaining derivatives are propylene oxide and cumene/phenol. Demand declined further in 2023 with a decrease of two percent despite the stable polypropylene production in 2023. Domestic demand has supported the consumption of polypropylene but exports was slow from global economic difficulties. Similar to other suppliers in the region, Thai operating rates fell on the back of thin margins and high feedstock costs. PTTGC started operation of propylene oxide unit with capacity of 200 000 tons in early 2021. Propylene consumption in Thailand declined but at a rate lower than GDP contraction in 2020. Despite relatively stable in domestic demand for polypropylene, COVID-19 outbreak in other countries resulted in lower export opportunities and consequently reduced polypropylene production in Thailand in 2020. Polypropylene bags and single-use polypropylene items were promoted during pandemic and country lockdown. For other derivatives, propylene oxide and cumene/phenol production went sharply lower in 2020. Polypropylene production in Thailand benefited from both domestic market and higher export volumes in 2019. Polypropylene demand went up to replace polyethylene as a trend of durable plastic usage. For propylene oxide, production went up in 2019 to support new downstream polyols unit. Growth of propylene consumption in Thailand is expected to be driven by capacity addition of propylene oxide and polypropylene. HMC Polymers already announced new polypropylene production lines with the capacity of 250 000 tons per year and propylene feedstock is expected to be transferred from its parent company, PTTGC. A new naphtha-fed cracker by PTTGC will help boost feedstock advantage.

Vietnam

Propylene consumption in Vietnam is only for polypropylene production. There are currently three polypropylene producers in Vietnam; Binh Son Refinery (BSR), Nghi Son Refinery and Petrochemical (NSRP), and Hyosung. In 2019, NSRP ramped up the production after start-up, increasing propylene consumption by around half. Hyosung commissioned its first polypropylene production line in February 2020. Hyosung's second polypropylene production line and upstream propane dehydrogenation was brought on-stream in August 2021. Production at Hyosung was able to ramped-up in 2022, and even though running at a reduced rate it boosted the consumption of propylene in the country. This brought the total polypropylene capacity to 1.15 million tons per year and contributed to 27 percent growth propylene demand in 2022. Construction of the petrochemical complex by Long Son Petrochemical is now fully completed. Collectively, polypropylene capacity in Vietnam will reach 1.6 million tons in 2024 when the production at Long Son is able to operate for a full year.

4.3.9.2 Supply

Indonesia

Chandra Asri Petrochemical and the state-owned refiner Pertamina are the only propylene producers in Indonesia. In April 2018, Chandra Asri Petrochemical started to revamp its furnaces, aiming to raise ethylene output and consequently propylene output. During the third quarter of 2019, Chandra Asri Petrochemical conducted a major turnaround and brought the expansion part online. Propylene capacity was raised by another 20 000 tons per year from this expansion. Further from that, Chandra Asri Petrochemical plans to invest around US$4-5 billion for its second steam cracker in Indonesia. The complex is expected to produce around 560 000 tons per year of propylene and is expected to come onstream in 2026. Incentive packages and a tax-holiday were already granted to this project in January 2020, and the company obtained budget approval for land and engineering design. The project is expected to be on schedule as contractors were confirmed in 2021 and final investment decision was made in 2022.

After lengthy research and discussions, Lotte Chemical Titan from South Korea finally executed the groundbreaking for a naphtha cracker at Merak, West Java in December 2018. This US$3.5-billion facility is expected online in 2026 and will be able to produce around 540 000 tons per year of propylene. Furthermore, CPC from Taiwan and Pertamina signed a memorandum of understanding (MoU) in 2018 to set up a new naphtha cracker in Indonesia.

Apart from investment in steam cracker, Pertamina also plans an upgrade of its refinery in Balikpapan, raising its refinery capacity by 38 percent. The company already awarded an EPC contract to Korean firms SK Engineering & Construction and Hyundai Engineering in December 2018. This contract called the Refinery Development Master Plan (RDMP) Balikpapan is worth around US$4 billion. Residual fluid catalytic cracking (RFCC) unit is also part of this project. There will be propylene output of around 230 000 tons per year. The first phase of the upgrade project was completed in 2022 and is expected to come onstream during 2024. Pertamina also agreed with the Russian Oil company Rosneft to form a joint venture called Pertamina Rosneft Pengaolahan (PRPP). PRPP plans to develop new grass root refinery and petrochemical complex in Tuban, East Java. PRPP already signed a contract to conduct the engineering design for the complex in late 2019. Propylene output from this project is expected to be more than one million tons per year capturing from steam cracker and refinery off-gas recovery. The complex is expected to consume all propylene into polypropylene. However, the project is still considered speculative.

Malaysia

The start-up of PETRONAS's RAPID (Refinery and Petrochemical Integrated Development) project at Pengerang lasted only for a short period in early 2020 before it was forced to shutdown for strict inspection and reparation again after a fatal explosion. Therefore, propylene capacity in Malaysia stood around 1.2 million tons per year again during 2020-2021. Operation was able to resume in late 2022 and continue into 2023 increasing the total capacity to 2.5 million tons. Propylene output is collectively from naphtha-based steam cracker and recovery from refinery off gases. Around three quarters of its output is expected to be consumed internally into polypropylene and the remaining is expected to be sold into the market.

Philippines

The Philippines has historically imported much of its propylene requirements, with production limited to Petron's FCC facility that started up in 2008 at Bataan. JG Summit's naphtha cracker at Batangas started up near the end of 2014, and is the first in the Philippines, with a design capacity of 190 000 tons per year of propylene. JG summit expanded its cracker by 50 percent, increasing propylene capacity from 190 000 tons per year to 245 000 tons per year in March 2021. The original plan was to complete the expansion by 2020 but travel limitations due to COVID-19 delayed the project into March 2021. Petron also brought another RFCC unit online which boosted the propylene capacity by 250 000 tons per year since 2016. This made Philippines long in propylene and the country was able to export propylene since 2014.

Singapore

There are four propylene producers in Singapore; ExxonMobil, PCS Singapore, Shell and Singapore Refining (joint venture between Caltex and Singapore Petroleum). The most recent capacity addition was by ExxonMobil as a part of its Singapore Parallel Train petrochemical complex in 2013, while Shell's expansion at Pulau Bukom was completed in early 2015 as part of steam cracker upgrade. Shell additionally debottlenecked its naphtha cracker in early 2015. However, Shell had to declare a force majeure at is cracker in Pulau Bukom from November 2015 until August 2016 due to technical problems. Although the nameplate capacity remains unchanged, Singapore recently imported more LPG for steam cracking, which has a negative effect on propylene output.

Thailand

Thailand's propylene activity is concentrated in Map Ta Phut, Rayong province at the eastern gulf. The capacity steadily increased until 2013, but then remained static until IRPC expanded its naphtha cracker in December 2015 as part of the Phoenix project to upgrade low value products. Map Ta Phut operations are heavily geared towards petrochemicals and include two of the few DCC (deep catalytic cracker) units commissioned outside China. The second DCC unit increased the company's propylene capacity by 320 000 tons per year in 2016. DCC's maximise propylene output from refinery heavy residue upgrading but compromise the quality of the liquid stream which comprises the bulk of the unit's output. PTT has a new naphtha cracker in Map Ta Phut under construction, however the start-up was delayed to 2021 due to traveling restriction caused by COVID-19. This has increased propylene capacity by 260 000 tons per year. SCG Chemical expanded its naphtha cracking facility in late 2021. Propylene capacity is estimated to be increased by around 170 000 tons per year. ExxonMobil also declared its interest to invest around US$8 billion to establish a steam cracker facility near its existing refinery in Sri Racha. Currently, the company has entered a 66 percent majority stake purchase agreement with Bangchak Corp. Public Co. Ltd. (BCP). The purchase is expected to be completed by the end of 2023 or early Q1 2024, at which point all other investment for petrochemical facilities are on-hold.

Vietnam

Commercialisation of Hyosung's new propane dehydrogenation unit with capacity of 600 000 tons per year in August 2021 resulted in propylene capacity in Vietnam exceeding one million tons with a full year operation in 2022. Previously, propylene output was from the refineries of PetroVietnam and Nghi Son Refinery.

Vietnam's petrochemical business will develop significantly in coming years. Long Son Petrochemical will add a further 450 000 tons per year of propylene capacity through its mixed-feed steam cracker in 2023. SCG is now the sole owner of Long Son's project after the company bought out Qatar Petroleum in March

2017 and PetroVietnam in May 2018. SCG is considering a second phase of the petrochemical complex in Vietnam due to high demand growth. The new complex is expected to include propylene capacity with polypropylene but the plan has not yet been finalised. Phu My Plastics also showed an interest to set up an integrated polypropylene production unit with propane dehydrogenation unit. Though there was an announcement for polypropylene technology selection already, the project is still considered uncertain. The capacity is likely to be around 300 000 tons per year for propylene.

4.3.9.3 Supply, Demand and Trade

Indonesia has periodically been a significant propylene importer in South-East Asia, importing around 130 000 tons per year during 2020-2021. Import volume increased by 25 percent in 2022 as production in the country was reduced due to high feedstock cost. Indonesia primarily imports from other South-East Asian countries and Saudi Arabia. In 2019, Chandra Asri conducted major turnarounds at its steam cracker for maintenance and expansion. In 2020, lower gasoline prices restricted refinery production, resulting in lower propylene output by Pertamina. Massive blaze eruption at Balongan refinery in March 2021 by Pertamina did not increase propylene import as the situation became in control in short time. Imported volume from Saudi Arabia vanished in 2021 but Indonesia imported more propylene from Malaysia, Singapore, and Thailand to serve domestic demand.

Malaysia has slight surplus of propylene mainly from propane dehydrogenation and OCU units. Propylene operating rates in Malaysia have remained lower than regional average due to small scale with less integration to downstream. In 2020, PETRONAS’s RAPID complex started operations but only for a short period before an explosion forced the complex to shutdown for long reparation and inspection. The plant was able to resume operation in 2022 which brought down the overall operating rate of the country. Malaysia’s export volume of propylene remained stable through in 2021 to 2023. .

In the Philippines, JG Summit and Petron are the only two propylene producers and consumers, both for polypropylene production. In 2020, COVID-19 reduced the demand for refinery products and propylene which resulted in a low operating rate. JG Summit expanded propylene capacity by debottlenecking its cracker in the first half of 2021 enabling the Philippines to export more propylene over the year. Demand for polypropylene production increased in 2022 which brought down export volume.

In Singapore, major propylene sources are by-products from steam crackers, and with limited feedstock flexibility, propylene production followed ethylene. Singapore remained as almost net balanced in propylene trade position during 2020-2023. Import volumes grew fractionally in 2022 as steam crackers reduced rates due to unfavourable economics.

Thailand is the largest propylene exporter in South-East Asia and currently supplies propylene to China, Taiwan, and South-East Asian neighbours. All propylene producers in Thailand have downstream integration, and metathesis/OCU capacity runs as the secondary source of propylene for exports. The output by these units was limited at times due to bad margins. In 2020, Thailand’s propylene export volume benefitted from a new propylene requirement by a new polypropylene unit in Vietnam. This was only for a short period as new PDH unit in Vietnam started operation in August 2021 which reduced Vietnam’s propylene import requirement. Export volume from Thailand reduced even further in 2022 as feedstock cost for production increased and major export destinations became more competitive.

Vietnam had been essentially balanced in propylene as FCC units are all integrated with polypropylene before 2020. Start-up of polypropylene unit without upstream by Hyosung altered this in 2020. Vietnam mainly imported propylene from Thailand during 2020-2021. Import dependency was further reduced in 2022 as the Hyosung PDH unit started up in late 2022.

Figure 4.20 South-East Asia Propylene Supply, Demand and Trade

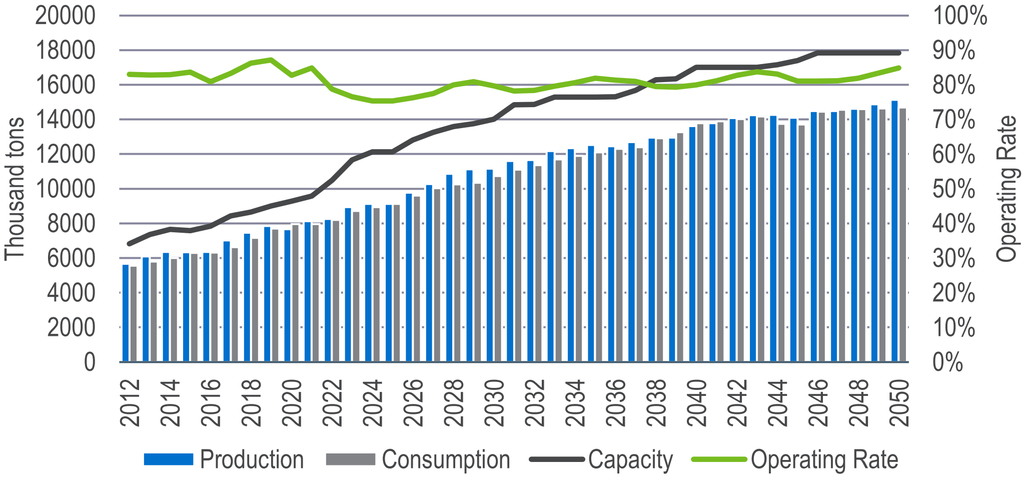


Table 4.24 South-East Asia Supply, Demand and Trade

(thousand tons)

	Actual			Estimate	Forecast									Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2027	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Firm Capacity	6,832	8,427	10,480	11,671	12,129	12,124	12,816	13,264	13,264	13,264	13,269	13,264	13,264			
Speculative	-	-	-	-	-	-	-	-	753	2,033	3,746	4,132	4,584			
Total Capacity	6,832	8,427	10,480	11,671	12,129	12,124	12,816	13,264	14,017	15,297	17,015	17,396	17,848	5.0	2.7	1.2
Operating Rate	83%	83%	79%	77%	75%	75%	76%	77%	80%	82%	80%	81%	85%			
Production	5,669	7,018	8,253	8,933	9,132	9,133	9,769	10,277	11,166	12,528	13,611	14,102	15,140	4.2	3.2	1.5
Net Export	117	391	60	223	200	(0)	170	253	439	434	(172)	397	451			
Consumption	5,552	6,627	8,193	8,710	8,932	9,133	9,599	10,024	10,727	12,093	13,783	13,705	14,689	4.2	3.0	1.6

4.4 POLYPROPYLENE

4.4.1 Global

4.4.1.1 Consumption

Global polypropylene demand was estimated at 84.2 million tons in 2023, an increase of 3.7 percent from 2022, after growing by 0.6 percent in the previous period. The slowdown in the Chinese market as well as other key markets in Western Europe and North America led to the fall in demand growth after growth of five plus percent in the previous two years. New regulations targeting debt-funded construction in China as well as severe COVID-19 lockdowns led to the fall in polypropylene demand there while inflationary pressures led to decreased consumer spending and higher interest rates in North America and Europe. This was primarily caused by the conflict in Ukraine which began in February 2022 and led to inflation in key energy commodities as well as other goods due to market disruption.

Polypropylene markets had shown strong growth over several years, thanks to the polymer's versatility, performance and competitive value which have enabled substitution for other polymers used in film, injection moulding and blow moulding. In particular, the evolution of BOPP films, including their role in stand-up pouches which have replaced large amounts of blow-moulded retail packaging, has been a major demand driver for several years.

The dominant regional market is China with over 40 percent of global demand. China's demand share for polypropylene is higher than for other polyolefins due to its usage in many forms of exported manufactured goods such as durable containers, luggage, garden furniture and automotive components. Asia excluding China is the second largest market followed by North America and Western Europe. Injection moulding applications lead global market, followed by fibre and film. The consumption profile is not expected to change dramatically in the foreseeable future.

The polypropylene market is dominated by homopolymer polypropylene, accounting for more than three quarters of total demand. Film for food packaging, fibre and injection moulding for houseware appliances are the main markets for this type. Impact copolymer polypropylene represents around 15 percent of total demand, primarily for injection moulding, blow moulding and fibre. Meanwhile, random copolymer polypropylene has only around three percent share of total demand, mainly used for film, coating, and blow moulding grades.

The global polypropylene market is expected to increase by 3.4 percent in 2024. With inflation abating and a return to economic growth globally, the market demand growth is also expected to recover. However, strong economic headwinds remain and will limit growth to less than historic rates.

Figure 4.21 Global Polypropylene Demand by Region, e-2023

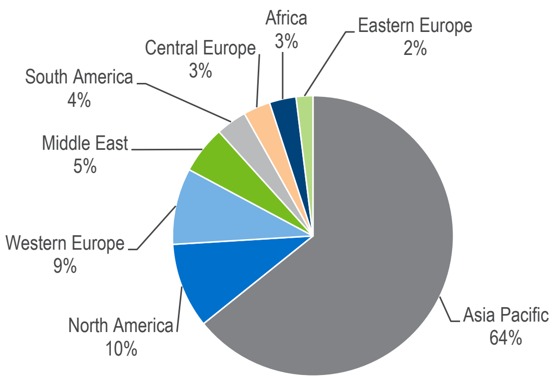


Figure 4.22 Global Polypropylene Demand by End-Use, e-2023

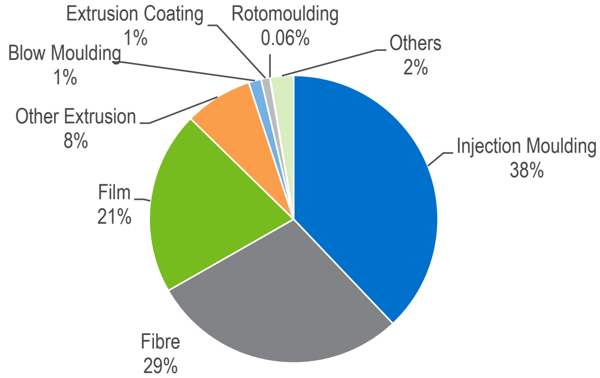


Figure 4.23 Global Polypropylene Demand by Polymer Type, e-2023

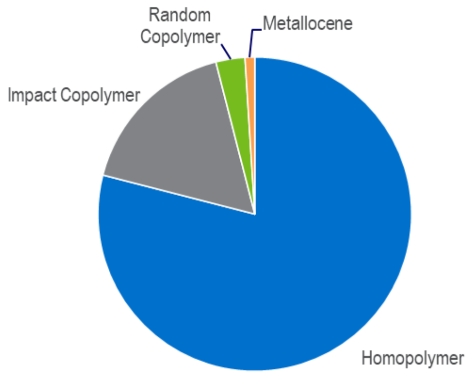


Table 4.25 Global Polypropylene Demand by End-Use
(thousand tons)

	Actual			Estimate	Forecast								Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Injection Moulding	21 367	27 188	30 646	31 954	32 884	34 069	35 494	40 653	46 638	52 040	59 286	65 600	3.7	3.5	2.4
Fibre	14 486	19 237	23 687	24 258	25 177	26 284	27 593	32 200	37 054	41 124	46 648	51 392	4.8	4.1	2.4
Film	10 270	13 081	16 484	17 364	18 075	18 836	19 741	22 978	26 679	29 964	34 465	38 341	4.9	4.1	2.6
Other Extrusion	4 447	5 619	6 292	6 421	6 609	6 885	7 220	8 295	9 429	10 264	11 492	12 545	3.4	3.7	2.1
Blow Moulding	825	1 002	1 160	1 185	1 216	1 259	1 311	1 506	1 715	1 889	2 122	2 322	3.3	3.5	2.2
Extrusion Coating	492	660	783	822	855	894	942	1 105	1 304	1 479	1 727	1 945	4.8	4.3	2.9
Rotomoulding	2	15	50	52	53	54	56	62	69	73	80	86	34.4	2.8	1.6
Others	1 634	1 828	2 119	2 184	2 233	2 301	2 387	2 680	2 980	3 200	3 528	3 800	2.7	3.0	1.8
Total	**53 522**	**68 628**	**81 222**	**84 239**	**87 103**	**90 582**	**94 745**	**109 479**	**125 868**	**140 034**	**159 348**	**176 029**	**4.2**	**3.8**	**2.4**

Table 4.26 Global Polypropylene Demand by Region
(thousand tons)

	Actual			Estimate	Forecast								Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
North America	7 156	8 115	8 198	8 266	8 329	8 525	8 789	9 714	10 785	11 668	12 941	14 037	1.3	2.3	1.9
South America	2 723	2 793	2 945	2 987	3 069	3 183	3 324	3 873	4 440	5 005	5 760	6 397	0.8	3.8	2.5
Western Europe	7 382	7 958	7 166	7 412	7 419	7 494	7 612	7 872	8 211	8 207	8 297	8 380	-	0.9	0.3
Central Europe	1 531	2 157	2 586	2 619	2 664	2 740	2 842	3 140	3 479	3 684	4 041	4 341	5.0	2.6	1.6
Eastern Europe	1 089	1 477	1 584	1 629	1 624	1 670	1 727	1 911	2 135	2 312	2 558	2 769	3.7	2.3	1.9
Middle East	3 691	4 287	4 571	4 633	4 706	4 855	5 079	5 794	6 513	6 999	7 984	8 719	2.1	3.2	2.1
Africa	1 616	2 145	2 570	2 591	2 720	2 873	3 054	3 741	4 559	5 247	6 087	6 863	4.4	5.4	3.1
Asia Pacific	28 334	39 695	51 602	54 102	56 573	59 242	62 318	73 435	85 746	96 913	111 679	124 523	6.1	4.5	2.7
Total	**53 522**	**68 628**	**81 222**	**84 239**	**87 103**	**90 582**	**94 745**	**109 479**	**125 868**	**140 034**	**159 348**	**176 029**	**4.2**	**3.8**	**2.4**

Polypropylene Grade Selection and Characteristics

Polypropylene is a versatile polymer due to the various types and grades that can be produced. The selection of which grade to use for a product depends on a number of factors. There are four primary criteria that should be considered:

- Fabrication process to be used
- Aesthetic requirements of the application
- Mechanical function of the part
- Special additive requirements

There are three primary types of polypropylene – homopolymer, random copolymer, and impact copolymer. Each is manufactured differently and has some unique properties relative to the other types.

- Homopolymer (isotactic structure)
  - Typically made in a single reactor with propylene and a catalyst.
  - Stiffest of the three types and has the highest tensile strength at yield
  - Translucent in a natural state
  - Provides contact clarity when there is intimate contact with the container wall
  - Less impact resistance than other types, especially below 2 °C
- Random Copolymer (homophasic copolymer structure)
  - Typically made in a single reactor with a small amount of ethylene (2-5 percent), which disrupts the crystallinity of the polymer
  - Clearest type, providing contact clarity and see-through clarity
  - Most flexible type with lowest tensile strength
  - Better room temperature impact than homopolymer, but same relatively poor impact resistance at low temperatures
- Impact Copolymer (heterophasic copolymer structure)
  - Made in a two-reactor system, where ethylene and propylene are polymerized in the second reactor to create microscopic ethylene propylene rubber nodules in the homopolymer matrix
  - High impact resistance at ambient and cold temperatures due to nodules
  - Intermediate stiffness and tensile strength
  - Cloudy appearance, except for film and very thin-wall parts

The relative importance of each primary criterion will depend on the application, for example, whether it is a one-time use item or an automotive part. Since the three types of polypropylene (homopolymer, random copolymer, impact copolymer) have distinct characteristics and are typically not interchangeable without compromising a performance property, choosing the type of polypropylene is generally the first choice in selecting a grade. Some of these characteristics are listed in the table below. After the polypropylene type is decided, then the criteria must be considered and prioritized based on the requirements of each application.

Table 4.27 Characteristics of Polypropylene Types
(Source: LyondellBasell)

Characteristic	Homopolymer	Random Copolymer	Impact Copolymer
Contact Clarity	Yes	Yes	No
See-Through Clarity	No	Yes	No
Cold Temperature Impact	No	Limited	Yes
Extreme Elevated Temperature	Yes	No	Limited

The fabrication process to be used requires the choice of an appropriate melt flow rate (MFR). Processes that require high melt strength, such as blow moulding, blown film extrusion, and profile extrusion, require high molecular weight/low MFR grades. Due to the inherent low melt viscosity of polypropylene, a wide range of MFRs can be easily injection moulded. In general, high-speed, thin-wall moulding applications require a higher MFR grade, while thicker-walled, functional parts can utilise a lower MFR grade. Impact properties of impact copolymers are somewhat controlled by the MFR, and lower MFR grades generally have better impact properties.

Aesthetics are important for many applications, such as packaging and housewares, where contact or see-through clarity are necessary characteristics. For these applications, the choice is limited to homopolymers and random copolymers, except for extremely thin-walled parts or film, where almost all products exhibit some degree of clarity. Both homopolymers and random copolymers provide contact clarity when there is close contact between the object and the container wall, but only random copolymers provide see-through clarity. The degree of clarity can be enhanced by nucleating agents called clarifiers. For most wall thicknesses for functional applications, impact copolymers exhibit a milky, opaque appearance, but some degree of clarity is achieved in very thin-wall applications.

For each type of polypropylene, the mechanical properties of different grades are controlled by the molecular weight (MFR), molecular weight distribution (MWD), ethylene content (random copolymers), and the content and composition of the modifier phase (impact copolymers). General trends are listed in the table below.

Table 4.28 Effect of Resin Characteristics on Mechanical Properties

(Source: LyondellBasell)

		Homopolymer	
Property	**Increasing MFR**	**Narrowing MWD**	
Tensile Strength	+++	-	
Stiffness	+++	-	
Impact Resistance	-	+++	
Heat Distortion	+++	-	
Hardness	+++	-	
		Random Copolymer	
Property	**Increasing MFR**	**Narrowing MWD**	**Increasing Ethylene Content**
Clarity	NME	-	+++
Tensile Strength	+++	-	-
Stiffness	+++	+++	-
Impact Resistance	-	-	+++
Heat Distortion	+++	-	-
Hardness	+++	-	-
		Impact Copolymer	
Property	**Increasing MFR**	**Narrowing MWD**	**Increasing Modifier Content**
Tensile Strength	+++	-	-
Stiffness	+++	-	-
Impact Resistance	-	+++	+++
Heat Distortion	+++	-	-
Hardness	+++	-	-
Bruise Resistance	NME	NME	-

The relationships in the table were simplified by LyondellBasell, and it is not unusual to observe synergism when two or more controlling variables are changed at the same time. It is also important to note that a change in one property often creates change in another property and is often in the wrong direction.

Specific additives can enhance the characteristics of polypropylene or impart properties that are not normally present. The prioritised list of application requirements should be used to specify the additives required. Additives may have a negative effect on material processing or application properties. Some of the more common additives used include anti-oxidants, acid scavengers, anti-static agents, anti-block agents, nucleators, clarifiers, Mold release agents, slip agents, UV stabilizers, pigments, and flame retardants. Since polypropylene has poor resistance to UV, UV stabilizers are added for applications with UV exposure. In addition to the listed additives, polypropylene properties can be improved by compounding and blending with fillers (e.g., talc, calcium carbonate, clay (e.g., kaolin), wollastonite, mica, etc.) and reinforcements (e.g., glass fibres, carbon fibres, or natural fibres (e.g., hemp, flax, sisal, wood, and cellulose fibres)).

4.4.1.2 Supply

Global capacity to produce polypropylene was estimated at 107.1 million tons per year in 2023 with an additional 8.3 million tons per year of capacity added. In 2023, an additional nine million tons per year of capacity were expected to be added. By 2025, an additional 25 million tons per year of capacity are expected to be added based on current estimates, although not all projects are likely to go ahead in the given timeframe.

Of this firm capacity, 60 percent of the additions have been announced for China. China accounts for 38 percent of global polypropylene capacity in 2022 and its market share will increase to 42 percent by 2025 based on current announcements.

Figure 4.24 Global Polypropylene Capacity Share by Marketer, e-2023

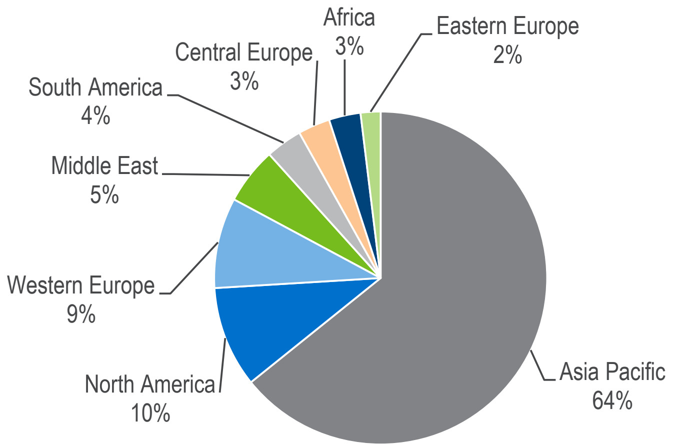


Figure 4.25 Global Polypropylene Capacity

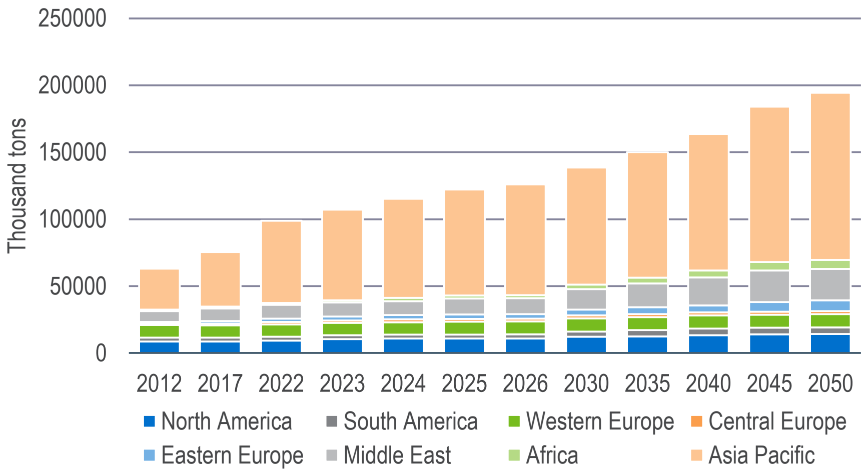
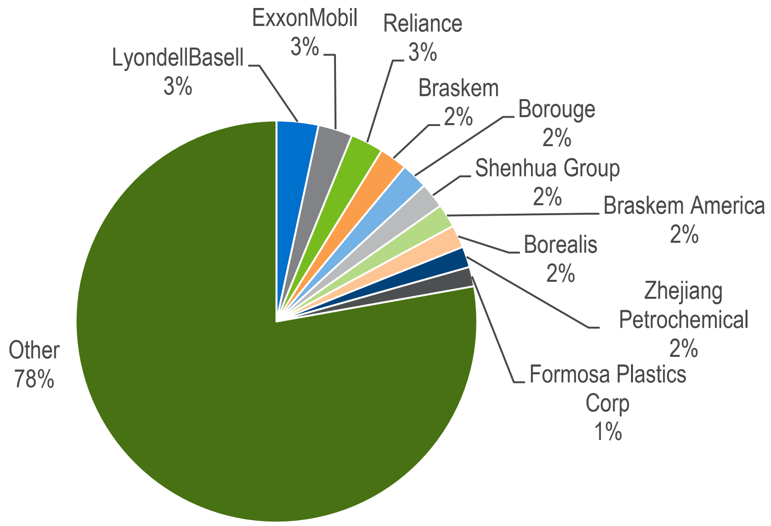


Figure 4.26 Global Polypropylene Capacity Share by Producer, e-2023



4.4.1.3 Supply, Demand and Trade

Global operating rates in 2023 fell about three percent, indicating a slowdown in operating rate drop from about six percent observed in 2022 as slow demand growth was met by the wave of new Chinese capacity growth. Despite recovering demand growth, the amount of capacity coming online in the near term is expected to depress rates through to 2025 before recovering.

The Middle East remained the largest global exporter of polypropylene in 2023, most of which is homopolymer. The region is expected to retain this position through the forecast with exports expected to increase given the favourable feedstock situation and ambitions of regional governments. South Korea is the next single largest exporter followed by Singapore and the United States. Capacity additions in China are expected to impact marginal exporters in the main exporting regions to the country – the Middle East, North-East Asia and South-East Asia. Rates in other regions are also expected to be negatively impacted as the new volumes come online and trade routes begin to re-organise.

Figure 4.27 Global Polypropylene Supply and Demand

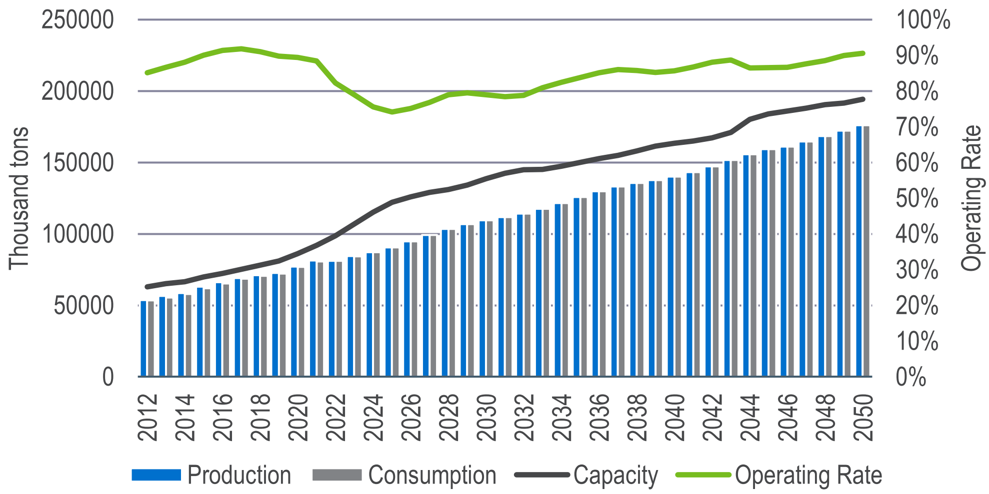


Table 4.29 Global Polypropylene Supply, Demand and Trade
(thousand tons)

	Actual			Estimate	Forecast								Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Firm Capacity	62 943	75 347	98 718	107 051	115 185	122 039	125 283	127 933	127 933	128 284	127 933	127 933			
Speculative	-	-	-	-	-	60	760	10 700	22 200	35 246	56 100	66 400			
Total Capacity	62 943	75 347	98 718	107 051	115 185	122 099	126 043	138 633	150 133	163 530	184 033	186 333	4.9	3.8	1.5
Operating Rate	85%	92%	82%	79%	76%	74%	75%	79%	84%	86%	87%	94%			
Production	53 555	69 117	81 231	84 555	87 103	90 582	94 745	109 479	125 868	140 034	159 348	176 029	4.2	3.8	2.4
Net Export	33	489	9	316	-	-	-	-	-	-	-	-			
Consumption	53 522	68 628	81 222	84 239	87 103	90 582	94 745	109 479	125 868	140 034	159 348	176 029	4.2	3.8	2.4

4.4.2 Turkey

4.4.2.1 Consumption

By far the largest polypropylene market in the Middle East is Turkey. Fibre for the production of woven bags and carpets is the main use of polypropylene in Turkey. Finished product exports make up a significant element of polymer polypropylene demand in the country, and sales of carpets in particular were badly hit by inflation and cost of living effects worldwide in 2023.

Turkish polypropylene demand came under extreme pressure leading to a contraction of seven percent in 2022 to around 2.3 million tons. The impact on demand was from a combination of both local and global concerns. Soaring energy and food prices hit local demand and triggered the return of Turkey's long-standing inflation-related problems which have impacts across the economy. Furthermore, the increase in interest rates in Western regions in particular choked demand for manufacturing exports from Turkey, while higher food and energy costs impacted demand for manufactured goods in regional markets. The evolving market situation in 2023 gave little reason for cheer. Demand was down in the first five months of the year, although there remain hopes for a recovery sufficient to overcome this in the second half of the year with demand expected to remain at 2.3 million tons.

The polypropylene fibre demand from the country's famous carpet industry was particularly hard-hit by the ongoing constraints in buying power in key export destinations such as Europe and the United States. The impact of recessionary conditions and higher borrowing costs is also compounded by an end to some COVID-type buying behaviours. Consumers had less disposable income, and are spending more on travel, and less on home furnishing etc products.

Further challenges were seen in the construction and automotive sectors, which had been struggling even before COVID-19 badly impacted the sectors. Turkey's own construction industry contracted by slightly over one percent in 2022, reflecting economic uncertainty and currency instability. The return to conventional economic wisdom in Turkey (increasing interest rates to control inflation) is likely to continue to impact the construction sector in the near term. The re-election of President Erdogan dashed hopes of widespread reform which may have unlocked some potential for growth but did at least end uncertainty and provide some continuity.

Automotive production was heavily impacted by the pandemic, and the resulting knock-on effect of global supply chains caused further problems in 2021. Production increased by six percent in 2022 however and has continued to growth strongly in 2023.

Leading appliance manufacturers faced much more challenging trading conditions in 2022, and post margins far below those of 2022, mainly as a result of hyperinflation and weak export demand to the EU.

Following from the COVID-19 outbreak there has been an increase in the demand for plastic products in the medical sector. New capacity has been installed, and producers of masks and gloves have been running flat out to account for heightened demand. Furthermore, there has been a significant increase is observed in the disposable packaging and film sector as consumers changed habits to prioritise public health and prevent the speak of COVID-19. Accordingly, the demand for all these products has increased.

The country is heavily reliant on imported polypropylene due to the small domestic production capacity. The local producer Petkim only produces homopolymer, although the market is heavily oriented towards homopolymer, particularly for the fibre and raffia sector. Turkey is a key market for exporters in Western Europe, the Middle East and Egypt however, as well as new capacity in Russia and Central Asia. Domestic consumption is led by the fibre segment, with strong demand also into other extrusion, injection moulding and film segments.

Turkey is home to a large textile and carpet industry and polypropylene fibre is commonly used in carpet production as it is hard wearing and stain resistant, and also competitive in carpet backings. Carpets produced with acrylic fibre are preferred in the local market, polypropylene fibre-based carpets are mostly produced for export so long-term growth is very dependent on the health of export markets. Fibre products for textiles in this sector include BCF and non-woven grades. The U.S. has now terminated Turkey's preferential trade status, which previously allowed Turkey to export several types of carpets to the U.S. duty free. Raffia accounts for a large segment of fibre demand. After an initial dip early 2020, the textile industry in Turkey recovered well and performed significantly better in 2021 with exports of carpets increased 12 percent in volume terms as the global economy recovered during the year. There was also a significant boost in demand for the production of face masks and hygienic products amid the coronavirus outbreak. In 2022 the main impact was the sharp drop in export demand for carpets.

In 2019, Turkey issued a regulation to reduce the consumption of plastic bags, which banned free plastic bags, while packaging used in the Turkish market must be at least partially made from recycled materials. Plastic bag usage has dropped by 75 percent since retailers began charging for plastic bags due to this legislation. This is despite the preference for single use plastic bags by some consumers during the pandemic. At the start of 2022 a Deposit Return System will come into force across the country, allowing the public to return empty bottles in exchange for cash in an attempt to curb bottle waste and increase the level of recycling across the country.

Figure 4.28 Turkey Polypropylene Demand by End-Use, e-2023

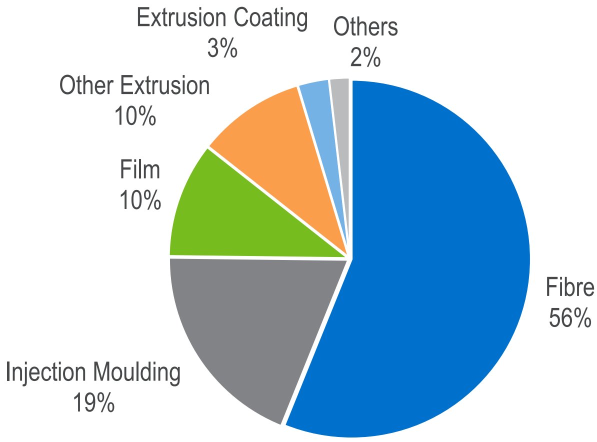


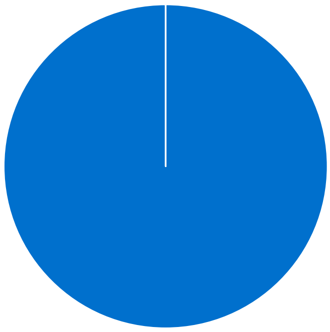
Table 4.30 Turkey Polypropylene Demand by End-Use
(thousand tons)

	Actual			Estimate	Forecast								Average Annual Growth Rate, %		
	2012	**2017**	**2022**	**2023**	**2024**	**2025**	**2026**	**2030**	**2035**	**2040**	**2045**	**2050**	**2012-2023**	**2023-2030**	**2030-2050**
Fibre	866	1 098	1 275	1 280	1 299	1 333	1 379	1 486	1 620	1 703	1 912	2 078	3.6	2.2	1.7
Injection Moulding	290	322	433	435	431	433	439	445	471	498	566	620	3.8	0.3	1.7
Film	261	250	235	238	244	253	264	295	334	363	416	461	(0.8)	3.1	2.3
Other Extrusion	215	211	220	222	224	229	236	255	287	316	367	411	0.3	2.0	2.4
Extrusion Coating	66	75	63	64	65	66	68	73	82	90	105	118	(0.2)	1.9	2.4
Others	62	63	41	42	43	45	47	52	58	61	67	72	(3.5)	3.1	1.7
Total	**1 760**	**2 019**	**2 267**	**2 281**	**2 306**	**2 359**	**2 433**	**2 605**	**2 853**	**3 031**	**3 434**	**3 760**	**2.4**	**1.9**	**1.9**

4.4.2.2 Supply

Petkim is currently Turkey's only polypropylene producer and has a 144 000 tons per year plant based in Aliaga, near Izmir in western Turkey.

Figure 4.29 Polypropylene Capacity Share by Producer - Turkey, e-2023



The Turkish government has an intention to increase petrochemical output and reduce dependence on imports. To support this there have been a number of proposed projects and there is a possibility that Petkim could further expand its existing facilities. After a small expansion at the Petkim steam cracker, the focus has now shifted to PDH.

In 2017, Bayegan, a Turkish private trading and distribution company for refining and petrochemicals, CPEY, a subsidiary of Rönesans Holding and Algeria's SPIC (Sonatrach Petroleum Investment Corp), agreed a deal to develop a PDH/polypropylene facility in Turkey. Bayegan is no longer part of the project however. The project company, which is a mixed company under Turkish law and called "Ceyhan Polipropilen Üretim Anonim Şirket" was created on 19 August 2019 and has a shareholding structure of 34 percent for SPIC and 66 percent for CPEY.

The Rönesans facility is to be based in Ceyhan Yumurtalik, southern Turkey, and to be supplied by propane from Algeria. The plans include a 457 000 tons per year PDH plant and 450 000 tons per year of polypropylene. Ground has been broken on its previously announced US$1.7-billion project and it is scheduled to start operations in 2025. UOP will license its C_3 Oleflex technology for the PDH unit and LyondellBasell's SPHERIPOL technology will be used for PP production using the Avant ZN catalyst covering the production of a full range of polypropylene grades. The project will triple Turkey's annual polypropylene production capacity, substituting 20 percent of Turkey's annual imports.

The major polyester producer SASA is now looking to invest in olefins. SASA has massively expanded its PET production and is investing upstream with a major PTA plant. It has now announced a US$20 billion investment program including two PDH plants of one million tons per year each, which will be the largest in the world. The first is to supply one million tons per year of polypropylene capacity, and the second will supply other propylene derivatives.

In early 2018, Turkey's Metcap Energy Investments announced a 50:50 joint venture project with Qatar's Fusion Dynamics for a new petrochemical facility in Turkey. Located in the Thrace region, the US$4 billion facility will be based on natural gas feedstock. Announced capacity includes 2.6 million tons methanol, one million tons of olefins, 600 000 tons of polypropylene and 400 000 tons of polyethylene. This project is in the early stages of planning and if it goes ahead, it will substantially reduce Turkey's reliance on imports. The initial plans for commissioning between 2020 and 2023 will be impossible, and it looks increasingly unlikely to go ahead with no revised timeline or further details being proposed.

4.4.2.3 Supply, Demand and Trade

Turkey’s polypropylene supply is limited to one small plant with a total capacity of 144 000 tons per year, while domestic consumption stood at 2.2 million tons in 2022. Around one-third of the imports are normally from Saudi Arabia, which is especially dominant on homopolymer but also supplies over 100 000 tons per year of copolymer polypropylene.

The large domestic markets have encouraged high operating rates at the regional facility however the output from the domestic facilities is insignificant compared to the volume of demand. Turkey’s status as the second largest polypropylene importer globally has driven interest in new capacity. Expansion at the existing site has not been possible due to a lack of available propylene. Rönesans Holdings is to be the first online with new capacity, at the coastal location of Yumurtalik, near Ceyhan. The plans include a 457 000 tons per year PDH plant and 450 000 tons per year of polypropylene with operations scheduled to start in 2025. Yumurtalik is around two hours by road from the city of Gaziantep which has around one million tons per year of polypropylene consumption in its surrounding area, much of which is for carpet. SASA is expected to follow with one million tons per year of polypropylene towards 2030. Capacity addition will significantly reduce Turkey’s import requirement but will be internally focused and is not expected to result in exports.

Turkey is one of the global major net importer markets for polypropylene with net imports approaching 2.4 million tons per year on average. The market is dominated by polypropylene homopolymer, which accounts for almost 82 percent of net imports, with the remaining 18 percent from polypropylene copolymers. Homopolymer is predominantly supplied by Saudi Arabia where approximately 40 percent of supplies originate. The remaining two-thirds of imports were obtained from a wide variety of different countries with other main suppliers being Egypt, Russia, South Korea, India, and Western Europe. Polypropylene copolymer is also supplied by a wide range of different countries with the larger suppliers being Saudi Arabia, South Korea, and Western Europe (mainly Belgium and Spain), while smaller suppliers include UAE and Singapore.

Turkey is part of a customs union with the EU, as well as free trade agreements with the European Free Trade Association (EFTA), and numerous other countries including Singapore and the UK. This allows tariffs to be removed from polyolefin trade volumes. Negotiations to do the same with Georgia, Moldova, and Malaysia are ongoing. Generalised Scheme of Preferences (GSP) countries are generally subject to a three percent duty. Those countries not included are subject to a 6.5 percent import tariff.

Figure 4.30 Turkey Polypropylene Supply and Demand

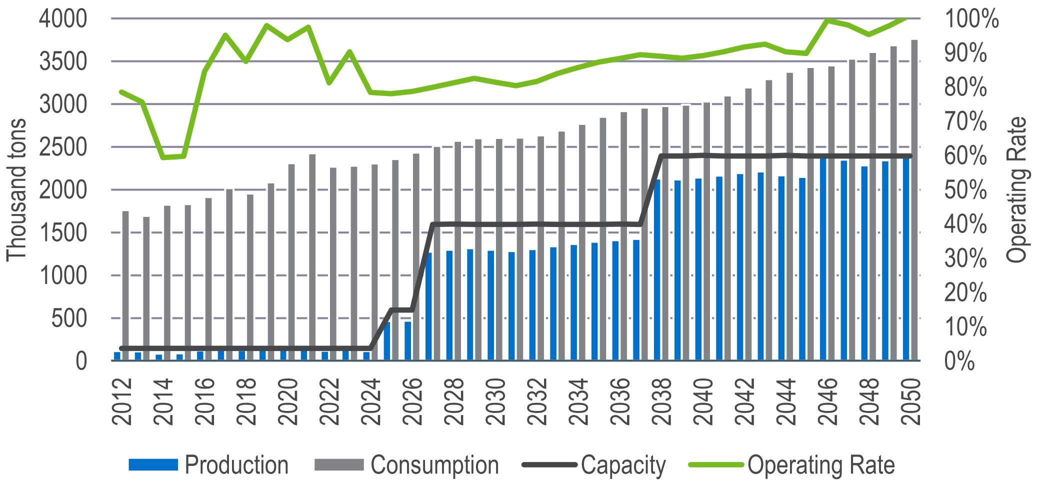


Table 4.31 Turkey Polypropylene Supply, Demand and Trade
(thousand tons)

	Actual			Estimate	Forecast								Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Firm Capacity	144	144	144	144	144	594	594	594	594	596	594	594			
Speculative	-	-	-	-	-	-	-	1 000	1 000	1 805	1 800	1 800			
Total Capacity	144	144	144	144	144	594	594	1 594	1 594	2 401	2 394	2 394	-	41.0	2.1
Operating Rate	79%	95%	81%	90%	78%	78%	79%	81%	87%	89%	90%	101%			
Production	113	137	117	130	113	463	468	1 298	1 391	2 141	2 149	2 417	1.3	38.9	3.2
Net Export	(1 647)	(1 882)	(2 150)	(2 151)	(2 193)	(1 896)	(1 966)	(1 307)	(1 461)	(890)	(1 285)	(1 343)			
Consumption	1 760	2 019	2 267	2 281	2 306	2 359	2 433	2 605	2 853	3 031	3 434	3 760	2.4	1.9	1.9

4.4.3 Western Europe

4.4.3.1 Consumption

Western European polypropylene consumption declined by around five percent in 2022. This is mainly attributed to domestic converters facing high feedstock prices and high energy costs, making it difficult to compete with imports of plastic goods, and causing converters to destock and trim production rates as price rises cannot be pushed through to customers. The high levels of inflation in the region and economic uncertainty also caused demand to dampen. Overproduction in 2021 also contributed to destocking downstream in 2022. Increased exposure to construction sector, fibre and higher-ticket items contributed to the worse performance of the polypropylene markets compared to polyethylene last year.

Polypropylene demand in Western Europe mainly depends on the performance of downstream domestic end-use markets; however, intermaterial substitution also affects demand. Currently, there are plans to increase polypropylene capacity in Europe in the medium-term, and higher oil prices disfavour naphtha cracking over lighter feeds, leading to a lower availability of propylene, and therefore intermaterial substitution with polyethylene is expected to have a larger impact in the market if oil prices remain high.

The automotive sector is also a large consumer of polypropylene, as it is used in bumpers, internal trim and external trim. The automotive parts supply chain is complex, and many parts are sourced from Asia, Central Europe, and Eastern Europe. However, there is ongoing investment in parts manufacturing in Western Europe with Steep Plastique, a tier one automotive supplier, completing its construction of a large injection moulding facility in Portugal during 2021. Furthermore, automotive manufacturers such as Volvo are planning expansions in Europe, which will lead to greater demand, which could lead to further part manufacturing in the region.

The automotive market makes up a large segment of polypropylene demand and therefore polypropylene demand was more significantly affected by the sharp decline in the Western European automotive market than other polyolefins. A shortage of semi-conductor chips has plagued the market with production falling, leading to a drawdown in inventory levels. Lightweighting trends have favoured increasing use of polypropylene in the past twenty years and the material continues to find new applications in the car interior and exterior, and under the hood, replacing some metal parts. However, the next phase in lightweighting involves substituting polymers with lighter composites, and so the trend is not expected to increase polypropylene demand significantly.

Injection moulding is the largest end-use segment, accounting for over half the polypropylene demand in Western Europe. Of this segment, the most influential sectors are rigid packaging, automotive and housewares. The largest of these sectors is rigid packaging. The automotive market recovered slightly in 2022; however, semi-conductor chip shortages have continued, and the Russia-Ukraine conflict has had a negative impact, while inflationary pressures will result in consumers putting off bit ticket items.

Fibre was the second largest segment in 2022, although there was a decline in demand due to weaker hygiene demand and increased competition with imported film products mainly from the Middle East and India, causing some lines to be idled in 2022. The drop in hygiene demand followed a normalisation of the hygiene and medical sectors as government eased mask mandates across the region. Fibre faces competition from other polymers such as nylon and polyester into carpet manufacture, which is also expected to fall due to increasing economic concerns. The withdrawal of the thin HDPE bags supports an increase in demand for the more environmentally friendly, reusable “bags for life” which are made from LDPE, blends of LDPE and LLDPE or more heavy-duty polypropylene. There is scope for recycled polypropylene substituting virgin polypropylene fibre for use in concrete strengthening applications.

The film segment was the third largest in 2022 although usage levels remain below historical peaks following changing consumer usage trends and EU regulations driving a reduction in waste. The BOPP sector has also been hit by cheap finished film imports from India and Saudia Arabia, which is expected to continue. The change in consumer trends has led to strong growth in e-commerce and food deliveries. Since film is used to package these, strong growth persisted in film applications. BOPP films are expected to support demand for polypropylene film, as multinational brands are looking to film producers and converters to provide mono-material plastic packaging solutions to meet their sustainability commitments. Sustainability is becoming increasingly important for consumers, with brands continually seeking to incorporate recycled plastic content; however, developments with recycled resin continue to be slow, limiting the substitution.

Other extrusion demand decreased slightly in 2022, due to poor construction performance. Moreover, the decline follows a spike in demand in 2021, which resulted in supply chain disruption and material cost escalation, putting increasing pressure on output and leading to unprecedented lead times and shortages in both material and labour. The shortages have pressured up material costs and companies are passing through price hikes to their sales prices.

Blow moulding is a relatively minor application for polypropylene in Western Europe as PET and polyethylene dominate the bottles and containers market. One niche for polypropylene blow moulding is the production of industrial containers, such as intermediate bulk containers (IBCs).

Intermaterial competition may actually boost polypropylene consumption, as polypropylene producers and some European retailers have been promoting polypropylene as a more environmentally friendly alternative to polystyrene. Polypropylene is more lightweight than polystyrene and is more economical to collect for recycling, as larger volumes are in circulation. Moreover, the production process is less energy and water intensive than polystyrene production.

The region continues to be affected by the introduction of legislation to reduce waste and to increase recycling, although the actual impact on virgin polymer demand is still limited with volumes available remaining limited and the quality of recycled polymers remains another issue. Polypropylene applications that are typically targeted by waste reduction drives including flexible packaging film, sheet, rigid packaging, caps and closures, containers, and injection moulding products. A flexible packaging tax in Italy has again been postponed, this time to the start of 2023, while Spain has also proposed a tax of €450 per ton on non-reusable plastic packaging to come into effect in 2023. A number of taxes have come into effect with the UK introducing a £200 per ton tax on plastic packaging in April 2022, while a levy of €800 per ton on plastics packaging in the EU was introduced at the start of 2021, appears not to have any material impact on polyolefins producers. Polypropylene is likely to be less affected by waste reduction legislation than other polymers, as lower volumes are used in the much maligned single-use plastics. In the past decade, several West European companies invested in polypropylene recycling and waste reduction projects:

Borealis acquired MTM plastics in mid-2016 and in 2019 announced a new technology, "Borcycle", used to produce polyolefin compounds containing over 80 percent recycled material. MTM plastics is regarded as one of the largest recyclers of polyolefins in Europe and owns a plant that can recycle 30 000 tons per year.

LyondellBasell announced production of virgin quality polymers from raw materials derived from plastic waste at its Wesseling, Germany, site. Produced by the thermal conversion of plastic waste, this raw material is converted into ethylene and propylene and then processed into polypropylene and polyethylene in the downstream units for plastics production. The products will be marketed under the Circulen brand name.

LyondellBasell opened a new recycling facility in early 2018, in a joint-venture with Suez located in Sittard-Geleen, Netherlands. The Quality Circular Polymers (QCP) plant has the capacity for 35 000 tons of recycling capacity for HDPE and polypropylene initially which can be expanded to 100 000 tons in future years. LyondellBasell have set a target to convert 50 000 tons annually by 2021 and in 2019, QCP expanded the grades and colours of HDPE and polypropylene. These products are also marketed under the Circulen brand name.

Borealis also acquired GmbH Ecoplast Kunststoff in 2018, a leading plastics recycling company.

In 2019 TotalEnergies acquired Synova, a leader in the production of recycled polypropylene. A project was implemented in 2021 to double Synova production capacity to 45 000 tons per year, including one product line for glass fibre-reinforced materials.

Repsol has introduced a project to promote the circular economy in chemicals, which involves the mechanical and chemical recycling of polyolefins with a capacity of 74 000 tons per year through its Project Zero and Reciclex. The range now incorporates four new polymers for the automotive industry and three new circular polypropylene grades for non-food containers, incorporating up to 80 percent recycled plastic content.

Figure 4.31 Western Europe Polypropylene Demand by End-Use, e-2023

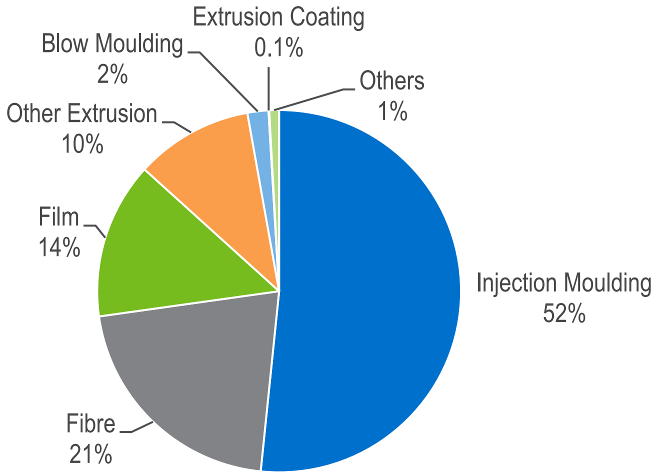


Table 4.32 Western Europe Polypropylene Demand by End-Use
(thousand tons)

	Actual			Estimate	Forecast								Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Firm Capacity	9 466	9 245	9 205	9 285	9 310	9 585	9 585	9 585	9 585	9 611	9 585	9 585			
Speculative	-	-	-	-	-	60	60	200	200	201	200	200			
Total Capacity	9 466	9 245	9 205	9 285	9 310	9 645	9 645	9 785	9 785	9 812	9 785	9 785	(0.2)	0.8	-
Operating Rate	87%	96%	80%	84%	82%	80%	82%	84%	90%	92%	93%	95%			
Production	8 277	8 886	7 388	7 797	7 608	7 734	7 869	8 262	8 802	9 047	9 084	9 329	(0.5)	0.8	0.6
Net Export	894	927	222	384	190	240	257	390	591	841	787	949			
Consumption	7 382	7 958	7 166	7 412	7 419	7 494	7 612	7 872	8 211	8 207	8 297	8 380	-	0.9	0.3

4.4.3.2 Supply

Borealis is expanding its polypropylene capacity at Kallo, in the port of Antwerp, by 80 000 tons per year. The FEED study was completed in June 2018, the final investment decision was made in October 2018 and the new capacity was initially expected to be brought onstream in 2020, but the project has been delayed. The polypropylene plant will be downstream of a new 750 000 tons per year PDH plant and will allow Borealis to reduce its reliance on feedstock from external sources, which has been delayed due to the impact on the schedule caused by the pandemic and its start-up is now expected in the middle of 2024. The product from the new polypropylene capacity will be for applications in the automotive sector, where polypropylene is used as the material of choice in designs for lighter vehicles.

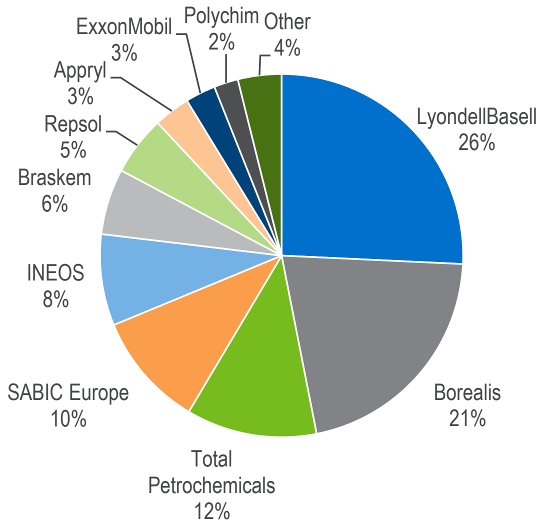
In line with the increased sustainability awareness, Borealis has started to produce polypropylene based on Neste-produced renewable feedstock in its production facilities in Kallo and Beringen, Belgium marking the first time that Borealis has replaced fossil fuel-based feedstock in its large-scale commercial production of polypropylene. Its circular polyolefin products are being marketed as part of its Bornewables™ portfolio, which it notes can be used in for a range of industries including food-contact packaging and healthcare applications.

Repsol is set invest €657 million at its facilities in Sines, Portugal to build two units to produce 300 000 tons per year of polyethylene and 300 000 tons per year of polypropylene. The two units are expected to start up in 2025 and this will increase the level of integration at the complex with the expectation of a new logistics facilities, incorporating the possibility of using rail transport to improve connection to the European market. Repsol has appointed Maire Tecnimont SPA as EPC contractor for both units and the plants will consume excess ethylene and propylene already available at the site. LyondellBasell's Spherizone technology has been selected for the plant.

TotalEnergies closed its 160 000 tons per year "PP1" line at Feluy in 2020 and expanding its 450 000 tons per year "PP3" line, which has reduced the overall capacity of polypropylene at Feluy by 40 000 tons. While the plants at Feluy are not the largest, there are considerable operational advantages from this, such as less frequent grade changes, which boosts the site's economics. Furthermore, at the start of 2022 TotalEnergies announced the start-up of new production of high-performance polymers with the commissioning of a new reactor in its polypropylene unit at Feluy, Belgium. The plant had a force majeure from October 20233 to May 2023.

INEOS has plans to build a new ethane cracker as part of its "Project One" investment in Antwerp to address the shortfall in the company's supplies. A PDH complex is set to follow the steam cracker with INEOS noting the growing need for ethylene over propylene in Antwerp to address the shortfall in the company's supplies. The world-scale PDH unit will have a capacity of 750 000 tons per year of propylene and will be supplied by feedstock from the U.S. A License Agreement was signed with McDermott technology in October 2018 and the contract with SK E&C for the FEED study was signed in June 2019. The plant was expected to come onstream in 2023 but this has been postponed prioritising construction of the cracker in response to the growing need for ethylene. The cracker is expected to stat-up mid-2026 and the PDH unit will follow, and increased capacity of propylene will be to support existing INEOS polypropylene production facilities.

Figure 4.32 Polypropylene Capacity Share by Producer – Western Europe, e-2023



4.4.3.3 Supply, Demand and Trade

Polypropylene trade remained remarkably stable in 2022 considering the turmoil in global markets. West Europeans lost volume to major export markets such as Turkey which were more actively contested by Russia, but volumes to more destinations such as Central European countries were relatively stable, although there was a drop to Poland the Czech Republic.

Western Europe is historically a net exporter of polypropylene, with levels regularly exceeding 800 000 tons in almost all years since 2012, but it surrendered some of its export position in 2021. Actual traded volumes are much higher, with Western Europe both importing and exporting over 1.4 million tons per year of homopolymer polypropylene. West European producers also export over 1.3 million tons per year of copolymer polypropylene but import much less just below 500 000 tons.

Propylene supply longer term will be supported by investment in PDH capacity, which will offset expected further declines in FCC propylene supply. Competition will increase due to recent investment in polypropylene capacity in other regions such as Turkey, Central Europe, the UAE, and Saudi Arabia. Meanwhile investment in Russia looks less certain following the political and economic pressures following from its invasion of Ukraine.

In terms of net trade for individual countries Belgium had the largest net exports in 2022, despite net exports decreasing as imports increased in the year against falling exports. It mainly supplies polypropylene to other countries in Western Europe from domestic production. The Netherlands also has significant net exports, with Austria and France retaining modest net export positions. Germany has surrendered its net export position to become balanced; however, it still accounts for the highest net exports to markets outside of Western Europe, followed by Belgium, while the Netherlands, France, and Austria are also modest inter-regional exporters.

Poland represents the single largest destination for Western European polypropylene, closely followed by Turkey. Significant volumes flow into other Central European countries, particularly to Czech Republic, Slovakia, Romania, Hungary, and Bulgaria. Trade with Russia fell in 2021 as the full impact of the extension of sanctions was realised and dropped sharply in 2022. Trade with Russia is expected to reduce in the year as European consumers continue to distance themselves from Russia which is increasingly impacted by the ever-mounting sanctions imposed on both individuals and companies. This will reduce the net imports from the country and producers in other regions, such as Central Europe are likely to make up for the loss of trade.

Italy remains Western Europe's largest net importer by far, with most imports sourced from within the region. A large proportion of imports from outside of the region were sourced from Saudi Arabia, while significant quantities were obtained from Central Europe (Czech Republic, Hungary, Poland, and Slovakia), South Korea, Russia, Egypt, Israel, and the United States.

Imports increased in 2022 with greater volumes from the United States on easing freight rates and increased domestic availability compared to 2021 where volumes were constrained by a severe winter storm. Furthermore, the spate of capacity additions in Asia Pacific will result in Middle Eastern producers marketing greater volumes into Western Europe as the Asian market remains long.

The EU has engaged in numerous free trade agreements with various countries worldwide. Significant agreements in place include Norway, Switzerland, Mexico, Turkey, South Korea, Ukraine, South Africa, Israel, Canada, Japan, Vietnam, Singapore, and Egypt, as well as numerous other countries. A trade agreement came into force with the UK during 2021 after it left the EU. There are also agreements signed but not fully implemented with countries including Canada in addition to a range of countries in the Caribbean and Africa. There are ongoing negotiations for agreements with Australia, China, Indonesia, and Philippines. These free-trade agreements have supported trade with the EU. It was estimated that the impact on prices is a reduction of seven percent.

Figure 4.33 Western Europe Polypropylene Supply and Demand

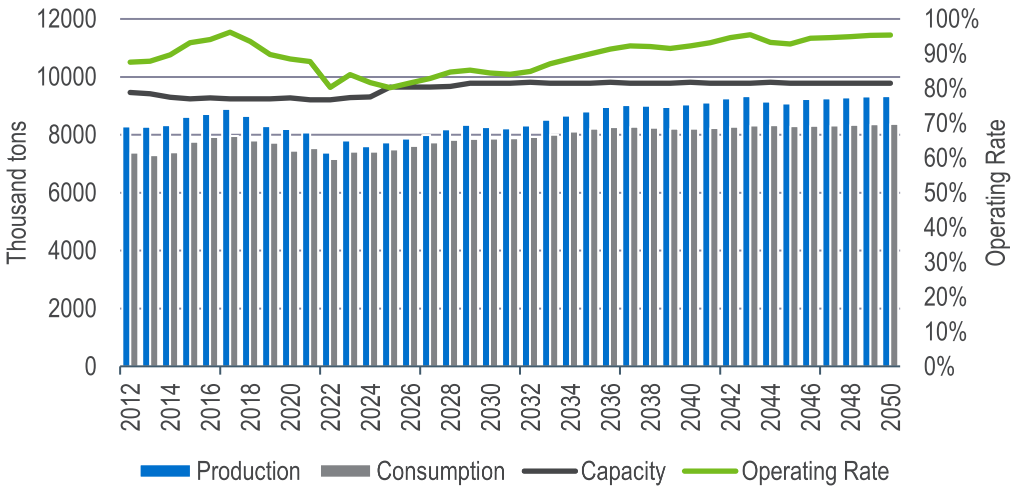


Table 4.33 Western Europe Polypropylene Supply, Demand and Trade
(thousand tons)

	Actual			Estimate	Forecast								Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Firm Capacity	9 466	9 245	9 205	9 285	9 310	9 585	9 585	9 585	9 585	9 611	9 585	9 585			
Speculative	-	-	-	-	-	60	60	200	200	201	200	200			
Total Capacity	9 466	9 245	9 205	9 285	9 310	9 645	9 645	9 785	9 785	9 812	9 785	9 785	(0.2)	0.8	-
Operating Rate	87%	96%	80%	84%	82%	80%	82%	84%	90%	92%	93%	95%			
Production	8 277	8 886	7 388	7 797	7 608	7 734	7 869	8 262	8 802	9 047	9 084	9 329	(0.5)	0.8	0.6
Net Export	894	927	222	384	190	240	257	390	591	841	787	949			
Consumption	7 382	7 958	7 166	7 412	7 419	7 494	7 612	7 872	8 211	8 207	8 297	8 380	-	0.9	0.3

4.4.4 Central Europe

4.4.4.1 Consumption

In 2022, the demand for polypropylene in Central Europe was approximately 2.6 million tons, an increase of two percent from 2021. Homopolymer made up 62 percent of this quantity, with the remaining being copolymer and related compounds and alloys. West European countries supplied around 49-50 percent of the demand, and intraregional trade accounted for about 23-25 percent. Injection moulding grades were the most processed, followed by biaxially oriented, cast, and other films processing technologies. The demand for personal protective equipment during the COVID-19 pandemic benefited fibre manufacturing processes. Non-thermoformed and thermoformed sheets processing technologies were used for packaging, and the market fared relatively well during the COVID-19 confinement measures. The extrusion segment also included pipes and conduits products processed by extrusion technologies. Per capita consumption rates for polypropylene were already high in Central Europe due to the automobile and appliances manufacturing industries, which were driven by local and export sales. The markets for biaxially oriented and cast films, as well as sheet manufacture for rigid packaging thermoformic applications, were still expanding, while growth rates for polypropylene compounds and alloys were expected to decline due to saturation and changes in the automotive industry.

The use of polypropylene resin in the production of expandable polypropylene resins, mainly for the automotive industry, has been a challenging sector since 2018. Polypropylene has been the most dynamically growing commodity polyolefin in the region, along with metallocene LLDPE. However, there are mixed signals due to already announced expansions and investment projects by suppliers in the polypropylene resin processing sector. These projects may be in doubt due to the significant volume losses caused by COVID-19 and the downtrend in vehicle production in recent years. Passenger car production in Europe declined by 1.6 percent in 2022, with contrasting underlying trends between the European Union and Eastern Europe. The EU contributed to an increase in production levels, with a gain of 7.1 percent for the full year. However, overall volumes across the region were significantly impacted by the collapse of the Russian and Ukrainian markets, which decreased by 67.4 percent and 79.7 percent respectively. In 2022, most of the Central and Eastern European countries increased their passenger car production. Despite the significant downturn in passenger car production numbers across the region in 2020, Sumitomo Chemical announced in February 2021 that its Sumika Polymer Compounds branch would build a 30 000-ton-per-year polypropylene compounding plant in Poland, which was expected to come on stream in the spring of 2022. Additionally, in the automotive industry, Magna Exteriors Bohemia and Simoldes Plasticos Lipovka (both in the Czech Republic) announced significant injection moulding capacity increases for the near future. Many of the region's automotive suppliers export the majority of their products to Germany. The optimism of a number of automotive suppliers in the region may stem from the EU-Chinese economic agreement, with German automobile exports to China at its core.

Figure 4.34 Central Europe Polypropylene Demand by End-Use, e-2023

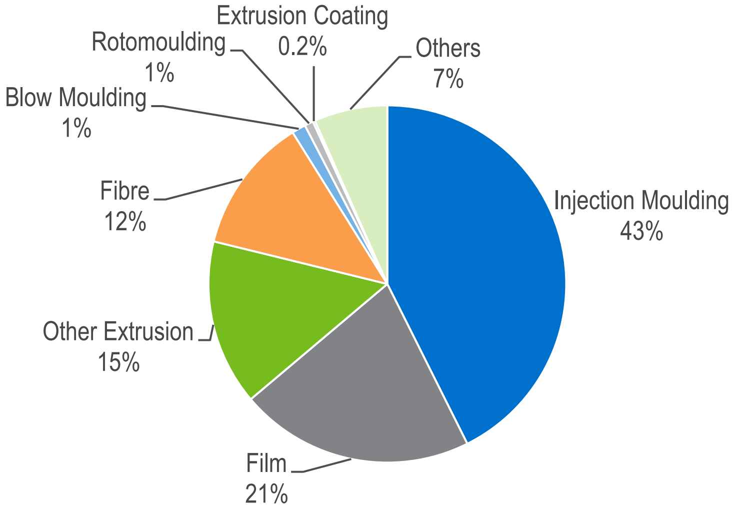


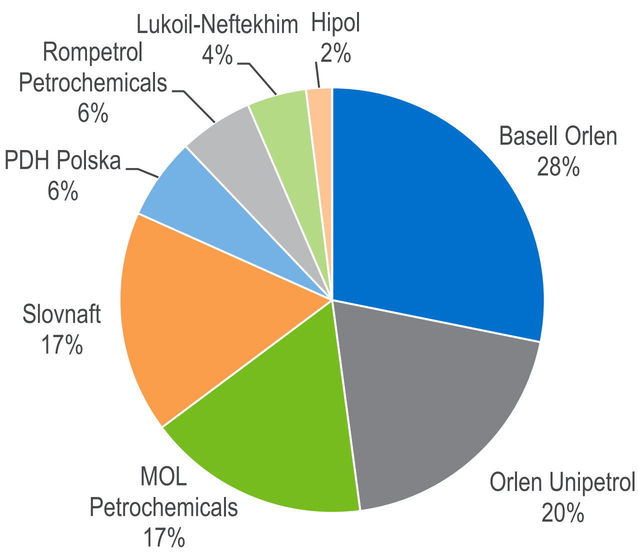
Table 4.34 Central Europe Polypropylene Demand by End-Use
(thousand tons)

	Actual			Estimate	Forecast								Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Injection Moulding	628	966	1 098	1 115	1 134	1 164	1 205	1 341	1 477	1 568	1 709	1 824	5.4	2.7	1.6
Film	252	400	548	555	566	584	608	674	758	812	909	993	7.4	2.8	2.0
Other Extrusion	236	314	388	393	400	412	428	466	511	530	574	610	4.7	2.5	1.4
Fibre	272	283	321	321	324	332	343	372	411	432	472	507	1.5	2.1	1.6
Blow Moulding	27	30	33	33	33	34	36	39	43	44	46	48	1.8	2.6	1.0
Rotomoulding	2	15	20	21	21	22	23	25	28	30	34	37	23.6	2.8	2.0
Extrusion Coating	3	4	5	5	5	6	6	7	7	8	8	8	5.2	3.3	1.2
Others	111	144	174	176	180	186	194	217	245	261	290	315	4.3	3.0	1.9
Total	**1 531**	**2 157**	**2 586**	**2 619**	**2 664**	**2 740**	**2 842**	**3 140**	**3 479**	**3 684**	**4 041**	**4 341**	**5.0**	**2.6**	**1.6**

4.4.4.2 Supply

The largest polypropylene producers in Central Europe are Hungary's MOL group and Poland's Basell Orlen. MOL operates two plants in Hungary and also controls Slovnaft in Slovakia. As of 2022, MOL's Hungarian plants had an operating rate of about 75 percent, while the Slovakian Slovnaft plant's operating rate was 73 percent. Basell Orlen operates a world-scale SPHERIPOL technology plant in Poland in cooperation with Basell, and also owns Unipetrol RPA in the Czech Republic. PDH Polska is a venture of Grupa Azoty, and there is an expected merger of the refinery Lotos Gdansk PKN Orlen. Basell Orlen's polypropylene plants have an estimated operating rate of about 82 percent, while Unipetrol's Czech subsidiary's polypropylene plant operating rate approached 80 percent. In 2022, the region's total polypropylene output was 1.3 million tons, a year-on-year decline of about one percent.

Figure 4.35 Polypropylene Capacity Share by Producer – Central Europe, e-2023



4.4.4.3 Supply, Demand and Trade

Central Europe heavily relies on imports for both polypropylene homopolymer and copolymers, with almost 90 percent of homopolymer consumption and all copolymer consumption being imported in 2022. Around 75 percent of the polypropylene produced is exported outside national borders but remains within the region. West European countries supply about 50-51 percent of the polypropylene, while other countries such as Saudi Arabia, Korea, Egypt, India, Russia, and Israel supply 23-24 percent. Intraregional manufacturers provide approximately 24-25 percent of the supply. Russian polypropylene exports to the region fell significantly in 2022.

Central Europe mainly imports polypropylene homopolymer and copolymers from EU member states, South Korea, Russia, India, Turkey, Egypt, Israel, and Saudi Arabia. In 2022, major non-West, non-EU countries exported the following amounts of polypropylene to the region: Saudi Arabia – 110 000 tons (mostly homopolymer), Korea – 122 000 tons (50 percent homopolymer, 50 percent copolymer), Egypt - about 60 000 tons (mostly homopolymer), and the Russian Federation – 77 000 tons of homopolymer. In 2021, extra regional imports mainly came from the USA (10 000 tons primarily to Poland), India (20 000 tons to Hungary), and Turkey (27 000 tons to Romania and Bulgaria). In 2021, China started exporting polypropylene to Poland, amounting to about 6 000 tons of homopolymer. In 2022, non-West European polypropylene imports amounted to approximately 600 000 tons. Despite the projected medium-term slow demand growth for polypropylene, Central Europe will remain a net importer of polypropylene homopolymer and copolymer.

Western Europe will continue to be the primary supplier of polypropylene to Central Europe, particularly impact-resistant and random copolymers, supported by two PDH plants currently under development in Belgium, each with an annual capacity of 750 000 tons. BasellOrlen Poland expanded its polypropylene production capacity by up to 80 000 tons per year in 2018, based on a new metathesis plant-derived propylene feedstock at PKN Orlen's Plock site. Additional propylene monomer stocks have been made available to PKN Orlen by the Lithuanian Maizhekiai refinery FCC installation, with a portion sent to Plock and the rest exported to Germany. MOL-Ina Rijeka has also started producing propylene at its Rijeka FCC splitter installation. MOL-Slovnaft in Bratislava is expanding its plant capacity by altering the structure of the resin portfolio while maintaining an unchanged 8 000 h/year operating time. PDH Polska's new polypropylene capacity of 437 000 tons per year has come online in June 2023.

The major raw material suppliers for Polymery Police PDH/Polypropylene site include TOTSA Total Energies Trading SA and Trafigura Pte Ltd Singapore as propane suppliers, Azoty ZAK as the propylene supplier, and Marubeni International (Europe) GmbH as the primary ethylene supplier. Grupa Azoty Polyolefins, the parent company, has selected leading traders of the resin to be marketed under the TM Gryfilen, including Ter Hell Plastic GmbH, Nexeo Plastic Europe B.V., Biesterfeld Plastic GmbH, and Imlitex Industry UAB for the Baltic region. In Poland, the resin will be distributed by the company Grupa Azoty Compounding, and Unipetrol, MOL-Slovnaft, and BasellOrlen may also expand their polypropylene resin production capacities. The proposed new 180 000 tons per year polypropylene plant project in Serbia is still considered speculative capacity.

In October 2020, Lummus Technology was awarded a contract by Lukoil-Neftekhim for its petrochemical facility, which includes the technology license for a 280 000 tons per year polypropylene unit, basic design engineering, training and services, and catalyst supply. Since the major shareholder in the venture is the Russian Lukoil, the current economic sanctions may also affect Lukoil's European sister companies, and Lukoil-Neftekhim has put the Novolen polypropylene project on hold. In 2022, the Central Europe polypropylene plants operated at approximately 80 percent capacity.

Figure 4.36 Central Europe Polypropylene Supply and Demand

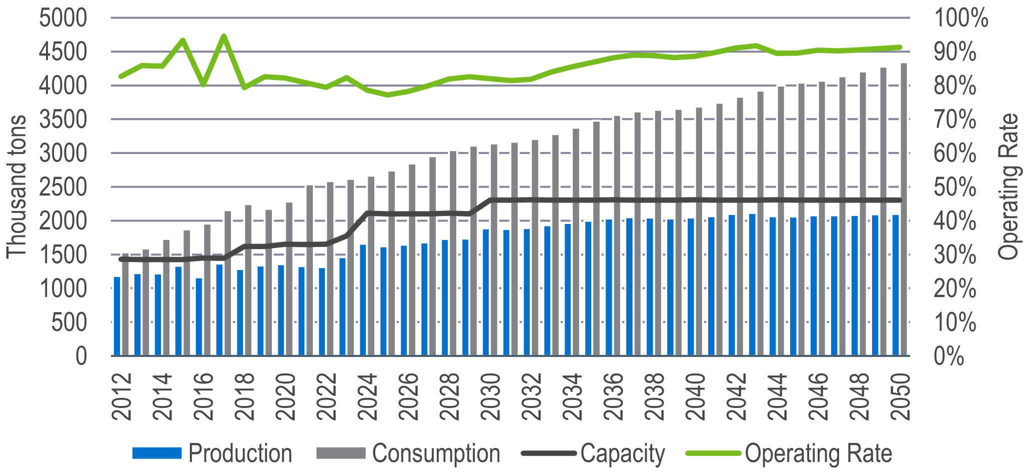


Table 4.35 Central Europe Supply, Demand and Trade

(thousand tons)

	Actual			Estimate	Forecast								Average Annual Growth Rate, %		
	2012	**2017**	**2022**	**2023**	**2024**	**2025**	**2026**	**2030**	**2035**	**2040**	**2045**	**2050**	**2012-2023**	**2023-2030**	**2030-2050**
Firm Capacity	1 429	1 445	1 653	1 775	2 108	2 102	2 102	2 102	2 102	2 108	2 102	2 102			
Speculative	-	-	-	-	-	-	-	200	200	201	200	200			
Total Capacity	1 429	1 445	1 653	1 775	2 108	2 102	2 102	2 302	2 302	2 308	2 302	2 302	2.0	3.8	-
Operating Rate	83%	94%	79%	82%	79%	77%	78%	82%	87%	89%	90%	91%			
Production	1 179	1 365	1 314	1 460	1 657	1 622	1 643	1 887	1 999	2 046	2 062	2 100	1.9	3.7	0.5
Net Export	(352)	(792)	(1 272)	(1 159)	(1 007)	(1 118)	(1 199)	(1 253)	(1 480)	(1 638)	(1 978)	(2 241)			
Consumption	1 531	2 157	2 586	2 619	2 664	2 740	2 842	3 140	3 479	3 684	4 041	4 341	5.0	2.6	1.6

4.4.5 Eastern Europe

4.4.5.1 Consumption

Polypropylene consumption decreased by over ten percent in 2022 due to the impact of sanctions on polypropylene exports, and the intense competition in export markets for almost all derivatives. This came after a sharp increase in 2021 as global markets recovered from COVID-19 and the ZapSibNeft plant came onstream.

The Russian economy has proved relatively robust in the face of sanctions, but the near-term outlook remains challenging, and it is hard to gauge how some demand areas will be affected due to restrictions on data.

The performance of the Russian market generally dictates the performance of Eastern Europe, as Russia accounts for 77 percent of the Eastern Europe market. Injection moulding is the largest application in the market in Eastern Europe, followed by film, and will continue to be the largest application for polypropylene during the forecast period.

Figure 4.37 Eastern Europe Polypropylene Demand by End-Use, e-2023

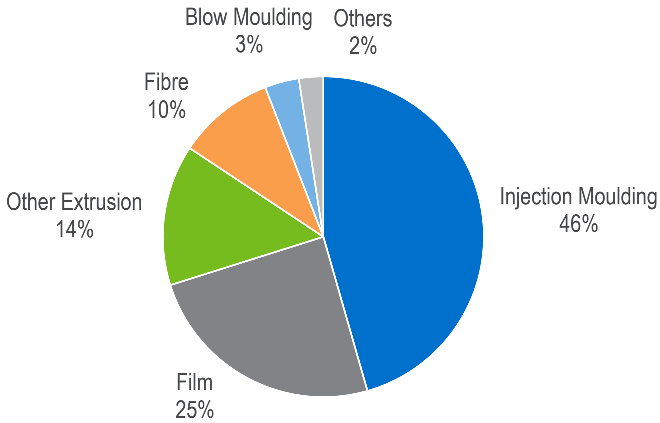


Table 4.36 Eastern Europe Polypropylene Demand by End-Use
(thousand tons)

	Actual			Estimate	Forecast								Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Injection Moulding	483	676	721	743	741	762	788	868	961	1 031	1 132	1 217	4.0	2.3	1.7
Film	234	345	388	400	397	407	420	464	521	567	628	681	5.0	2.1	1.9
Other Extrusion	194	204	218	232	231	238	246	276	314	349	396	437	1.6	2.5	2.3
Fibre	96	160	161	159	160	166	173	195	219	237	260	280	4.7	2.9	1.8
Blow Moulding	46	55	55	56	56	57	59	64	69	73	78	83	1.9	1.8	1.3
Others	35	38	40	39	39	40	41	45	50	55	63	70	0.9	2.0	2.2
Total	**1 089**	**1 477**	**1 584**	**1 629**	**1 624**	**1 670**	**1 727**	**1 911**	**2 135**	**2 312**	**2 558**	**2 769**	**3.7**	**2.3**	**1.9**

Table 4.37 Eastern Europe Polypropylene Demand by Region
(thousand tons)

	Actual			Estimate	Forecast								Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Russia	819	1 109	1 251	1 300	1 298	1 339	1 388	1 550	1 749	1 916	2 144	2342	4.3	2.5	2.1
Other Eastern Europe	270	368	333	329	326	331	339	362	386	396	414	427	1.8	1.4	0.8
Total	**1 089**	**1 477**	**1 584**	**1 629**	**1 624**	**1 670**	**1 727**	**1 911**	**2 135**	**2 312**	**2 558**	**2 769**	**3.7**	**2.3**	**1.9**

Russia

Russian consumption of polypropylene has been affected worse than polyethylene by sanctions. The overall economy has suffered, with construction activity declining by one percent and vehicle production dropping by over 60 percent. In the forecast, efforts to internalise some manufacturing activity may support growth, although exports of finished good will remain challenging.

The polypropylene market accounts for 30 percent of total polyolefin demand in Russia. The largest market is injection moulding, which mainly goes into packaging applications. Following the COVID-19 pandemic, demand for non-woven fibre applications, such as face masks, and demand for film increased due to greater emphasis on hygiene and packaging.

The invasion of Ukraine led to disruption in polypropylene derivative markets as foreign companies pulled out of Russia. For example, Freudenberg, a producer of non-woven PP, halted all trade with Russia and Belarus in March 2022.

Other Eastern Europe

In ‘Other Eastern Europe’ polypropylene is the largest polyolefin market, accounting for over a third of all polyolefins consumed. Polypropylene is the strongest growing polyolefin market in the region and is taking market share in moulding applications from HDPE.

Injection moulding is the largest application of polypropylene, accounting for 48 percent of demand. The second largest application for polypropylene is for film, where it is used in food packaging, which allows for downgauging as compared to polyethylene. Injection moulding will remain the largest end-use application. More than 80 percent of demand is for homopolymer grade; impact polypropylene represents ten percent of the market, while random copolymer market share is approximately seven percent.

Similar to other polyolefins, Ukraine is the largest consuming country within the rest of Eastern Europe, accounting for almost 30 percent of the region’s demand, followed by Belarus with 22 percent. Uzbekistan is the next largest with 12 percent, and then all other countries have smaller levels of demand of 30 000 tons per year or less.

In the past five years, although demand in Turkmenistan and Uzbekistan was boosted by the start-up of polypropylene derivative plants, overall regional demand has dropped to around 2014 levels, due to the COVID-19 pandemic in 2020 and the invasion of Ukraine in 2022:

- Even prior to the invasion, political instability and a weak economy in the largest consuming country, Ukraine, affected polypropylene demand, with fluctuations between years of growth and contraction. The largest decline in Ukrainian demand occurred in homopolymer grade with lesser decline in random polymer grade.
- Demand growth has been healthy in Turkmenistan, Kazakhstan and Uzbekistan over the past ten years, besides 2020.
- In late 2018, the Turkmenbashi Complex of Oil Refineries started production of biaxially oriented polypropylene (BOPP) film, specifically two types; transparent single layer and coextruded film. It is understood that the capacity of the plant is 20 000 tons per year. This significantly boosted the demand for polypropylene in Turkmenistan.
- Another small BOPP project with 3 500 tons annual capacity was completed in Uzbekistan by LG International and Uzkimesanoat in 2020.
- In addition, in Uzbekistan polypropylene demand has been growing strongly due to demand from local carpet manufacturers, which produce carpets for export.

In 2022, the total regional polypropylene demand dropped by around five percent, due to the invasion of Ukraine.

4.4.5.2 Supply

Russia

Total capacity increased significantly in the past five years after the successful completion and start-up of SIBUR's subsidiary ZapSibNeftekhim's new cracker and polyolefin complex in Tobolsk (Western Siberia). LyondellBasell was chosen as the licensor for the world's largest SPHERIPOL polypropylene unit at 500 000 tons per year.

Outside Tobolsk, plants are located in Omsk, Nizhnekamsk, Budyennovsk, Tomsk, Moscow, and Ufa. Prior to ZapSibNeftekhim, the last start-up of new build capacity was two units at Tobolsk and the plant at Omsk in 2013.

Despite growing production of polypropylene, there is a shortage in copolymer grades of the polymer, the demand for which is still being met by imports. Nizhnekamskneftekhim, Ufaorgsintez, Tomskneftekhim and Stavrolen have technological capability to produce copolymer grades of polypropylene in Russia. Nizhnekamskneftekhim holds a 70 percent share in production of copolymer grades, followed by Tomskneftekhim (19 percent), Stavrolen (nine percent) and Ufaorsintez (two percent).

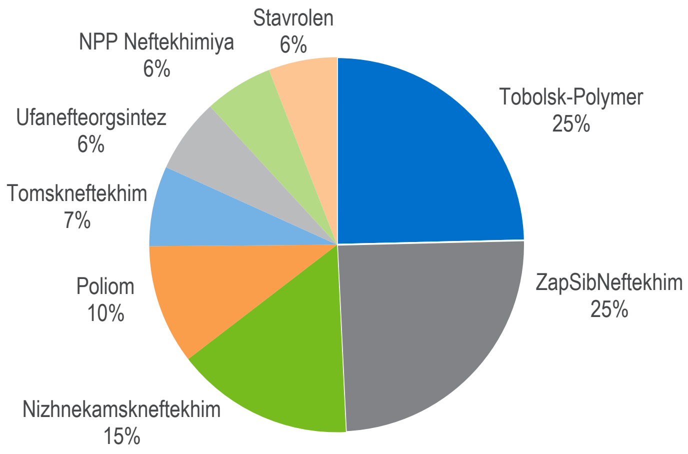
There are several planned capacity developments in the polypropylene market that are considered as speculative capacity:

- The potential expansion of the cracker at Angarsk Petrochemicals will support developments of its polyolefin facilities, which may include a new 250 000 tons per year polypropylene plant.
- Nizhnekamskneftekhim started construction in the third quarter of 2019 on its new US$3 billion olefin and polyolefin complex in the Tatarstan region. The planned complex has been downsized slightly to 180 000 tons per year of polypropylene. LyondellBasell is the technology licensor. Completion of construction is due in mid-2024. However, it is anticipated that startup of this facility will be delayed, due to sanctions as LyondellBasell withdrew from Russia and closed both of its offices there in 2022.
- LUKoil is developing plans to build a petrochemical hub in Southern Russia, using natural gas liquids provided by LUKoil's offshore gas fields in the Caspian Sea. As part of the plans LUKoil is considering an upgrade to its Stavrolen plant in Budyennovsk. Originally stating planned completion by 2021, with the addition of 150 000 tons per year of polypropylene capacity, this project remains unconfirmed.
- SIBUR and Gazprom are discussing the construction of the Amur gas chemical complex. Exact capacity is currently not known, but its strategic location in the Amur region makes it well place to export into China. This plant was also based on LyondellBasell technology and therefore is likely to be delayed or cancelled.
- Baltic Gas Chemical are planning a large polymer production unit on the Western border of Russia at Ust-Luga, but the exact composition of polymer product is not known. Two steam crackers with a capacity of 1.5 million tons per year would each feed UNIPOL polyethylene plants, creating around three million tons of HDPE/LLDPE supply. The Baltic Chemical Complex is not yet fully firm and due to sanctions, it is likely to be cancelled.

The start-up of a number of polypropylene plants outside of Russia in post-Soviet countries is likely to strengthen the competition in the polypropylene market in Russia. Stronger competition is likely to push the prices down thus encouraging investments in the downstream plastics converters segment.

SIBUR completed its new logistics hub in 2019, in collaboration with the Russian government, Karl Schmidt Spedition GmbH & Co. KG and Freight Village Kaluga. The hub has been designed to distribute polymer product from SIBUR's new ZapSibNeftekhim polymer unit. The logistics hub and polymer processing cluster is located in in Kaluga region, South West of Moscow, and targets 500 000 tons of polymer conversion per year, as well as contributing to the development of polymer processing and manufacturing of end products for automotive, healthcare, utilities and other sectors in Kaluga region.

Figure 4.38 Polypropylene Capacity Share by Producer – Russia, e-2023

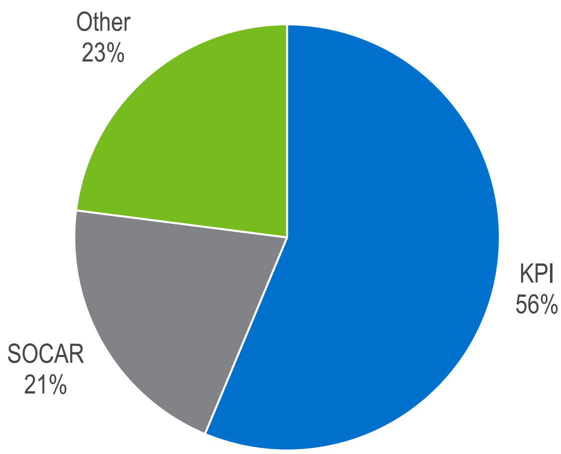


Other Eastern Europe

Considerable polypropylene capacity has been added to the market in the last five years:

- In Uzbekistan, an 83 000 ton per year polypropylene plant owned by Uz-Kor Gas Chemicals began commercial production at the beginning of 2016.
- Turkmeneftegas completed the construction of a new gas separation and cracker complex in Kiyanly, Turkmenistan. The cracker provides feedstock to a new 81 000 tons per year polypropylene plant. The project was implemented by Toyo Engineering, LG International and Hyundai Engineering and was commissioned in the end of 2018.
- SOCAR announced plans for the modernisation program for its petrochemical facilities in Azerbaijan, which will include repairing and upgrading the existing cracker and polymer facility. As part of this project SOCAR started-up a 200 000 tons per year polypropylene unit at Sumgait, Azerbaijan in the end of 2018. Azerbaijan has emerged as a supplier of copolymer since 2021.

Figure 4.39 Polypropylene Capacity Share by Producer – Other Eastern Europe, 2023



As well as the additions over the last few years, there remain plans for additional projects:

- In Kazakhstan, the Atyrau Project, with 500 000 tons of polypropylene capacity, is currently under construction. The progress of this project was affected by the coronavirus pandemic, however. It has fully delayed the polyethylene part of the project, with Borealis reportedly pulling out of the project. Chevron Phillips are rumoured to be entering the project to provide technology, but this currently unconfirmed.
- Uzbekneftegaz had announced a project to expand its capacity at the Shurtan gas chemical complex, but the location of the site has now moved to Karakul FEZ. The plan includes a capacity of 405 000 tons per year for polyethylene and up to 100 000 tons per year polypropylene from the deep processing of synthetic naphtha of 430 000 tons per year. Enter Engineering Pte Ltd, controlled by Gazprombank, has signed an EPC contract for the expansion and the commissioning of new facilities, which was slated for 2024.

4.4.5.3 Supply, Demand and Trade

Over the last decade Eastern Europe was a net importer of polypropylene but in recent years polypropylene investment in Russia, and across several countries in ‘Other Eastern Europe’ has changed the market considerably. Following the contraction in demand across the region due to the conflict in Ukraine, there will be an increased drive to find export opportunities from new capacity additions.

Figure 4.40 Eastern Europe Polypropylene Supply and Demand

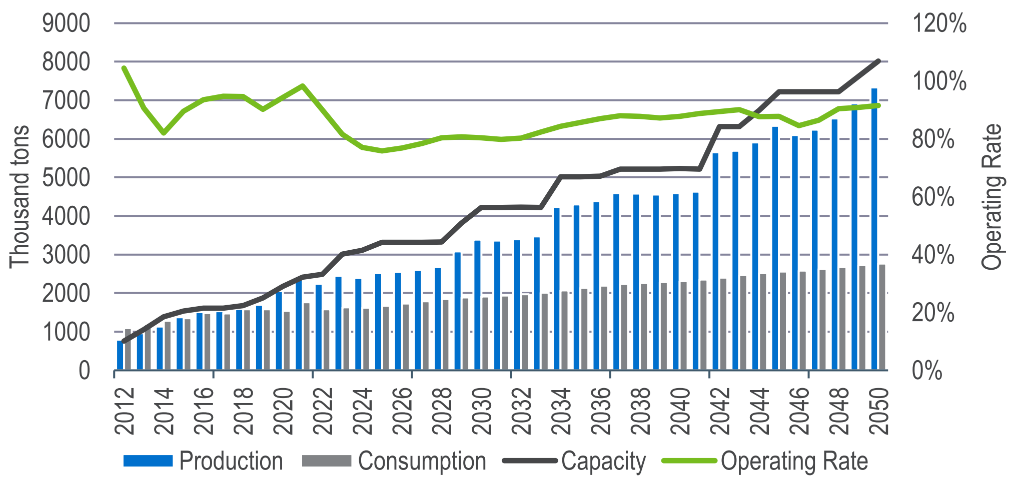


Table 4.38 Eastern Europe Polypropylene Supply, Demand and Trade
(thousand tons)

	Actual			Estimate	Forecast								Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Firm Capacity	758	1 613	2 492	3 009	3 106	3 318	3 318	3 718	3 718	3 728	3 718	3 718			
Speculative	-	-	-	-	-	-	-	500	1 300	1 504	3 500	4 300			
Total Capacity	758	1 613	2 492	3 009	3 106	3 318	3 318	4 218	5 018	5 232	7 218	8 018	13.4	4.9	3.3
Operating Rate	104%	95%	90%	82%	77%	76%	77%	80%	86%	88%	88%	91%			
Production	791	1 527	2 242	2 453	2 395	2 518	2 550	3 390	4 301	4 590	6 337	7 336	10.8	4.7	3.9
Net Export	(298)	49	658	824	771	848	823	1 479	2 166	2 279	3 779	4 566			
Consumption	1 089	1 477	1 584	1 629	1 624	1 670	1 727	1 911	2 135	2 312	2 558	2 769	3.7	2.3	1.9

Russia

Russia is a net exporter of polypropylene, and the start-up of ZapSibNeftkhim at the end of 2019 means that that Russia’s net export position is established at over 400 000 tons per year. The ZapSibNeftkhim plant targets 40 percent of its output to the export market. Operating rates have been consistently high in the country at 95 percent or above but dropped in 2022 due to the impact of sanctions on export markets. Russian producers are trying to compensate for sanctions and reduce dependency on other polypropylene imports for a wide range of industries and applications such as automotive and food packaging.

Exports are dominated by homopolymer polypropylene grades. Despite growing domestic production of impact and random copolymer grades, Russian demand for these grades is still mainly being met by imports.

Upon ZapSibNeftkhim starting up, it targeted exports to China and to Turkey, and this will continue into the forecast. Russia’s geographical proximity to China will ensure exports will continue, as will politically ties between the two countries.

The wave of sanctions on Russia in 2022 due to the invasion of Ukraine has caused considerable challenges in exporting Russian material as many logistics companies refuse to work with Russia, including Maersk, Hapag-Lloyd, Ocean Network Express and Yang Ming, as insurers also refused to ensure ships and cargoes related to Russia.

Russian imports of polypropylene from South Korea dropped in 2022, partly due to lower demand inside the Russian market and also a reorientation of Russian polypropylene producers towards the domestic market. Polypropylene trade between Russia and China in 2022 was relatively balanced, as China’s market for homopolymer was weak, reducing opportunities for Russian exporters. Also, imports of copolymers from China to Russia increased. Russian exports to China increased as markets in Europe become harder to access, particularly after the fifth wave of sanctions which became effective from 10 July 2022. Imports from South Korea increased in the middle part of the year but then declined as South Korean sellers tried to avoid secondary sanctions.

The emergence of Azerbaijan as a copolymer supplier in 2021 for Russian consumers has helped to reduce the impact of lost EU suppliers. SIBUR established the domestic market as its chief priority for 2022 but the group is looking to develop new external markets, particularly to countries within East Asia and South-East Asia, but still needs to create transit points and distribution centres.

Other Eastern Europe

‘Other’ Eastern Europe has long been a net importing region of polypropylene, but the new capacity added in the last three years has been reversing this and there is sufficient capacity now to cover total demand. ‘Other Eastern Europe’ covers a large area with many countries, and country specific trade dynamics vary and so although a net trade position gives an indication, there are many complex trade dynamics. For example, Turkmenistan and Azerbaijan and Uzbekistan are now largely exporters following the commissioning of polypropylene plants by Uz-Kor Gas Chemical’s in late 2015, Turkmengas in Kiyanly, Turkmenistan and SOCAR in Sumgait, Azerbaijan in 2018, which have added new supplies to the region. Exports coming out of Uzbekistan have been quite low in the last two years however, suggesting low operating rates for the capacity since starting up. Existing facilities in Kazakhstan look to have ramped up production during 2020, with an increase of export reported after several years of low output.

The main export destination for Other Eastern Europe polypropylene is Turkey and Central Europe, as the new exports are set to displace supplies from Western Europe.

4.4.6 North Africa

4.4.6.1 Consumption

Polypropylene demand in North Africa was around 900 000 tons in 2022. The African polypropylene market was resilient throughout the COVID-19 pandemic and benefitted specifically from increased carpet sales. Following the initial impact of COVID-19, the recovery only saw demand for polypropylene increase further, leading to strong expansion in 2021; however, as economic sentiment abruptly changed in 2022, economies in the region felt this impact which translated into a stagnating polypropylene market.

Polypropylene is the largest polyolefin market in Africa, closely followed by HDPE. Fibre remains the major end-use for polypropylene (notably so in Egypt), mainly in the production of woven bags for agriculture and synthetic carpets. The Egyptian company Oriental Weavers is reckoned to be the largest carpet producer in the world, although this also includes plants outside Africa.

Polypropylene's durability and strength make it ideal for the heavy-duty bags and packaging required in industry, in agriculture, and manufacturing. In many countries across the continent, agriculture's importance to GDP underlines its importance for storing goods. Fairly limited logistics mechanisms in the region favour the use of "big bags" (one ton woven polypropylene bags) for bulk handling.

Egypt is the largest market for polypropylene in Africa, accounting for 28 percent of polypropylene demand, with significant polypropylene fibre carpet manufacturing facilities. Egypt's domestic demand will be supported by investments in capacity, with several polypropylene plants planned.

Strong growth of Africa's large population, low labour costs and potential for high long term economic growth will continue to drive demand growth in the forecast as economies will recovery from high inflation rates and the weakening local currencies against the U.S. Dollar. The strongest growth will be in injection moulding applications for household goods. Higher disposable incomes as economies evolve drives an increase in the purchase of consumer goods. Use in caps and closures, is supported by containers which can be re-used, and therefore avoid restrictions on single use items. Fibre will remain as the largest end use application.

Algeria

All polypropylene in Algeria is imported and mainly used in fibre production, either for raffia for heavy duty woven bags predominantly for the agricultural sector or synthetic carpet production. Fibre accounts for around 74 percent of the market and is expected to maintain its position as the leading polypropylene end-use in such is the importance of the agriculture sector of the economy. Harvesting figures during 2022 have remained at similar levels verses previous seasons. Harvesting areas and therefore demand to fibre have not appeared to have grown in a meaningful way despite plans to increase output and land areas dedicated to agriculture.

It is also a resilient market and so polypropylene demand in Algeria remained stable throughout the pandemic, recovery year, and also in the more economically challenged year during 2022. Smaller amounts are used in film or injection moulding for housewares and general consumer goods, where it has historically competed with domestically produced HDPE. Domestic fibre applications will remain under pressure from imports in the polypropylene fibre sector, such as Egypt, as well as Middle Eastern producers looking to shift volumes towards Africa.

There is greater emphasis towards recycling which could displace virgin polymer demand and in Oggaz, a mechanical recycling plant will recycle polypropylene and HDPE plastic waste after construction of the 40 tons per day facility was completed in September 2022. At least 70 percent of this secondary raw material will be supplied to the national and international plastic processing industry and the remainder will be used to produce 30 pallets and pallet boxes per hour.

Egypt

There has been a weaker investment environment in Egypt in the past decade, due to the political climate, which has impacted consumer confidence. Despite this GDP growth has remained healthy since 2018. Growth has slowed into the end of 2022 to 3.9 percent during quarter two of the 2022-2023 fiscal year.

Polypropylene in Egypt is largely consumed in fibre, which accounts for almost 50 percent of demand. Fibre and raffia are used largely for the production of sacks and bags for agriculture, and this reflects the importance of agriculture to the Egyptian economy, the third largest contributor to national GDP. Fibre will continue to be the largest end-use, as it will have the highest volume growth throughout the forecast across all end-uses. Significant carpet production in Egypt also supports polypropylene fibre consumption, with the Egyptian company Oriental Weavers, arguably the largest carpet producers in the world, locating several production facilities in Egypt.

With 60 percent of the population below the age of 30, and a significant portion of that group buying homes and starting families, strong demand for new housing and furnishings supports carpet growth domestically. Real GDP per capita in Egypt will almost double in the forecast period, increasing the expenditure on home furnishings in Egypt. This coupled with further export opportunities across North Africa and across the globe to keep polypropylene fibre demand growth above six percent per year. Oriental Weavers alone export to 130 countries. Oriental Weavers is already looking to debottleneck and add to its existing capacity in Egypt, but sales volumes declined marginally during whole year 2022 as the economic climate and inflationary pressure saw volumes decrease into the last quarter against a strong start to the year.

As the polypropylene market is primarily for fibre, there is little inter-polymer competition. Moulding applications compete with HDPE, but this competition does not significantly impact overall polypropylene demand. Competition in the carpet industry comes from wool and nylon and polyester. Polypropylene offers good stain resistance and generally a more competitive price, and this combination will retain its market share. It generally has inferior durability to other materials, but this again will ensure good growth prospect with some replacement sales in the forecast. The investment outlook is strong for Egypt, and investments requiring polypropylene fibre application will ensure growth averages above six percent per year through the forecast.

In Egypt, approximately 87 percent of the market is homopolymer, with ten percent impact copolymer and three percent random copolymer.

Figure 4.41 North Africa Polypropylene Demand by End-Use, e-2023

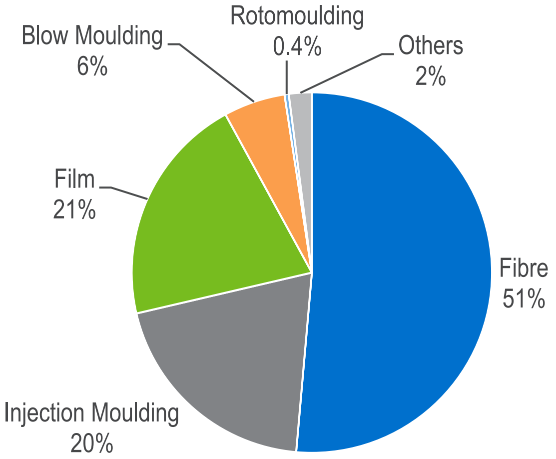


Table 4.39 North Africa Polypropylene Demand by End-Use

(thousand tons)

	Actual			Estimate	Forecast								Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Fibre	300	391	480	425	444	472	505	623	777	902	1 082	1 243	3.2	5.6	3.5
Injection Moulding	103	143	172	165	173	185	198	247	315	378	474	558	4.4	5.9	4.2
Film	108	146	177	171	180	192	206	254	317	368	445	513	4.2	5.8	3.6
Blow Moulding	28	41	48	46	48	51	55	68	85	100	123	143	4.6	5.8	3.8
Rotomoulding	-	-	3	3	3	3	4	4	5	5	6	7	-	3.8	2.8
Others	12	15	17	17	18	19	20	24	29	33	38	43	2.9	5.0	3.0
Other Extrusion	2	3	-	-	-	-	-	-	-	-	-	-	(100.0)	-	-
Total	**553**	**738**	**898**	**826**	**866**	**921**	**988**	**1 220**	**1 527**	**1 785**	**2 168**	**2 508**	**3.7**	**5.7**	**3.7**

Table 4.40 North Africa Polypropylene Demand by Country

(thousand tons)

	Actual			Estimate	Forecast								Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Algeria	78	107	136	117	120	125	131	152	170	183	206	224	3.8	3.8	2.0
Egypt	475	632	762	709	745	796	856	1 068	1 357	1 602	1 962	2 283	3.7	6.0	3.9
Total	**553**	**738**	**898**	**826**	**866**	**921**	**988**	**1 220**	**1 527**	**1 785**	**2 168**	**2 508**	**3.7**	**5.7**	**3.7**

4.4.6.2 Supply

Algeria

There is currently no polypropylene capacity in Algeria, although this is expected to change over the forecast as a result of the Sonatrach TOTAL Enterprise Polymères (STEP) joint venture, which has undertaken to build a new integrated 550 000 tons per year PDH/polypropylene complex at the Skikda refinery site. Honeywell has been awarded the contract to provide technology and provide basic engineering design and services for the proposed plant. There are expectations the construction of the polypropylene plant will begin in July 2023 following announcements in February 2023. The plant is expected to produce homopolymer to satisfy demands in North Africa with an expected 50 percent of material reserved for export, primarily to Europe.

Algerian gas and energy will provide STEP with a competitive price advantage for exports into Europe and it will be able to supply product more quickly than material which comes from the Middle East and Asia. Elsewhere, Sonatrach is also to supply propane to a similarly sized PDH/polypropylene project in Turkey, the Ceyhan Polipropilen Üretim Anonim Şirket project, which may affect the progress of additional domestic supply should this reach financial close.

Egypt

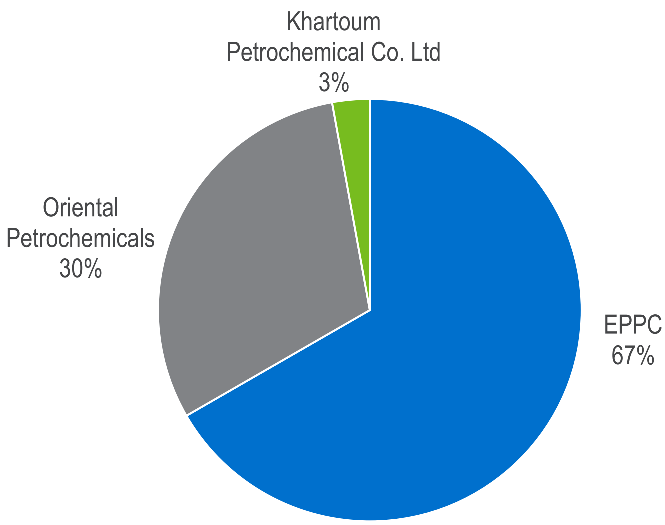
The Egyptian domestic market is supplied by two domestic producers; Egyptian Propylene & Polypropylene Company (EPPC) and Oriental Petrochemicals Company (OPC).

- EPPC has a 350 000 tons per year facility in Port Said, which started production in quarter three 2010. The plant is integrated with propylene production based on propylene dehydrogenation (PDH) technology. At times over the last five years there have been supply issues which have affected petrochemical producers and other industries, and so at times EPPC had to secure additional propane as required from Algeria. These propane imports have however been sufficient for the most part to ensure minimal disruption in propylene supply to the polypropylene plant. In 2022 there was a greater impact from the changes in global trade flows. Oversupply from new capacity in Asia displaced imported volumes which originated in the Middle East, which in turn turned volumes West into Turkey and Western Europe, key markets for Egyptian producers. Additionally, Russia turned increasing volumes towards Turkey as it was the only NATO member not to impose sanctions on Russia. The combination of these two effects drove prices down from highs and squeezed margins against firming propane feedstock costs. Ultimately, this led EPPC shutting down the plant for a period of time in the second half of 2022 when demand also became challenged. Supply was further impacted by a turnaround completed in December 2022.
- OPC has a 220 000 tons per year plant in Suez, which prior to 2010 was the only domestic source of production. The plant was originally based on propylene feedstock supply from Libya, but from 2011 when Libyan production halted, it struggled to source feedstock. Following an equity reshuffle in which Carbon Holdings acquired the Oriental Petrochemicals site from Oriental Weavers Company in 2012, the plant reopened in the fourth quarter of 2015. Carbon Holdings invested to increase the capacity of the plant from the original 160 000 tons per year to 220 000 tons per year, and OPC imported propylene feedstock from the UAE. Borouge 5 came online in February 2022 which consumes the propylene which was previously exported, which has created supply issues for Carbon Holdings, particularly with the diminishing market for propylene in the region. This combined with margin pressure has impacted production at the facility.

There are several plans being discussed for further polypropylene capacity in Egypt, but these continue to be considered more speculative:

- Carbon Holdings plans to expand the OPC capacity in Suez as part of the Tahrir Petrochemical Project, by adding OPC II and OPC III, two 350 000 tons per year polypropylene plants, supplied with propylene feedstock by a naphtha cracker which is part of the complex. The project will be based on Novolen technology, and Bechtel are the EPC contractors. FEED was carried out in 2016, but there is currently no firm date for construction to start as funding is still to be fully secured. There has been no progress in recent years, and the project now seems to be halted but it has not been cancelled.
- Also in planning is a new polypropylene unit from the state-backed chemical holding company ECHEM and its subsidiary SIDPEC, for a 450 000 tons per year polypropylene unit based on propylene from propane dehydrogenation technology. Feedstock and land for this project are understood to have been obtained, but final investment decision has not yet been made and EPC selection is ongoing following the completion of the pre-feed with Jacobs engineering. However, it was confirmed that SIDPEC has upgraded its operating system to Honeywell's latest version, which will pave the way to facilitate the proposed integrated expansion into polypropylene.
- The state-backed Red Sea Refining and Petrochemicals Company has proposed a refinery integrated steam cracker and derivatives complex, including polyethylene and polypropylene as part of plans to produce 2.8 million tons of petrochemical products per year. The plan is part of Egypt's petroleum sector modernisation program. No details on capacity have been announced yet and this project remains speculative at this stage.

Figure 4.42 Polypropylene Capacity Share by Producer – North Africa, e-2023



4.4.6.3 Supply, Demand and Trade

North Africa is a net importer of polypropylene, and this will continue throughout the forecast period with more limited capacity additions when compared to other regions. North Africa's net import requirement continues to grow for polypropylene, as it was just approximately 542 000 tons in 2022 rising from around 226 000 tons in 2016. Output from planned and speculative capacities expected to come online in the coming years can therefore be absorbed within the region, therefore reducing the import requirement briefly while consumption in the region grows.

Figure 4.43 North Africa Polypropylene Supply and Demand

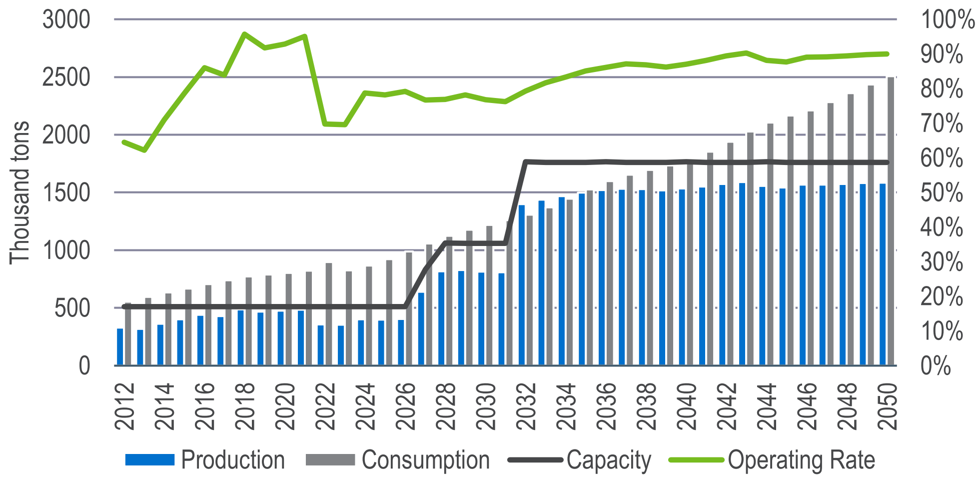


Table 4.41 North Africa Polypropylene Supply, Demand and Trade
(thousand tons)

	Actual			Estimate	Forecast								Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Firm Capacity	511	510	510	510	511	510	510	510	510	511	510	510			
Speculative	-	-	-	-	-	-	-	550	1 250	1 253	1 250	1 250			
Total Capacity	511	510	510	510	511	510	510	1 060	1 760	1 765	1 760	1 760	-	11.0	2.6
Operating Rate	65%	84%	70%	70%	79%	78%	79%	77%	85%	87%	88%	90%			
Production	330	428	356	355	402	399	404	814	1 497	1 536	1 543	1 585	0.7	12.6	3.4
Net Export	(223)	(311)	(542)	(471)	(463)	(522)	(584)	(406)	(29)	(250)	(625)	(923)			
Consumption	553	738	898	826	866	921	988	1 220	1 527	1 785	2 168	2 508	3.7	5.7	3.7

Algeria

Algeria is a net importer of polypropylene and is expected to continue as a net importer in the short term and is expected to switch to a much larger net export position in the medium term when the first new project is confirmed. NexantECA notes the STEP project is not currently regarded as firm, but it has a high likelihood of going ahead with construction set to begin in 2023. Algeria's import requirement is largely sourced from Saudi Arabia, with some smaller cargoes from Western Europe.

Egypt

Egypt has a net import position over 200 000 tons per year, but within this there are even greater trade flow volumes. Across polyolefins and other petrochemicals in Egypt, most material is exported out of Egypt and local demand is served by imports. Typical splits can be 75 percent of product is for export, with 25 percent for the domestic market, as a way to bring foreign currency into the economy. For polypropylene, exports are targeted to Turkey and Western Europe. Exports to Turkey fell by almost 35 percent in 2022 as Russian exports were targeted towards Turkey after the sanctions imposed on it by European countries saw significantly lower volumes head into the continent. Turkey, although an EU applicant and NATO member did not extend sanction on Russia, with saw Egyptian export volumes displaced. To account for this more Egyptian product was pushed into Western Europe but this did not offset the loss in volumes exported to Turkey during the year. Imports to Egypt come primarily from Saudi Arabia with smaller volumes from Asia. Volumes from the Middle East increased in 2022 as oversupply in Asia saw producers push increasing volumes west. To further impact imports, players in Egypt are still finding it difficult to open letters of credit following the implementation of new rules by the central bank which made it more challenging to import volumes.

The timing of new projects remains uncertain, but even if the net trade position alters, the existing pattern of most domestic capacity targeting exports while most domestic demand is served by import will continue. Egypt will continue to export to Turkey via a free trade agreement but will continue to be challenged as cheap Russian exports challenge Egyptian producers margins which will likely see volumes continuing to flow to Europe. Turkey is itself a major driving force in polypropylene fibre and textiles but plans are underway to supply greater demand locally which would offset import requirements and increase competition. The domestic market in Egypt will continue to be served mostly with imports from Saudi Arabia.

4.4.7 Middle East (excluding Turkey)

4.4.7.1 Consumption

Polypropylene accounts for 39 percent of the Middle East (excluding Turkey) polyolefins market. Fibre for the production of woven bags and carpets is the main use of polypropylene in the Middle East (excluding Turkey).

Iran is the largest consumer of polypropylene in the Middle East (excluding Turkey), with the 'Other Middle East' following behind in second. Iranian polypropylene consumption grew slightly in 2022 despite the considerable social unrest. Products which had fared well through the COVID-19 period such as food packaging and personal hygiene equipment suffered in 2022 due to inflation, higher food prices and increased travel.

The automotive sector performed well in 2022 although this is a minor sector in other parts of the Middle East (excluding Turkey). Part of the demand into auto components is also served by imports of compounds, which increased slightly in 2022.

Fibre demand was impacted by the cessation of COVID-19 concerns and the rapid drop in PPE demand. High oil prices supported national income in Arab Gulf states, but the demand effect was less than that of the soaring energy costs in non-energy rich states.

Polypropylene has made in-roads into the injection moulding applications for household goods, a sector previously dominated by HDPE. Polypropylene copolymers use is increasing gradually, continuing to gain share at the expense of other polymers, and is expected to growth strongly this decade. The region is also a major producer of BOPP film, with capacity dominated by Dubai, Saudi Arabia, and Oman. While some Saudi Arabian and other BOPP film producers are sufficiently competitive to export overseas, there seems little scope to develop other sectors such as injection moulding for automotive components due to the complexity of the products and the lack of vehicle production in the region. The market became extremely competitive in 2022, with low freight rates from Asia competing for both local BOPP sales and BOPP exports to Europe etc.

Figure 4.44 Middle East (excluding Turkey) Polypropylene Consumption by End-Use, e-2023

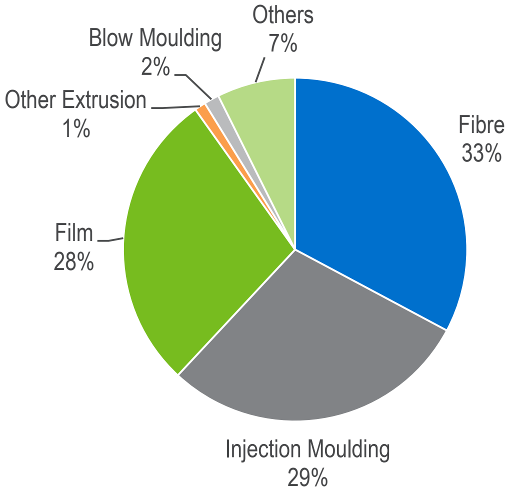


Table 4.42 Middle East (excluding Turkey) Polypropylene Consumption by End-Use

(thousand tons)

	Actual			Estimate	Forecast								Average Annual Growth Rate, %		
	2012	**2017**	**2022**	**2023**	**2024**	**2025**	**2026**	**2030**	**2035**	**2040**	**2045**	**2050**	**2012-2023**	**2023-2030**	**2030-2050**
Fibre	625	749	761	772	788	818	865	1 042	1 199	1 303	1 474	1 596	1.9	4.4	2.2
Injection Moulding	594	677	673	685	698	726	771	918	1 052	1 133	1 313	1 439	1.3	4.3	2.3
Film	474	584	644	664	680	711	757	924	1 071	1 166	1 345	1 471	3.1	4.8	2.4
Other Extrusion	55	53	23	25	26	27	30	41	49	54	64	70	(7.0)	7.4	2.7
Extrusion Coating	-	-	-	-	-	-	-	-	-	-	0	-	-	-	-
Blow Moulding	28	37	32	33	34	35	38	47	53	58	69	75	1.7	5.1	2.3
Others	155	170	171	173	174	177	185	216	237	253	288	309	1.0	3.2	1.8
Total	**1 931**	**2 269**	**2 304**	**2 352**	**2 400**	**2 495**	**2 646**	**3 189**	**3 660**	**3 968**	**4 551**	**4 959**	**1.8**	**4.4**	**2.2**

Table 4.43 Middle East (excluding Turkey) Polypropylene Consumption by Country

(thousand tons)

	Actual			Estimate	Forecast								Average Annual Growth Rate, %		
	2012	**2017**	**2022**	**2023**	**2024**	**2025**	**2026**	**2030**	**2035**	**2040**	**2045**	**2050**	**2012-2023**	**2023-2030**	**2030-2050**
Firm Capacity	7 922	9 308	10 192	10 350	10 378	11 300	11 300	12 230	12 230	12 264	12 230	12 230			
Speculative	-	-	-	-	-	-	-	1 600	4 000	6 167	8 800	8 800			
Total Capacity	7 922	9 308	10 192	10 350	10 378	11 300	11 300	13 830	16 230	18 430	21 030	21 030	2.5	4.2	2.1
Operating Rate	80%	92%	89%	85%	77%	76%	77%	80%	85%	87%	87%	93%			
Production	6 308	8 543	9 042	8 763	7 997	8 565	8 686	11 073	13 765	15 959	18 254	19 475	3.0	3.4	2.9
Net Export	4 377	6 274	6 738	6 411	5 597	6 069	6 039	7 885	10 105	11 992	13 703	14 516			
Consumption	1 931	2 269	2 304	2 352	2 400	2 495	2 646	3 189	3 660	3 968	4 551	4 959	1.8	4.4	2.2

Iran

The benefit of higher energy prices proved to be a greater influence on the economy than the massive civil unrest in 2022, and Iran posted positive economic growth. However, sanctions remain a major issue on some sectors of the economy. Economic activity in recent years has been impacted by marked oil price cyclicality and fall in 2020, and the COVID-19 pandemic. In 2021 recovery in the oil and service sectors, due to the return of global and domestic activity after the worst of the pandemic resulted in growth of polypropylene consumption of approximately three percent in 2021 but demand remained well below 2019 levels after an eight percent fall during 2020. Domestic polypropylene markets are dominated by the fibre segment, with the injection moulding and film segments also accounting for a significant proportion of the market. Polypropylene is used in applications for the automotive sector, appliances, carpet fibres, rugs, films, packaging films, food packaging, serial bags, kitchenware, stationery, toys, plastic bottles, pipes, and industrial goods.

Carpets are currently the strongest and most active sector of Iran’s textile industry, accounting for about one-third of Iran’s total textile exports. Iran’s machine-made carpet industry supplies the domestic market but most of the carpets are exported to Iran’s neighbouring countries, such as Iraq and Afghanistan.

Both the personal protective equipment area the carpet sector suffered in 2022 due to both the unwinding of COVID-19 protocols and a precipitous drop in carpet exports. Some carpet categories experienced a loss of over 50 percent of export volume, although this tended to be worse in luxury categories rather than those with the highest content of polypropylene. The injection moulding market recovered from the major hit in 2020 with automotive output in 2021 increasing by around four percent.

Polfilm and Saaf Films remain the key BOPP producers in Iran, but neither have been investing in new capacity in recent years, and some of their equipment is now relatively compared to other regional competitors.

Iraq

As COVID-19 measures and market influences subsided in 2022 there was a slight increase in polypropylene consumption in the region of 2 000 tons. The political and commercial problems which have restricted industrial development in Iraq continue, with corruption and the reliance on energy export revenues serving as an obstacle to both local and foreign investment in other industrial sectors. Unlike some countries in the region, Iraq does not have a large scale carpet industry of modern or traditional types.

Iraq is a country with a larger population than Saudi Arabia and shows a weak but growing consumption per capita for polyolefins. In general, Iraq’s local markets are highly fragmented and require polyolefins of different grades and specifications. Economic reform has been proposed to shift the economy from a state-controlled model toward creating a robust private sector, but without obvious signs of progress in this regard. Any tangible progress towards economic reform is expected to move incrementally and significant changes are not expected in the short-term.

End use markets for polypropylene are mainly focused on film, fibre and injection moulding products.

Israel

Polypropylene demand continued to recover in 2022 but remained below historical peak levels. Growth is mainly because of increased usage of polypropylene products for food packaging, medical equipment, textile, and sanitation industries. Some demand into films is for export, and Israeli producers were able to achieve a slight increase in polypropylene film exports despite high levels of competition from Asian suppliers. The global BOPP has opened up slightly as lower East/West container rates have allowed increased shipments from countries such as China.

Domestic markets are supported by reliable domestic resin production, although efforts to force the closure of the olefin and polyolefin production in Israel may count against further investment in polypropylene conversion capacity. The Israeli economy has been relatively strong over the last five years despite regional disputes with Palestine and the war in neighbouring Syria causing some disruption. 2022 was another strong year for the economy which grew by six percent year on year, although the prediction for 2023 is for significantly lower but still positive growth.

Polypropylene markets are fairly fragmented, so converters are flexible and manufacture products for a wide variety of end uses. Injection moulding is by far the most dominant end-use segment for polypropylene in Israel. There are numerous companies that have polypropylene injection moulding capabilities including Amraz, Gil Pack, IPU Industries, Plasel, Plasglad, Polycad, Rimoni Industries, Starplast and ZDF Plastic Solutions. These companies contribute to robust demand for moulded polypropylene, although they are flexible and often process other materials in addition to polypropylene. Applications for injection moulded products include boxes, crates, pallets, containers, caps, closures, and consumer goods as well as for use in the, agricultural, food, industrial and chemical industries.

Israel recycles roughly six percent of its waste plastic, approximately 60 000 tons per year. The drive for recycling is still relatively weak despite some government incentives, with a low level of recycling, limited infrastructure, and processing capacity. Despite this, changes are being implemented in the country with Jerusalem set to provide limited plastic recycling bins to enable source separation to facilitate increased recycling. There are a few small recycling companies which process general recyclables, as well as a few which recycle polyolefins specifically such as Goldistica, and the volume of recycled plastic in Israel is about to expand, following the expected launch of two new factories whose final product can be used for producing bottles from the recycled material. Some of the actors in the value chain were hoping for deposit return (DRS) schemes to drive increased plastics collection, but this has not so far been imposed. Recyling is however going in other directions, such as the UBQ mixed plastic recyclate which could feasibly erode polypropylene demand as it is already being used in e.g. trays in fast food restaurants, albeit not in food contact applications.

Applications for fibre in Israel are largely for the textile and construction industry, for use in concrete, as well as for ropes and nets. Fibre consumption expanded as the construction sector continued to expand due to the high demand in the country for new housing and infrastructure. The film and other segments hold a similar market size in Israel, while the blow moulding segment is weak. Haifa Polymers is a producer of LLDPE and BOPP films. Sapir Plastics is a producer of LLDPE and polypropylene stretch film with production capacity of 40 000 tons per year. There is healthy demand for polypropylene into the others segment where strong demand for infrastructure supports pipe applications. Plassim can produce up to 20 000 tons per year of pipes per year made from polypropylene, HDPE, or PVC, while Huliot is also a major polypropylene, PVC and polyethylene pipe manufacturer. Polycad is a bottle and container producer using polyethylene, polypropylene, or PET for food or chemical applications. Converters in these segments, as well as injection moulding, are flexible and often use a variety of materials to manufacture products for a wide variety of end uses.

Kuwait

Polypropylene markets in Kuwait are small and have shown positive growth in recent years, aside from a COVID-19 related dip in 2020. Polypropylene in Kuwait is mainly used in fibre applications as well as injection moulding, film, and pipe applications.

The Plastic Pipes & Fittings Factory can produce 33 000 tons per year of pipes and fittings made from PVC, random copolymer polypropylene, polyethylene, and polybutadiene. National Industries Company has capacity for 2 000 tons of HDPE pipes and fittings as well as some capability for random copolymer polypropylene pipes. These are used in applications for pressure pipes, hot and cold-water services, irrigation, gas, sewage and drainage. KAI is a manufacturer of HDPE pipe, ducts, tanks, and other applications as well as random copolymer polypropylene pipe. GPI manufactures and supplies PET preforms and HDPE Closures for Mineral Water Bottling Industries.

Converters in Kuwait are flexible and often use a variety of materials to manufacture products for a wide variety of end uses. Plastic & Packaging Industries is a manufacturer of bags, sacks, shrink films, flexible food packaging, agricultural films, construction rolls and other products from LDPE, HDPE, BOPP, and CPP. KPMMC is a manufacturer of plastic products with a capacity of 30 000 tons per year, including plastic bags made from HDPE, LDPE, and polypropylene. Plastic Industries Company has 7 500 tons per year capacity for film, including shrink films, agricultural sheets and bags, injection moulding, blow moulding, rotomoulding and pipe applications. Al Bisher & Al Kazemi Plastic manufacturing company provide moulded plastic products for industrial, medical, construction, agriculture, and consumer product industries.

Kuwait's record for recycling is poor with over 90 percent of waste sent to landfill every year, including around 285 000 tons of plastics, while approximately 76 percent of Kuwait's waste is recyclable. The country has begun to change its perspectives on waste and recycling, and there have been recent developments. MRC has opened Kuwait's first plastic recycling plant in Amghara, where the company has facilities for processing and compounding. The company is currently constructing an integrated facility for plastics conversion to finished products. The Beatouna Recycling Company own a 12 000 tons per year recycling plant for plastics scraps of HDPE, LDPE, and polypropylene, also in the Amghara area. Recycle Kuwait is a smaller recycling company set up in 2016 that can recycle a variety of plastics, although there is a charge for collection. Equate has endeavoured to raise awareness of plastics recycling and sustainability and has launched a plastics recycling program with Omniya Recycling. This project is for the collection of bottles, although these are largely made from PET. There are notable start-ups that include Eco Star, a non-profit group that recycles rubbish including plastic from homes, restaurants, and schools, meanwhile PIC (Petrochemical Industries Company K.S.C.) signed a Memorandum of Understanding with Kuwait Municipality to study the establishment of a Plastic Waste Recycling Plant. There are currently no duties for plastic bags.

In 2017, Kuwait introduced its National Development Plan. This is to support a prosperous economy improved living environment, boosting infrastructure developments, and enhancing the country's global presence by 2035. One of the medium-term objectives is to develop Kuwait into a global hub for the petrochemical industry. This will be supported by an increase in direct foreign investment. Subsequently the plan for the expansion of the Al-Zour refinery and construction of petrochemical facilities by 2024 was announced, with the first part of the refinery expansion online in 2022 although the third CDU has yet to be commissioned. Petrochemicals developments are still in consideration for later phases, but without a firm timeline. Kuwait's polypropylene markets are expected to grow rapidly over the coming years as a result of planned investments in the film and fibre sectors.

Qatar

Polymer demand increased again in 2022 as the economy continued its recovery from COVID-19 measures and enjoyed a positive influence from energy export revenues. Qatar's polypropylene market is small and wholly supplied by imports. Downstream industries are fragmented, with companies able to produce a wide range of products using a variety of different materials.

Polypropylene demand was boosted by a return to growth in the construction industry, following falls in 2020. This was strongly supported by construction ahead of the 2022 FIFA World Cup. Demand for consumer goods is increasing as families have more surplus income and can achieve the higher income. This will support increased consumption into packaging material. In Qatar, polypropylene is used for film, bags, sacks, pipe, and moulding applications.

There are many companies that can process plastics, including polypropylene. Qatar Polymer Industrial Company (Qatar Pac) specialises in polypropylene products such as bags, sacks, fibre articles, raffia extrusion, blown film and BOPP film lamination. The company can manufacture up to 16 200 tons of products per year. Qatar Integrated Plastic Bags Factory (QIPBF) is a manufacturer of polypropylene industrial bags, commercial bags, fabric roll and fabric wrapping. The company can produce 4 200 tons products per year including 48 million polypropylene sacks. Qatar National Plastic Factory (Q-Plast) is a major pipe manufacturer using a variety of polymers including random copolymer polypropylene and can produce polypropylene bags. Applications include polypropylene ducts and water pipes. Qatar Pipeline & Fittings (QPF) is a producer of pipes and fittings made from polymers including random copolymer polypropylene. The company owns three factories, one of which is for the manufacture of polyethylene and polypropylene pipes and fittings. The pipes are used for applications in agriculture, irrigation, water supply, sewage, industrial waste disposal, drainage, ducting, and conduits. QPlastics has manufacturing lines that are dedicated to producing plastic containers made of HDPE or polypropylene for detergents, lubricant, oil, and paint containers as well as the emerging thin wall plastic containers such as carboys, bottles, plastic jars, buckets, drums, and flasks.

Qatar hosted the FIFA World Cup at the end of 2022 and the preparation for this event provided a boost to domestic markets. Polyolefin demand was driven by infrastructure developments as well as the construction of stadiums and associated infrastructure. As part of this, Coastal Qatar will manufacture seating for stadiums in the country made from polypropylene supported by an aluminium structure. There is a requirement for at least 300 000 seats and Coastal Qatar will manufacture them at a rate of 16 000 seats per month. Growth from this area will be limited as much of the construction for the stadiums will have already been completed ahead of the event.

In Qatar, approximately 15 percent of waste generated is plastic. There are some plastic recycling companies in Qatar, although there are few operating facilities. Doha Plastics is the country's leading recycler, and while mainly focussed on polyethylene, also offers recycled polypropylene granules mostly for fibre applications such as big bags and reinforcement for cement bags. Twyla Recycling was established in 2014 and it recycles LDPE, HDPE, and polypropylene at its factory to allow the product to be used for several applications which include bags, carpets and PP-R (random copolymer) for pipes.

Qatar does not have a tax on plastic bags although there is a consumer trend for the easing of plastic bag use as well as other single-use plastics. Despite this there has been an increasing trend of single-use plastic use because of the pandemic. The increased waste includes surgical masks, plastic gloves, and bottles of sanitiser.

In May 2022 Qatar's cabinet approved a draft resolution prohibiting single-use plastic bags, which was subsequently enacted in November 2022. This resolution includes the prohibition of single-use plastic bags in packaging from institutions, companies, and shopping centres. This follows a ban on the use of plastic and polystyrene containers for hot food that was introduced in 2009; however, the ban has not been strictly followed. Qatar is in the process of developing various tools and policies to combat the plastic problem and the Qatar National Environment and Climate Change Strategy which has been launched recently relies on developing waste management infrastructure and improving the consumption of materials such as construction, food, and the industrial sector. Qatar has also put in place ambitious aims to achieve its strategy which includes account for 100 percent of all wastes, achieving 15 percent material recycling rate of municipal wastes and using 35 percent of circular procurement in public infrastructure.

Qatar Foundation (QF) has been set up to reduce single-use plastic consumption within its flagship project, Education City. QF is the main contributor to the country's ecological footprint, steps have been taken since towards encouraging environmental stewardship and implementing a set of policies to reduce the consumption of single-use plastics.

Saudi Arabia

The economy expanded by nearly nine percent in 2022 on the back of higher energy export revenues and the effective absence of COVID-19 related effects which were still a factor in early-2021. While the oil industry is a major contributor to growth, non-oil sectors also saw strong growth. The oil-related sectors of the economy grew by over 15 percent in 2022, while non-oil sectors grew by around five percent.

Further growth was achieved in the performance polymers and chemicals sectors while major downstream sectors like automotive saw significant rises in sales during the year. The return to a small expansion in the construction industry has further supported the polypropylene market in Saudi Arabia. In other sectors polypropylene use for masks and PPE gowns took a sharp drop off as COVID-19 restrictions ended.

Domestic polypropylene markets are dominated by the film, fibre, and injection moulding segments. There is also weaker demand in the blow moulding and other extrusion segments. There are numerous companies based in Saudi Arabia that are involved in polypropylene processing. The spike in energy prices in many regions provided a source of competitive advantage for Saudi Arabian convertors in 2022, allowing a 30 000 ton increase in the volume of BOPP exported.

Asia Plastic & Packaging is a flexible plastic packaging manufacturer with applications in food packaging, plastic bags, and lamination applications. Al Watania Plastics is a leading manufacturer of plastic products for a variety of industries such as construction, packaging, agriculture, and food, through a range of processing techniques. The product range includes BOPP flexible packaging and polypropylene tubs and lids. SAPIN is a producer of high-impact polypropylene pails. Pack Plus manufactures a variety of flexible moulded products from HDPE, polypropylene, and other materials. Tahbib Plastic Company is a film manufacturer for the production of shopping bags and garbage bags, as well as a recycler for polyethylene and polypropylene. Al Watania Plastics is a leading manufacturer of plastic products for a variety of industries such as construction, packaging, agriculture, and food, through a range of processing techniques. Arabian Plastic Industrial Company is a leader in the packaging and moulding industries with 3 600 tons of film capacity for bags, as well as capacity for blow moulded chemical bottles, thermoformed containers and disposable articles, and moulded caps, containers, piles, crates, and garden toys. Saudi Plastic Factory is a major producer of rigid packaging in applications including household articles, food packaging and bottles. Compounder A. Schulman and Saudi Arabia's NATPET formed a joint venture to construct a new polypropylene compounding facility which opened in August 2017, with 100 000 tons per year capacity in Yanbu.

For pipe applications, PVC is the preferred material for the manufacturer of plastic pipes, while HDPE and polypropylene are strong alternative materials. Almunif Pipes is a leading domestic manufacturer of polyethylene, polypropylene, and PVC pipes with capacity of 42 000 tons per year. 3P Pipe is a manufacturer of PVC and polypropylene piping systems with a production capacity of one 50 000 tons per year. APLACO and M.T. Plast are two of the other large-scale manufacturers of plastic pipes, which support major construction and infrastructure projects.

Saudi Arabia's annual output of waste totals more than 15 million tons, of which plastics account for between five and 17 percent. Approximately 95 percent of this material ends up in a landfill and the country accounts for a large proportion of waste created in Middle East, with about a half from the construction sector, about a third from municipal waste and the remainder from industrial waste. Saudi Arabia recycles only around five percent of its total waste, including plastic, metal and paper. The lack of recycling infrastructure and collection provision has limited developments to date, and the drastic reduction in energy export revenues precludes major funding developments for recycling over the coming years. Waste-to-energy developments are viewed favourably in Saudi Arabia, which still consumes some crude oil in power generation.

The main sources of plastic waste in Saudi Arabia are packaging, shopping bags, PET bottles and consumer goods/appliances. Increased waste generation is driven by a rise in personal income and economic growth, as well as consumer behaviour changes to prevent the spread of COVID-19. Plastic waste is generally driven by middle to high income regions. Saudi Arabia has experienced rapid industrialisation, a high population growth rate and fast urbanisation. This is led to a sharp increase in the level pollution and waste created. One of the issues with plastics recycling is a lack of demand for recycled plastic and underdeveloped consumer markets. As part of Saudi Arabia's Vision 2030 plans, the Saudi Investment Recycling Company, supported by the Public Investment Fund is aiming to recycle or reuse 85 percent of industrial waste, 100 percent of solid waste, and 60 percent of construction and demolition waste away from landfills by 2035. Saudi Arabia aims to invest almost US$6.4 billion in the recycling of waste by 2035 as it attempts to switch to a more sustainable waste-management system and this will help establish a stronger recycling sector.

There are recycling companies in Saudi Arabia that process polyolefins. Recycling Industries specialises in processing over 7 000 tons of HDPE and polypropylene per year into pellets and granules. Napco Uniplast collects, sorts, and recycles up to 7 500 tons per year of polyethylene and polypropylene. South Arabia Factory for Plastic produces recycled LDPE, HDPE, and polypropylene, and is a producer of plastic bags for a number of applications. WASCO is a large paper recycling company which has recently expanded to accept plastics. This company has large potential for growth in plastics recycling. Other recyclers in Saudi Arabia include Nesmare Recycling, Techno Plast Factory, Tahbib Plastic Company, Recycling Industries Factory, Waleed Alhamed Est, Alyusra Recycling Factory. Most of the products from these companies do not however compete in virgin polymer applications.

There is no tax on plastic bag use in Saudi Arabia. Instead, the country has moved to change the properties of the plastics in use. As such SASO, the Saudi Arabian standards authority introduced legislation in 2017 to requiring certain products to be oxo-biodegradable. The range of products affected includes agricultural films, a range of bags, bubble wrap, secondary packaging, stretch films, shrink films, box liners, table covers, packaging for consumer goods, bakery product packaging and single use items such as shopping bags, waste bags, cups, and cutlery. Food packaging is exempt, however. Products need to be specifically labelled as part of the legislation. Under new regulations SASO has restricted the import of plastic articles all types of packaging material (including secondary packaging material) that are manufactured with polyethylene or polypropylene. All degradable plastic products that are to be imported must bear the SASO "Oxo-biodegradable" logo. The additives used to make products oxo-biodegradable makes them unsuitable for recycling.

Other Middle East

Growth dropped significantly in 2022 but remained positive in the basket of countries covered as "Other Middle East". This includes some highly prosperous energy rich nations such as the United Arab Emirates, and populous nations such as Lebanon and Jordan. The market has remained challenging in 2023 to date, with producers struggling to hold sales on par with 2022.

Film and fibre segments in 'Other Middle East' enjoyed some support in consumption into face masks made of polypropylene fibre, and have ongoing demand into disposable non-woven products. While e-commerce markets were supported by increased distance retailing during the pandemic, the effect of this unwinding subsequently is offset by the general increase in these practices.

Consumption of polypropylene in "Other Middle East" is mainly concentrated in the UAE and Oman, although there also significant consumers in Lebanon. Film and fibre production together account for 70 percent of polypropylene demand; whereas injection moulding accounts for a quarter of polypropylene demand. The spike in food prices in 2022 curtailed demand into some sectors of food packaging but did not trigger economic collapse in some countries as appeared likely for a time in late-2022.

Oman imposed a ban on the use of single-use plastic bags in January 2021. After a brief hiatus following the introduction of the ban, plastic bags have again started propping up with modifications in commercial outlets. While the supply is certainly less, commercial outlets appear ready to brave the fines rather than fear losing customers who are forgetful of bringing their reusable bags and reluctant to purchase alternatives at the outlets. As more shoppers get into the habit of bringing their own bags the demand for single-use plastic will be more heavily impacted in the medium term.

As part of the UAE's vision to enhance sustainable living the Environment Agency has commenced a program of measures to reduce plastic waste. Dubai imposed small tax on plastic bags of 25 fils (equivalent to around eight cents US), while Abu Dhabi banned most plastic bags altogether in mid-2022, leading to a reported 90 percent drop in volume. Sharjah plans to ban plastic bags in 2024.

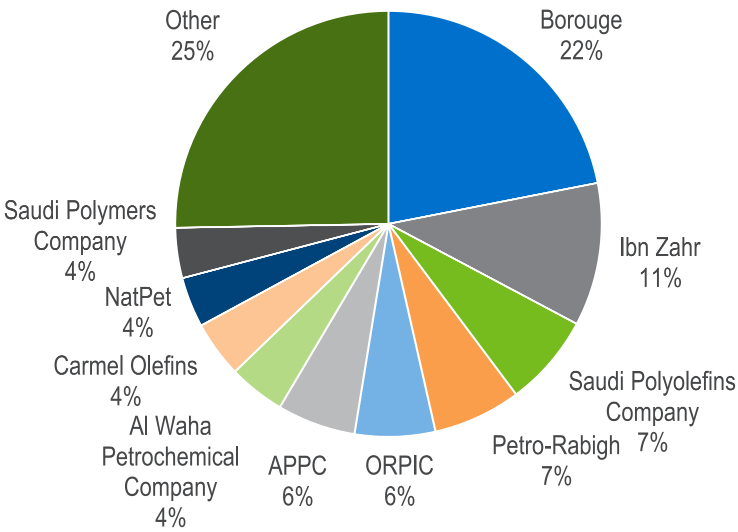
Consumption of polypropylene is set to increase in the medium term as OQ and the Public Establishment for Industrial Estates (Madayn) in Oman have signed an agreement to establish a complex for plastic industries in Sohar Industrial City, where OQ’s integrated cracker and polymer complex is located. The memorandum of understanding draws on the support of the Oman Vision 2040 Implementation. Under the memorandum, Madayn will provide land while OQ will basic raw materials at competitive prices within the complex.

4.4.7.2 Supply

The rate of capacity development in the Middle East has been slow over the last decade; however, there were significant capacity additions in both 2021 and 2022 to increase capacity by almost ten percent in two years. Volumes from OQ’s polypropylene unit as part of its LIWA project entered the market in 2021, while Borouge’s PP5 unit in the UAE started operations in February 2022. This was followed by Khomein Polypropylene’s smaller unit in July 2022. Prior to this much of the capacity growth in the region has been integrated PDH/polypropylene plants in Saudi Arabia, which were enabled by discounted propane. Following the establishment of several such operations the authorities were no longer prepared to grant propane allocations for additional plants as the economic benefit from additional polypropylene exports appeared less than the option to export propane at full market price. One new and very large scale PDH/Polypropylene project in Saudi Arabia was however given the go ahead in 2020 with expectation this is completed at the end of 2025. As a result, recent capacity developments have used propylene from mixed-feed steam crackers, refineries and PDH units. The Amiral steam cracker complex has now been confirmed in Saudi Arabia, although the propylene seems destined for acrylonitrile rather than polypropylene.

Borouge uses a unique approach to produce propylene at its Borouge II complex since the steam cracker is entirely ethane based. The process dimerises a proportion of the ethylene to butene, which is in turn fed into a metathesis plant along with more ethylene. Further capacity additions are expected in Saudi Arabia with AGIC receiving feedstock allocation for an integrated PDH and polypropylene facility in Al Jubail, while the further developments in the UAE from Borouge 4 will be based around an ethane cracker and therefore does not consider any large-scale polypropylene plants.

Figure 4.45 Polypropylene Capacity Share by Producer – Middle East (excluding Turkey), e-2023



Iran

Iran is the third largest polypropylene producer in the Middle East, behind Saudi Arabia and the United Arab Emirates. Capacity is approximately a fifth of leading producer Saudi Arabia's capacity. There are seven polypropylene production plants in Iran and the majority of these plants are small, with only two at 300 000 tons per year. Minimal investment has been made over the past few years with only Polynar expanding its plant in Tabriz by 30 000 tons per year to reach 110 000 tons per year in 2017. The polymer plants are supplied with propylene feedstock from domestic sources such as Amir Kabir, Faravaresh Bandar Imam, JAM Petrochemical and Tabriz Petrochemical, as well as from imports.

Khomein Polypropylene's 175 000 tons per year plant in Khomein was commissioned in July 2022, producing mostly homopolymer grades but also some copolymer.

There are a number of new plants planned and under construction in Iran and includes:

- Mehr Petro Kimia's 450 000 tons per year plant in Bandar Assaluyeh. The plant will be supported by propylene supplies from a new PDH unit. The project completion date has been delayed several times. Construction completion advanced from 18 percent in early 2022 to 33 percent in mid-2023. Commercial operations are conservatively forecast for 2027.
- Arghavan Petrochemical Company's 150 000 tons unit in Ilam, expected to be completed in 2025 with propylene to be sourced from the mixed-feed steam cracker at the site.
- Alvand Petrochemical Development Company's 180 000 tons per year plant in Arak, expected to be completed by 2027. Project completion may have accelerated however, and the first phase of the plant may feasibly enter operations sooner.
- Hirsa Sahand Polymer Company's 300 000 tons per year polypropylene plant which is set to be back integrated with a 300 000 tons per year PDH plant. The complex is expected to be located in Mahshahr Special Economic/ Energy Zone. Given the slow progress made on the project the timing of completion is unclear, with progress reportedly at 28 percent at the start of 2022.
- Seraj Gostarane Rejal's 291 000 tons per year polypropylene plant located in Mahshahr. Progress is reportedly at 18 percent and therefore it is not clear of the timing of project completion.

Similarly, there are several projects with remain more speculative and this includes:

- The Pars PDH/PP project which has an expected polypropylene capacity of 400 000 tons per year which is expected to be supported by a 600 000 tons per year PDH plant.
- The Fateh Kimia Company project with consists of a methanol to olefins project including a polypropylene plant. The capacity is undefined at this stage.
- The Jam PDH/PP (Kangan Polymer Development) project located in Kangan, which is expected to have a 600 000 tons per year polypropylene and PDH plant.
- The Alaye Mahestan (Kangan Petropalayesh) project consisting of a 450 000 tons per year PDH plant and equally sized polypropylene plant.

There are over ten PDH/polypropylene projects in Iran at different stages of development, although polyolefins capacity to date in Iran has developed at a much slower rate than announced. Some of the polypropylene projects now under development were proposed over ten years ago and remain far from completion. The effects of changing sanctions regimes and regulations regarding domestic contractor resources etc make project execution extremely challenging in Iran, and production is further restricted by gas availability and sanctions impact on shipping.

These project however may be further delayed due to further complications resulting from the sanctions regime in additions to the complexity of the proposed feedstock supply network in Iran. In 2021 Iran and China have signed an economic and security agreement that has been under negotiation for five years. The 25-year strategic cooperation agreement involves US$400 billion of investment in the overall Iranian economy out of which around US$280 billion will be invested in oil, gas, and petrochemicals. This geopolitical development will help Iran to increase its polymer production in the medium term. Iran’s trade is increasingly focused on China, which is among the most challenging markets globally due to overcapacity.

Iraq

There are no polypropylene plants in Iraq. Regional conflict has discouraged investment in recent years, and economic and industrial activity continues to be restricted by corruption and poor governance. Two speculative projects that are likely to include polypropylene are currently under discussion:

- A 650 000 tons per year polypropylene plant is proposed for the Al-Fawa peninsular in Basrah province. This project is likely to be supported by with refinery sourced propylene feedstock. The schedule for construction has not been announced.
- A greenfield refinery and petrochemical plant located near the port of Al-Faw on the coast of the Persian Gulf. This project could include a 1.5 million tons per year naphtha cracker to support polyethylene and polypropylene capacity. The contract for this project was initially signed in early 2018 with investment from Chinese companies including PowerChina and Norinco but failed to move forward. The project was relaunched in 2021 using a build-own-operate-transfer (BOOT) contract model, and a contract to build the complex was awarded to China National Chemical Engineering Co. (CNCEC). The timeline for the construction has not been provided and remains uncertain given that the project will have to be accompanied by infrastructure improvements including a port. The project's cost is estimated between US$7-8 billion. A Heads-of-Agreement was signed in 2022, but only for the first phase of the refinery which would not include petrochemicals.

Israel

Israel’s polyolefin industry is dominated by Carmel Olefins, which owns an integrated petrochemical facility in Haifa. Polypropylene capacity at this facility totals 450 000 tons per year, formed of two plants with capacity of 250 000 and 200 000 tons per year. Domestic production is reliable supported by strong feedstock availability. Due to the highly integrated nature of the plant a lengthy maintenance period can affect output across all units. Olefins/polyolefins production was sharply down in quarter four of 2022 as a result of both maintenance and poor demand.

As Israel's sole producer of polypropylene and polyethylene, Carmel Olefins enjoys a competitive advantage in Israel over importers of similar products. In contrast with its advantages in the domestic market, Carmel Olefins faces relative disadvantages on the international markets due to its limited production capacity and distance from target markets. To tackle these challenges, some of Carmel Olefins operations are carried out through forwarding warehouses in key target markets, and through its subsidiary, Ducor (located in the Netherlands).

In recent years, the company has increased the volume of ethane-rich gas at the expense of naphtha quantities. Ethane-rich gases allow Carmel Olefins to reduce its manufacturing costs compared to naphtha-based monomer production. This improves its ability to compete with manufacturers using naphtha exclusively as their raw material. Currently, Carmel Olefins policy is to replace the manufacture of commodity grades of polypropylene with other types of polypropylenes offering a higher added value, and which are sold at a higher price than commodity grades.

A panel led by Israel’s minister for environmental protection has confirmed its recommendation that the refinery and petrochemicals at Haifa be closed by 2025, to reduce pollution and make room for more ecologically focussed activities. It remains to be seen whether or not Carmel Olefins will be forced to close however, and the government reportedly has no concrete plan for what to do with the facilities and the Finance Ministry has no earmarked budget for this.

Kuwait

In Kuwait, EQUATE owns a facility in Shuaiba with two steam crackers, LLDPE and HDPE capacity, and Petrochemical Industries Company (PIC) owns a polypropylene plant in Mina Abdullah. The PIC polypropylene plant, supported by Nepal technology, has capacity of 150 000 tons per year.

PIC, a subsidiary of KPC, is investing in petrochemical facilities in Kuwait as part of the KPC Strategy 2030 objectives. Other stakeholders in the project are Dow, Boubyan Petrochemical and Qurain Petrochemical Industries. The plan includes an olefins and aromatics complex integrated with the Al-Zour refinery which has been progressively brought online in late 2022 and early 2023. The petrochemical additions to the complex are not yet firm, but the complex is likely to have access to refinery sourced propane and naphtha to supply feedstock for a mixed feed cracker of 1.4 million tons. Honeywell will provide technology for the refinery and petrochemical complex, including a 660 000 tons per year Oleflex PDH unit. The complex will feature 450 000 tons of LLDPE, 450 000 tons per year of HDPE and 940 000 tons of polypropylene. The FEED contract was awarded to Amec Foster Wheeler in 2017 but the project was severely delayed due to COVID-19 and other factors. The facility would use UNIPOL® polypropylene process technology for a full range homopolymer, random copolymer, and impact copolymer thermoplastic resins if it progresses, but no production is expected much before 2030.

Qatar

There are no polypropylene production facilities in Qatar. No firm or speculative capacity addition is expected over the forecast period. Unlike some other countries in the Middle East, the authorities in Qatar have not been willing to provide discounted feedstock for e.g. PDH, preferring to maximise export revenues for the basic hydrocarbons.

Saudi Arabia

Saudi Arabia is the largest producer of polypropylene in the Middle East with 5.5 million tons of capacity. This leading position has been somewhat eroded in recent years following new capacity in United Arab Emirates and to a lesser extent from new capacity in Oman. There has been no new polypropylene capacity in Saudi Arabia since 2012 with the last expansion occurring in 2018 as Advanced Petrochemical (APPC) debottlenecked its polypropylene capacity in Al Jubail.

As a result of the debottleneck, APPC increased propylene offtake from SATORP from January 2018, rising to around 100 000 tons per year, with an amendment being made from end December 2021 to increase propylene offtake to 120 000 tons per year. The company has also extended its offtake agreement to end-2025 and this will further boost polypropylene output and increase operating rates. This will be supported by downstream demand from investors located in the adjacent PlasChem park in Jubail, which is a collaborative effort between Sadara and Royal Commission for Jubail and Yanbu, located next to Sadara's chemical complex. While this will largely support output from Sadara's facilities, there will likely be demand for polypropylene in end-use sectors such as automotive and packaging sectors.

While the Amiral steam cracker is now confirmed downstream of the SATORP refinery, plans include HDPE but not polypropylene. If the acrylonitrile plant is not however built as planned, then it is feasible polypropylene could take its place.

A joint venture between SK Gas and APPC subsidiary AGIC (Advanced Global Investment Company) under the name Advanced Polyolefins have rapidly progressed plans for a large-scale PDH and polypropylene complex at Al Jubail which targets 840 000 tons per year of propylene with 800 000 tons per year of propylene being earmarked for two polypropylene plants. This is the first new PDH project to receive approval and feedstock allocation for many years in Saudi Arabia, enabled partly by the addition of supply for what would be the first isopropanol plant in the Kingdom. The EPC contracts for the two polypropylene plants were signed with Tecnimont and Tecnimont Arabia and they will use Basell Poliolefine Italia Spheripol and Spherizone technologies. Work started in November 2021 and the contracts have a term of 37 months from notice to proceed and mechanical completion is expected in November 2023. Construction is understood to be underway. The project proposal included a 100 000 tons per year polypropylene compounding unit; however, the announcement did not include plans for this plant.

There is a potential for further investment in Saudi Arabia, particularly for more speculative long-term developments. AGIC has received approval from the Ministry of Energy for the allocation of feedstock to supply its proposed petrochemical complex in Jubail Industrial City. The complex will include a mixed-feed steam cracker and will produce 1.15 million tons per year ethylene, 850 000 tons per year propylene and 400 000 tons per year of aromatics, fuels, and their derivatives. The scale and complexity (expected to include metathesis) are likely to mean that the originally announced timeline of 2025 looks unlikely, and startup could be closer to 2030.

SABIC and Saudi Aramco have agreed to develop plans for an integrated crude oil to chemicals project in Saudi Arabia. The project has been under consideration for several years, and the planning and decision process made more difficult by the extraordinary size, complexity and budget for the investment. The location of Ras Al-Khair has been selected, but no firm details have emerged on timing or the nature of the facilities. Previous discussions involved refinery-integrated liquids crackers, and therefore substantial volumes of steam cracker propylene.

Other Middle East

The Borouge III complex which started up in 2014 was based around a 1.4 million tons per year ethylene cracker and it included two 480 000 tons per year polypropylene plants. The polypropylene units consume refinery and PDH-based propylene from Takreer and construction of a fifth polypropylene unit (PP5) at the complex began in December 2018. Construction was completed on-time with the unit successfully starting-up in February 2022 after commissioning started at the end of 2021. The PP5 unit adds 480 000 tons per year of polypropylene capacity to the other Middle East region, representing a 25 percent increase in capacity.

The start-up follows the announcement made by ADNOC and Borealis in November 2021 that the final investment agreement has been signed for Borouge IV at Ruwais, Abu Dhabi. Plans include a 1.5 million tons per year ethane cracker which would increase the availability of propylene and therefore there is no further expansion of polypropylene capacity as part of the project.

ADNOC has announced the discovery of gas off Abu Dhabi, with interim results from the first exploration well indicating between 1.5 and two trillion standard cubic feet of raw gas in place. This follows from the discovery of up to one billion barrels of oil equivalent announced in December 2021. Awards have been announced for a new record investment in a drilling programme during February 2022. With the discovery of significant natural resources and investment into drilling, there is potential for further investment into polymer derivative units in the region.

In Oman, OQ effectively doubled its production of polypropylene in 2021 with a 300 000 tons per year plant in Sohar. The plant is part of its Liwa Plastics Industries Complex (LPIC) project which includes a 440 000 tons per year LLDPE unit, a 440 000 tons per year HDPE unit, and a 300 000 tons per year polypropylene with feedstock supplied by a mixed-feed cracker as part of the project. The plant started up in May 2020 but volumes from the polymer plants only entered the market in 2021 and the facility has been ramping up since.

4.4.7.3 Supply, Demand and Trade

There has been significant capacity addition in the Middle East in the last two years following slow growth over the last decade, with capacity increasing almost ten percent in two years with OQ's new polypropylene entering the market in 2021, while Borouge's PP5 unit in the UAE started operations in February 2022, and Iran's Khomein Polypropylene's 175 000 tons per year plant in Khomein came onstream in mid-2022. Capacity is again set to expand in the medium term with a number of integrated PDH/polypropylene complexes from Advanced Polyolefins in Saudi Arabia.

Saudi Arabia is by far the largest exporter in the region, with over 4.7 million tons of net exports in 2021, of which more than 96 percent was homopolymer. Middle East producers have primarily focused on supplying Asia Pacific but have also established a growing presence in North Africa, Western Europe, and in particular Turkey. A substantial share of supply growth will come from PDH-based plants, including one complex in Saudi Arabia following several years of suspension due to a perceived lack of economic benefit from supplying discounted propane into such businesses. This is exemplified by the feedstock allocation granted to Advanced Polyolefins being the first such development for around a decade.

Despite ongoing strong consumption growth, the new capacity developments planned post 2023 will permit substantial additional growth in polypropylene exports. The lack of major new capacity growth in the Middle East in the near term coincides with an excess capacity build in China, and therefore a very steep drop-off in operating rates is avoided; however, operating rates have been impacted by capacity coming online in Other Middle East.

Figure 4.46 Middle East (excluding Turkey) Polypropylene Supply and Demand

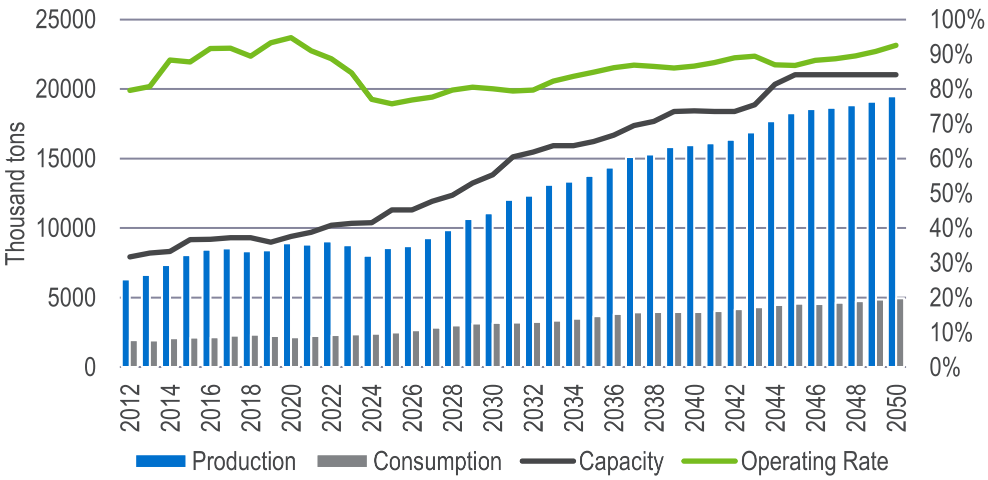


Table 4.44 Middle East (excluding Turkey) Polypropylene Supply, Demand and Trade
(thousand tons)

	Actual			Estimate	Forecast								Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Firm Capacity	7 922	9 308	10 192	10 350	10 378	11 300	11 300	12 230	12 230	12 264	12 230	12 230			
Speculative	-	-	-	-	-	-	-	1 600	4 000	6 167	8 800	8 800			
Total Capacity	7 922	9 308	10 192	10 350	10 378	11 300	11 300	13 830	16 230	18 430	21 030	21 030	2.5	4.2	2.1
Operating Rate	80%	92%	89%	85%	77%	76%	77%	80%	85%	87%	87%	93%			
Production	6 308	8 543	9 042	8 763	7 997	8 565	8 686	11 073	13 765	15 959	18 254	19 475	3.0	3.4	2.9
Net Export	4 377	6 274	6 738	6 411	5 597	6 069	6 039	7 885	10 105	11 992	13 703	14 516			
Consumption	1 931	2 269	2 304	2 352	2 400	2 495	2 646	3 189	3 660	3 968	4 551	4 959	1.8	4.4	2.2

Iran

Polypropylene production was flat in 2022, providing an operating rate slightly below 60 percent. Despite a slight recovery in 2021 from the COVID-19 related low in 2020, production remains well below peak levels despite some capacity addition.

Higher gas output during 2021 allowed a small increase in production, although facilities remained generally underutilised. Iran is a net exporter of polypropylene homopolymer and a small net exporter of polypropylene copolymer after the country switched from a marginal net importer in 2020.

Net exports of polypropylene homopolymer had previously almost disappeared but strengthened somewhat in 2021 but continue to remain below levels achieved between 2015 and 2018. Previously, exports to Turkey declined but rebounded in 2021 as there was less competition from other exporters and despite issues relating to sanctions remaining. Exports to Turkey have historically made up almost two thirds of the total exports, but volumes dropped in 2022 due to the sharp decrease in demand there. Other key export destinations are mostly in Eastern Europe, with Uzbekistan, Georgia, Azerbaijan, and Armenia making up most of the remaining exports. Iran has a free trade agreement with the EAEU which has facilitated these exports. Iran was previously a significant net exporter to China but has now almost entirely lost its position there and instead imports a small quantity.

Iran switched from a marginal net importer of polypropylene copolymer in 2020 to a small net export position in 2021, closing at 7 000 tons, according to the trade data. This has occurred as imports from South Korea have dried up while only a small amount of imports remain from Turkey, China, and the UAE. Exports have increased in 2021 with volumes mainly shipped to Turkey and smaller quantities exported to Eastern Europe.

Following the lifting of sanctions in 2016 Iran started seeking free trade agreements with numerous other regions. A free trade agreement was reached with Pakistan at the end of 2017. A similar agreement was made with Oman in early 2018. In May 2018 Iran signed an interim free trade agreement with the Eurasian Economic Union (EAEU), which is led by Russia and includes Belarus, Kazakhstan, Kyrgyzstan, and Armenia. The interim free trade agreement has been extended until October 2025, or until a final agreement is reached and takes effect. In 2019 Iran began preparations for its accession to the EAEU but this has not progressed. For other countries, import duties for polyolefins are five percent for most grades, with for some polyolefin compounds this increases to ten percent.

The U.S. sanctions imposed in June 2019 continue to be strictly imposed and these remain in place despite recent efforts made by the Biden administration to engage in talks over the last two years. Iran's support for Russia during its invasion of Ukraine has made the lifting of sanctions a more distant prospect.

Iraq

Polypropylene markets in Iraq have been hampered by regional conflict and political instability. There is no domestic capacity, so the country is dependent on imports. Market growth in the past two years has recovered loses experienced in 2019 as the country as the country continues to regain some control: conflict was reduced, and an election was held in October 2021.

Imports are mainly supplied from within the Middle East with volumes form Saudi Arabia, Iran, and increasing volumes from Jordan after the Iraqi-Jordanian border was reopened in mid-2017. Imports also originate from South Korea.

Import duties for plastics and plastic products have been set at ten percent since 2018 after previously being five percent. Iraq has concluded Free Trade Agreements with Algeria, Egypt, Jordan, Oman, Qatar, Syria, Sudan, Tunisia, and UAE; however, the government suspended these agreements pending a five-year review of the extent to which these agreements have benefitted Iraq.

Israel

A sharp drop in production shifted Israel into a net import position on polypropylene in 2022. The drop was due in part to major maintenance activity in quarter four, but also due to the tough market conditions. Margins were markedly lower on polypropylene, while refining margins were much higher, motivating the production of gasoline etc instead of raw materials for polymer production.

There are numerous downstream converters which require polypropylene, which mainly acquire their supplies from Carmel Olefins. The market is well developed and in close proximity to the Haifa facilities. Carmel Olefins holds about a 70 percent share of the market for polypropylene products. Imports have increased as a result of the normalization agreements signed in 2020 by the State of Israel and some neighbouring countries which facilitate trade.

Carmel Olefins has conducted a research and development program to customize existing products and develop special types of polypropylene grades those are suitable for special industries so that the Company can better defend its market volume and margins. Grades include products for the automobile industry and unique transparent and unbreakable polypropylene products suitable for various applications, such as storage boxes and suitcases.

In 2020, Carmel Olefins became a partner with two EU sponsored consortiums as part of which R&D activities were carried out in the Horizon 2020 Programme, one in antimicrobial packaging that extends the shelf life of food products and the other in energy storage for geothermal systems. The Company also became a partner in a consortium sponsored by Israel Innovative Authority for the development of generic technologies for the manufacturing of smart non-woven fabrics together with its customers. Carmel Olefins also heads a plastic recycling consortium sponsored by Israel Innovation Authority, aimed at developing plastic recycling solutions and is a partner in a new consortium for the development of smart materials for agriculture. More recently in Israel, a purchase tax on disposable tableware made of plastic was increased significantly at the end of 2021.

The National Economic Council brought in a consultant as part of inter-ministerial discussions on the future of the Bazan Group's companies and operations at the Carmel Olefins facility in Haifa. It was tasked with examining the economic costs of moving the refinery and petrochemical facilities and specifically of considering the costs and benefits of four options: maintaining the facilities as it is, in the same place; partially shutting it down; shutting it down totally, according to various proposed timescales; or moving it to a non-urban location elsewhere in the country. Complete closure now looks the most likely.

Imports of homopolymer polypropylene are mainly obtained from China, India and the EU, while imports of copolymer polypropylene are mainly from the EU and the United States.

Israel has bilateral trade agreements with the EU and the U.S., which contribute to a reduction or elimination of duties. The country also has free trade agreements with Bulgaria, Canada, the Czech Republic, Hungary, Mexico, Poland, Romania, the Slovak Republic, Slovenia, Turkey, EFTA, MERCOSUR, and Jordan. Agreements with India and China are under discussion and there is generally no duty on polymer imports.

Kuwait

In Kuwait, there are numerous small downstream converters which require polypropylene for applications such as fibre, moulding and pipe. Domestic polypropylene capacity outstrips local consumption, so the country is a net exporter. The market is small and underdeveloped with modest growth potential, so production levels are largely determined by the trade situation. Net exports in 2022 were similar to those in 2021 as the operating rates of the PIC facility have been good. Year-to-date exports in 2023 have been similar as well, with a slight shift geographically reflected the contested market in Turkey. Over the forecast period the country will stabilise and maintain the net export position and will strengthen if new capacity is constructed.

Kuwait has a five percent tariff on imports. As a member of the GCC, Kuwait is part of the customs union and imports into this region at the point of entry have a five percent tariff. The goods can then travel freely to other GCC countries including Saudi Arabia, United Arab Emirates, Qatar, Oman, and Bahrain. The GCC has entered into a free-trade agreement with Singapore, which has been in force since 2013. Kuwait also has an agreement with the European Free Trade Association (EFTA), which includes the countries of Iceland, Liechtenstein, Norway, and Switzerland. The EU resumed discussions about a trade agreement with the GCC in 2017, although progress has been slow. Furthermore, Kuwait has signed bilateral investment agreements with a range of nations (including some in the EU) but not all of the agreements have been implemented.

Qatar

Polypropylene markets in Qatar are small supplied solely by imports due to the lack of domestic capacity. The region's polyolefins industry relies on ethane-based olefins capacity for feedstock, so propylene is less available domestically. There are numerous small downstream converters, which require polypropylene for applications in the injection moulding, fibre and film segments.

Qatar is a small net importer of polypropylene due to the small domestic market and the vast majority of this import requirement is polypropylene homopolymer, which is sourced from countries in the Middle East. The vast majority of supplies originate from Asia Pacific, in particular from China, India, Thailand, and South Korea. In the long-term the country will remain a small net importer of polypropylene, with low growth in domestic markets.

Qatar has a five percent tariff on imports at the point of entry since it is a member of the GCC and therefore the customs union. Qatar signed 59 bilateral investment treaties (BITs) including with Armenia, Azerbaijan, Belarus, Belgium-Luxembourg Economic Union, Bosnia and Herzegovina, China, Costa Rica, Cyprus, Egypt, Finland, France, Gambia, Germany, Indonesia, Iran, Italy, Jordan, Montenegro, Morocco, Portugal, Romania, Russia, Singapore, South Korea, Switzerland, and Turkey.

Saudi Arabia

Saudi Arabia is the leading producer of polypropylene in the Middle East despite a lack of capacity addition in recent years, due to limited additional propylene supply and a preference for other derivatives such as propylene oxide. This is set to change in coming years with a feedstock allocation granted to Advanced Polyolefins for discounted propane. Plans will include 800 000 tons per year of polypropylene as part of the PDH complex, expected to reach mechanical completion in November 2023.

Saudi Arabia is a globally leading exporter of polypropylene, despite the healthy levels of domestic consumption. The major export market for polypropylene is Turkey which accounts for almost 20 percent of all exports, followed by Egypt, China, Malaysia, India, Singapore, and Pakistan. The intense competition in export markets and the particularly difficult trading conditions in Turkey are due to global recessionary conditions which are compounded by particular economic and currency issues in Turkey. Exports for 2023 therefore appear unlikely to reach the levels achieved in 2022 unless there is a particularly strong recovery in the second half of the year, which does not at this stage appear likely.

A large amount of exports are delivered to Singapore since it acts as a trading hub to enable Saudi Arabian polymers to be shipped to other destinations around China and South-East Asia. This volume declined in the first half of 2023, partly due to increasing Chinese exports. Imports are extremely low in comparison and are mainly sourced from the UAE.

As a member of the GCC, Saudi Arabia is part of the customs union and imports into this region at the point of entry have a five percent tariff, but exports to most destinations are also moderately taxed. The GCC Customs Union stipulates the free movement of local goods among member states, while the United States signed a Trade and Investment Framework Agreement (TIFA) with Saudi Arabia. Negotiations occurs on a wide variety of trade and trade policy issues every one to two years, with the last meeting being held in 2018.

Other Middle East

The region of 'Other Middle East' included significant exporters such as UAE and Oman, and numerous small importers such as Syria, Lebanon and Bahrain. Net exports continued to increase in 2022, due to higher production in both Oman and UAE. Net exports are set to increase further in 2023 due both to a slight further increase in production, and lower imports into some of the East Mediterranean countries. The combination of higher energy and food costs has chronically stretched some of the regional economies which are dependent on imports.

Almost two-thirds of Oman's exports are sent to Asia Pacific (mainly to China with smaller volumes to India), while around 15 percent is exported to Turkey. Borouge, the major producer in the UAE, is also focussed on Asia, with almost 80 percent of all exports to the region, partly to avoid competition with one of its parent companies Borealis in Europe. Within Asia the majority of exports are to China, followed by India with smaller amounts to Malaysia. As with Oman, volumes are also exported within the Middle East with volumes exported to Turkey.

Borouge's PP5 unit entered operation in February 2022, while OQ achieved full capacity by the middle of the year. There are no further plans for expansion currently, although capacity addition could occur at either site.

4.4.8 North-East Asia

4.4.8.1 Consumption

China

China's consumption of polypropylene pellets reached 33.3 million tons in 2022, with a growth rate of two percent compared to the previous year. This growth rate is lower than the four percent growth rate seen in the previous year due to a decrease in downstream demand. Production has increased by six percent, while import volume has declined by 24 percent. In 2020, there was a significant growth in virgin polypropylene consumption, reaching 17 percent compared to 2019. This growth was due to an increase in domestic demand, high import volumes, and strong downstream product exports. However, there was a decline of 29 percent in mechanical recycled plastics during the year due to hygiene concerns, which boosted demand for virgin polypropylene.

In 2021, there was a 125 percent increase in mechanical recycled PP plastic production, encouraged by the "Circular Economy Development Plan of the 14th Five-Year Plan." Polypropylene represented over 45 percent of the total Chinese polyolefin market in 2022. Injection moulding is the largest application for polypropylene, accounting for around 34 percent of total domestic demand. Fibre and film account for around 31 percent and 24 percent, respectively. The biggest downstream consumers for injection moulding are the automotive vehicle and household appliance sectors, especially for washing machines. Other household appliances, like electric fans, fridges, and televisions, also contribute. Packaging accounts for a significant portion of polypropylene consumption, supported by the large catering industry, especially for take-away services. Polypropylene has better sealing performance and higher temperature resistance stability than EPS, which has led to a decline in the use of EPS for disposal meal boxes. Packaging drives PP consumption in blow moulding, extrusion coating, and film. Fibre demand is supported by the production of personal protective equipment (PPE) and use in agriculture.

In 2022, the production and export growth rate of plastic products declined compared to 2021. China's total export value achieved 10.3 percent growth, weakened from 21.2 percent in 2021. Plastic product export value grew by 12.7 percent against 20.5 percent in the previous year. Output of primary plastic grew by 3.0 percent compared to 4.7 percent in 2021. The zero-covid-case policy resulted in at least three months of lockdown in many major Chinese cities in the first half of 2022, which constrained travel domestically and across borders for most of the year. As a result, 2022 GDP weakened to three percent against eight percent in 2021.

Injection moulding demand was constrained during 2018-2019 due to the global economic recession, which lowered consumer confidence and decreased consumption of big-ticket items like cars, houses, and electronics. This affected demand in the injection moulding industry. There had been continuous negative growth in automotive production since 2018, and the ongoing U.S.-China trade dispute also constrained exports of finished products. However, in 2020, demand in injection moulding achieved more than 17 percent growth as the COVID-19 pandemic disrupted supply chains globally and boosted exports from China, which had successfully controlled the spread of the pandemic in the early stages. In 2021, the home appliance industry was driven by export, which accounted for 44 percent of total sales revenue. PP consumption growth for the injection moulding segment was estimated at almost ten percent. In 2022, total output quantity and revenue growth of the four leading home appliances were reported at 1.4 and 1.1 percent, respectively. Household refrigerators' output quantity declined four percent, export declined 23 percent. Household washing machines' output quantity declined four percent, export declined six percent. Air conditioner output quantity increased two percent, export declined 13 percent. Coloured TV output quantity increased six percent, export increased ten percent. Automobiles reported an output of 27.2 million units, a 3.5 percent growth, and export quantity reached 3.3 million units, increased 57 percent. PP consumption for the injection moulding segment was estimated at around four percent. Polypropylene consumption in the injection moulding sector is expected to grow at an average rate of less than five percent through to 2027 and around three percent for 2027-2045. It will remain the main driver with continuous positive growth for economic activity, income growth, and personal spending.

In the fibre industry, raffia polypropylene makes up no more than 70 percent of the total PP fibre market, followed by spunbond polypropylene. Prior to 2018, recycled materials were commonly used in woven bags for cement, fertilizer, and agriculture products, as well as non-woven fabric like shopping bags, which limited the demand for virgin polypropylene. However, the ban on importing plastic scrap has since driven growth in virgin polypropylene consumption, particularly in response to the COVID-19 pandemic. The pandemic has led to a significant increase in demand for raffia grade polypropylene for packaging and melt blown grade polypropylene for mask production. Although melt blown grade polypropylene only accounted for less than 0.1 percent of total polypropylene consumption in 2019, it had a significant impact on overall consumption in 2020, contributing to an 18 percent growth in the fibre sector. However, in 2021, total production of masks declined by eight percent to 9.2 billion pieces, resulting in a 30 percent decline in PP consumption for non-woven spunbond grade fibre. Woven grade only grew by seven percent, causing a four percent decline in PP consumption for fibre. In 2022, the non-woven spunbond grade fibre reported approximately three percent growth, while woven grade demand was weak due to countrywide lockdowns in the first half. By 2023, with the full liberalization of epidemic control in China, masks are no longer compulsory, resulting in a 36 percent decline in non-woven spunbond grade fibre production. On the other hand, while economic activities resumed, woven grade production grew by almost 20 percent. In the forecast period, demand for PP fibre will continue to be driven by non-woven products such as masks, as well as diapers and other hygiene products. Raffia will remain the main sector, but growth will mainly follow GDP growth, construction activities, and changes in cultivated land area.

The demand for polypropylene film has been driven by the increasing capacity of biaxial oriented polypropylene (BOPP) film, which dominates around 75 percent of the market, followed by cast polypropylene (CPP) film and isotactic polypropylene. BOPP film capacity has grown significantly in recent years and reached over 7.7 million tons per year in June 2023, while CPP film capacity was at 1.3 million tons per year in 2022. China Soft Packaging Group is the world's largest BOPP film producer, with a total capacity of one million tons per year across five manufacturing bases. Large producers are expected to invest in specialty films in the future. Polypropylene film is primarily used in food packaging, accounting for around 50 percent of the market, followed by garment packaging and adhesive tape packaging, which make up around 40 percent of the market. Demand for polypropylene film has increased due to the rise of take-away food orders, as COVID-19 restrictions have limited in-restaurant dining since 2020. In 2021, food delivery transactions grew by over 40 percent year-on-year, with the express delivery business reaching 108.3 billion pieces, a 29.9 percent year-on-year increase. BOPP production growth is estimated at ten percent, while consumption for PP film is estimated at ten percent in 2021, following a 17 percent growth in 2020. In 2022, the express delivery business only increased by two percent, to 110.6 billion pieces, due to COVID-19 lockdowns. Film production reported zero growth. However, in the first half of 2023, film output increased by over 25 percent, and PP consumption growth for film is expected to be the highest growth segment in 2023, with the full liberalization of epidemic control.

The extrusion coating market has mainly grown with raffia production, as well as film production for packaging, where polypropylene copolymer is coated onto raffia or film. Other extrusion sectors mainly include sheets and pipes. Polypropylene sheets usually undergo a thermoforming process and have low-cost advantages compared to thin wall injection moulding. Since the beginning of 2021, plastic straws have been banned in the catering industry, and around 90 000 tons per year of polypropylene consumption is expected to disappear. Polypropylene random copolymers (PPR) are widely used for rigid clear container production and films used in clear film for flexible packaging. Another major application is PPR pipe, which is currently the third-largest consumed pipe material in the Chinese market, accounting for over ten percent of total polymer consumption for pipes. PPR pipes are mostly used for water, especially for water and heating supply inside buildings. Demand for PPR pipe has been growing rapidly, competing with other major piping materials, and has become popular in in-house applications, particularly in home decoration. PPR consumption is expected to grow by more than five percent annually in the medium term, faster than the overall pipeline industry.

Homopolymer polypropylene accounts for over 70 percent of total consumption in China and is primarily used in fibre and film for packaging applications, injection moulding for housewares applications, and sheet and pipe applications. The household appliance and automotive industries are key sectors linked to China's polypropylene industry, particularly impact copolymer. The electric/electronic industries have also accelerated demand growth for impact copolymer polypropylene.

Japan

In Japan, the demand for polypropylene increased by 1.1 percent to 2.3 million tons in 2022, following a growth rate of ten percent in 2021. However, due to a slowdown in the country's GDP, the consumption of polypropylene decreased. Japan faced challenges with high inflation and interest rates, which affected both the manufacturing sector and consumer spending.

The automotive industry, which is the largest domestic market for polypropylene, saw a contraction of 12 percent in 2020 due to the COVID-19 pandemic. However, it was able to fully recover in 2022 as the chip shortage situation subsided towards the end of the year. But the recovery in demand may be short-lived as consumer spending is expected to decrease in 2023 due to concerns about high inflation rates and the increase in the cost of living.

Japan's economy faced headwinds due to the poor economic situation caused by the pandemic and the imposition of a higher national sales tax in 2019, leading to a slump in consumer spending. This affected demand for injection moulding and extrusion, especially for big-ticket items like cars, houses, and expensive electronics. The demand for film was also hindered by environmental policies. The government implemented plastic bag fees for all retailers in July 2020, and Japanese consumers started to adapt their behaviours to reduce plastic waste. Additionally, a new policy was launched in April 2022, which would ban shops and businesses from providing single-use cutlery for free.

In Japan, injection moulding is the major polypropylene application, accounting for more than half in 2022. Together with demand into automotive production, demand into plastic parts for consumer goods and appliance housing is still going well in 2022. However, due to high polypropylene per capita consumption combined with a demographic-driven growth slowdown, consumer concern on the overall economic situation is expected to affect Japan's polypropylene consumption, causing it to slow. High labour costs will continue to motivate Japanese automobile and electronic producers to invest in downstream assembling capacity abroad.

South Korea

South Korea's demand for polypropylene increased by 2.5 percent to 1.7 million tons per year in 2022. The largest end-use for polypropylene is injection moulding, with impact polypropylene dominating around 43 percent of the market. The growth of injection moulding was driven by the automobile, electrical/electronics, and home appliance industries in 2022. South Korea's automotive industry saw an increase of almost ten percent due to growth in export markets and increased investments from South Korean auto producers in foreign markets. However, the growth of the electrical/electronics and home appliance industries slowed down both domestically and in export markets. The global automotive industry showed signs of recovery in 2021 after suffering a negative 16 percent production growth in 2020 due to the coronavirus pandemic. Although the South Korean automobile industry also suffered negative production growth, it recovered better than most countries and continued to grow in the electric vehicle (EV) production segment. South Korea retained its position as the fifth-largest global automotive production country after rejoining the list in 2020.

In 2022, homopolymer accounted for 46 percent of polypropylene, impact copolymer accounted for 35 percent, random copolymer accounted for ten percent, and others accounted for nine percent. The demand for copolymer polypropylene has continuously increased due to high demand from the injection moulding sector and compounds. In contrast, the demand for homopolymer polypropylene decreased by five percent over the last ten years.

Despite the Covid-19 pandemic subsiding, the demand for non-woven fibre for face masks continued to grow in 2022 due to the high health awareness among the population. The trend of increasing single-person households and couples without children or smaller-sized families resulted in the lowest birth rate among OECD member countries, generating a higher packaging demand on a per capita basis. The demand for non-woven fibre for baby diapers continued to decrease, while the demand for adult diapers increased due to the aging population. Polypropylene also found new applications in the medical sector, such as syringes, tubes, and bottles.

However, in 2023, the economic slowdown will result in a slower demand growth, with each sector experiencing growth at different rates. The main demand support will be from exports as South Korean companies have increased their investment in foreign markets in recent years. The construction industry is likely to slow down compared to the automotive sectors, as the global semiconductor shortage situation subsides. Despite the reopening of borders for tourism and commercial activities, domestic demand is expected to be hindered in the medium term due to the tightening regulation of single-use plastic, affecting the demand for disposable plastic.

Taiwan

In 2022, Taiwan's demand for polypropylene decreased by 21.5 percent compared to 2021 due to high crude oil prices and poor global economy, resulting in weak domestic and export demand. The largest end-use of polypropylene is injection moulding, which produces automotive parts, housewares, luggage, and electrical/electronics items. Taiwanese converters supply automotive parts to other countries, but they face competition from Chinese finished products. Although the production of passenger cars in Taiwan in 2022 decreased by 1.5 percent, Taiwan's main export markets for automotive parts, such as the U.S., Japan, China, and Western Europe, increased by four percent. In the next decade, the expected consumption of polypropylene for injection moulding is around the GDP growth rate.

In 2022, demand for film decreased below the pre-pandemic level after strong demand in 2020 and 2021. Flexible packaging applications primarily consume film, with BOPP being the largest film application, accounting for more than 80 percent of total film demand. IPP represents nearly 15 percent, while CPP represents five percent. Demand for food packaging increased due to the pandemic, but local packaging producers faced severe competition from imported ready-packaged foods. However, the restriction of imports benefitted packaging producers in 2020. Despite the well-controlled pandemic, demand for packaging remained stable in 2021. Once global economies resume normal, Taiwan is expected to import packaged foods again. Local converters will need to adapt to high-end products.

Fibre is mainly used in non-woven applications, such as diapers and medical products, accounting for more than 60 percent of total fibre demand. The remaining 40 percent is consumed for industrial and agricultural usage. Fibre demand increased significantly in 2020 due to protective equipment against COVID-19, such as masks and PPE. The aging population also supported demand for diapers. Taiwan's PP non-woven demand grew strongly as elderly people could not immigrate to other countries for their retirement. The restriction in travelling confined people to stay in Taiwan, which supported strong growth in fibre. The growth for fibre remained above the GDP in 2021 as the pandemic outbreak continued. Masks were mandatory in indoor settings until April 17, 2023, while it was no longer compulsory in outdoor settings from December 1, 2022. In 2022, polypropylene demand for fibre weakened, but it still remained higher than the pre-pandemic level.

Blow moulding applications are relatively small and mainly used for bottle production. Other extrusion is used for thermoforming containers, profiles, and stationaries. Single-use plastics for food packaging became more popular during the controlled period of COVID-19. However, the government's policy to ban single-use plastic items, such as disposable cups, would limit the demand for thermoforming containers in the medium term. In the "others" segment, a large share of the volume is used to produce pipes and master batches.

Figure 4.47 North-East Asia Polypropylene Consumption by End-Use, e-2023

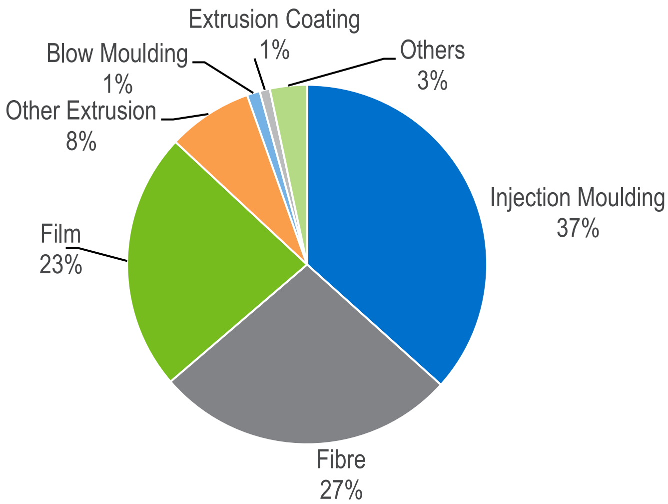


Table 4.45 North-East Asia Polypropylene Consumption by End-Use
(thousand tons)

	Actual			Estimate	Forecast								Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Injection Moulding	7 724	10 532	13 690	14 445	14 986	15 614	16 345	18 963	22 008	24 787	28 412	31 624	5.9	4.0	2.6
Fibre	5 321	7 729	10 454	10 656	11 157	11 725	12 369	14 613	16 926	18 862	21 372	23 582	6.5	4.6	2.4
Film	4 321	6 253	8 529	9 158	9 544	9 982	10 477	12 225	14 236	16 025	18 344	20 392	7.1	4.2	2.6
Other Extrusion	1 671	2 306	2 963	3 012	3 142	3 295	3 469	4 061	4 648	5 104	5 682	6 195	5.5	4.4	2.1
Blow Moulding	238	354	451	458	474	492	514	594	685	756	844	923	6.1	3.8	2.2
Extrusion Coating	191	272	344	360	375	392	411	478	565	640	744	838	5.9	4.1	2.9
Others	963	1 045	1 278	1 311	1 344	1 385	1 434	1 605	1 782	1 910	2 087	2 239	2.8	2.9	1.7
Total	**20 429**	**28 491**	**37 709**	**39 401**	**41 022**	**42 884**	**45 019**	**52 540**	**60 849**	**68 083**	**77 485**	**85 793**	**6.2**	**4.2**	**2.5**

Table 4.46 North-East Asia Polypropylene Consumption by Country
(thousand tons)

	Actual			Estimate	Forecast								Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
China	15 868	23 780	33 289	34 878	36 473	38 279	40 329	47 616	55 736	62 919	72 124	80 303	7.4	4.5	2.6
Japan	2 480	2 509	2 286	2 285	2 296	2 310	2 333	2 370	2 401	2 387	2 424	2 444	(0.7)	0.5	0.2
South Korea	1 521	1 623	1 662	1 697	1 704	1 734	1 779	1 932	2 056	2 107	2 235	2 323	1.0	1.9	0.9
Taiwan	560	579	472	542	548	561	578	622	657	670	702	724	(0.3)	2.0	0.8
Total	**20 429**	**28 491**	**37 709**	**39 401**	**41 022**	**42 884**	**45 019**	**52 540**	**60 849**	**68 083**	**77 485**	**85 793**	**6.2**	**4.2**	**2.5**

4.4.8.2 Supply

China

It has been reported that there is a new surge of capacity addition in China's polypropylene industry since 2020. The industry has seen a double-digit growth in capacity from 2020 to 2023, with the current start-up schedule. In 2022, there was an addition of 3.5 million tons per year, bringing the total capacity to 39 million tons per year, which accounts for 38 percent of global capacity. However, due to poor margins and low operating rates, almost four million tons per year of new capacity have been postponed until 2023. As of now, around 15 million tons of new capacity are set to start up between 2023 and 2025, with more than six million tons per year of new capacity scheduled to start up in 2023. In the first quarter of 2023, two million tons have already gone onstream successfully.

Capacities addition in 2022 and 2023, include:

- Zhongjing Petrochemical phase two, line one 600 000 tons per year polypropylene plants with LyondellBasell technology, started up at September 2022. The startup of line two with the same capacity and technology is expected to delay to December 2023 or into 2024. It affiliates Shangjing New Material Co., Ltd. has received EIA approval for 1.5 million tons of polypropylene plants (six 250 000 tons per year lines) in January 2022. There plants are expected to start up in various phases from 2024. Raw materials will be provided by the integrated 900 000 tons per year new PDH facility to be operated by Wanjing. Currently Zhongjing purchase raw material propylene externally.
- Dongguan Juzhengyuan started up 600 000 tons per year polypropylene plant integrated with PDH unit with the same scale in the fourth quarter of 2019. They are also building their second phase project including another 600 000 tons per year propylene capacity from propane dehydrogenation unit. Start-up of the integrated 600 000 tons per year polypropylene capacity plant was delayed from quarter three 2022 to 2023. So far NexantECA have not seen confirmation that this facility has started up.
- Ningxia Baofeng’s three lines with 500 000 tons per year polypropylene capacity, which is a CTO integrated, was delayed from end 2022 to 2023. So far NexantECA have not seen confirmation that this facility has started up.
- Oriental Energy added two polypropylene lines with 400 000 tons per year capacity each in May and June 2021, integrated with the upstream PDH units in Ningbo, Zhejiang. They have also planned a large manufacturing base in Maoming, Guangdong with three 400 000 tons per year polypropylene lines integrated with PDH units. The 400 000 tons per year facility started operation in September 2023. The company’s total polypropylene capacity will reach 2.8 million tons at the completion of the Maoming complex, with 0.4 million tons per year at Zhangjiagang, 1.2 million tons per year at Ningbo and 1.2 million tons per year at Maoming.
- Zhejiang Petrochemical has built 900 000 tons per year polypropylene capacities integrated with its naphtha/gasoil-based steam cracker in each of the two phases. The first phase with two 450 000 tons per year polypropylene capacity has already started up in January and February 2020. The second phase was started at end December 2021 and March 2022. Other than the refineries, propylene can also be supplied from the company’s two 600 000 tons per year PDH units in two phases.
- Liaoning Bora started up two polypropylene plants with 400 000 tons per year and 200 000 tons per year capacity respectively, integrated with the upstream gas cracker, started up in September 2020.
- Qilu petrochemical is planning to start up a 250 000 tons per year polypropylene plant at the end of 2022.Sinopec Tianjin Petrochemical has started up a 200 000 tons per year polypropylene plant in April 2021.Wuhan Petrochemical was restarted and renamed to Zhonghan Petrochemical on

1 July 2019 (65 percent owned by Sinopec, 35 percent owned by SK Group of Korea). The company had three polypropylene plants with a total capacity of 500 000 tons per year. A fourth polypropylene plant with 300 000 tons per year was started up on 26 March 2021, using Sinopec third generation technology.

- Sinopec Zhenhai Refinery started up a 300 000 tons per year polypropylene plant in February 2022.

Projects linked to PDH units include:

- Formosa Plastics expanded its polypropylene capacity by 70 000 tons per year to 520 000 tons per year by the end of 2021, integrated with the start-up of a new PDH unit.
- Jinneng Science and Technology built a first phase 450 000 tons per year polypropylene plant integrated with 900 000 tons per year PDH unit, was onstream in the middle of October 2021. The construction of second phase 450 000 tons per year polypropylene plant began in February 2022, the plant is expected to start up in second half of 2024.
- Ningxia Runfeng New Materials started up a 300 000 tons per year polypropylene plant integrated with upstream PDH unit with the same scale at the end of 2021.

Projects integrated with MTO/MTP capacity include:

- Huating Zhongxu Coal Chemical has completed construction for a new 200 000 tons per year polypropylene plant, integrated with upstream MTP plant in 2020, start-up was delayed to April 2022 due to high cost of coal in the past two years.
- Qinghai Damei Coal Industry has completed construction for the 400 000 tons per year polypropylene plant, integrated with upstream MTO plant in 2020, but the start-up time is not firm due to the high cost from coal.
- Tianjin Bohai Chemical has started up a 300 000 tons per year polypropylene plant, integrated with MTO complex, in April 2022. A second 300 000 tons per year polypropylene plant is scheduled to start up in 2023. So far NexantECA have not seen confirmation that this facility has started up.
- Shaanxi Yanchang China Coal Yulin Energy and Chemical added a new polypropylene line with 400 000 tons per year capacity in December 2020.
- Other than the above firm projects, Shanxi Coke and Sinopec Bijie also have plans to add 700 000 tons per year capacity integrated with MTO projects, but the progress is slow.

Polypropylene projects integrated with steam cracker propylene:

- Wanhua Chemicals added 300 000 tons per year polypropylene capacity, integrated with the upstream gas cracker, in December 2020.
- Hainan Petroleum Refining Chemical is building two polypropylene plants with 200 000 tons per year and 250 000 tons per year capacity respectively, integrated with the upstream steam cracker. These facilities were commissioned in December 2022.
- Sinochem Quanzhou Petrochemical is constructing a 350 000 tons per year polypropylene plant as part of their phase II project in Quanzhou, Fujian province, was onstream in September 2020.
- Shandong Shouguang Luqing added 300 000 tons per year new polypropylene capacity, integrated with upstream mix-feed cracker in April 2022.
- Gulei Refinery has a 350 000 tons per year polypropylene capacity integrated with its new steam cracker started up in August 2021.
- The JV of PetroChina and PDVSA has put onstream in 2023 a 600 000 tons per year polypropylene capacity, integrated with upstream steam cracker.
- PetroChina Liaoyang Petrochemical added 300 000 tons per year polypropylene line in August 2021.

Japan

By the end of 2022, the annual capacity for polypropylene was 2.8 million tons. Japan Polypropylene recently closed down its plants in Kashima and Chiba, reducing their annual capacity by 106 000 and 79 000 tons respectively. The country had been gradually shutting down older and smaller units that were not cost-effective. While Japan's reform of propylene derivative markets seems to be complete, there are no expected capacity closures in the near future. In 2019, Japan Polypropylene announced a plan to replace its recently closed units with a new plant that has a capacity of 150 000 tons per year and will utilize equipment from older units. Prime Polymer also announced plans in 2021 to construct a new polypropylene unit in Ichihara with a capacity of 200 000 tons per year using Mitsui Chemicals Hypol technology. The construction of the unit is scheduled to start in August 2021 and it is expected to come online by early 2024. This new unit will replace an obsolete production line with a capacity of 114 000 tons, which will be permanently shut down by early 2023 at the same location.

South Korea

Total production capacity of polypropylene in 2022 has reached 6.1 million tons per year. The current largest producer is still Lotte Chemical with a capacity of 1.1 million tons per year. The most recent polypropylene capacity addition was from SK Advanced Co, Hanwha Total Petrochemical and Hyundai Chemical in 2021.

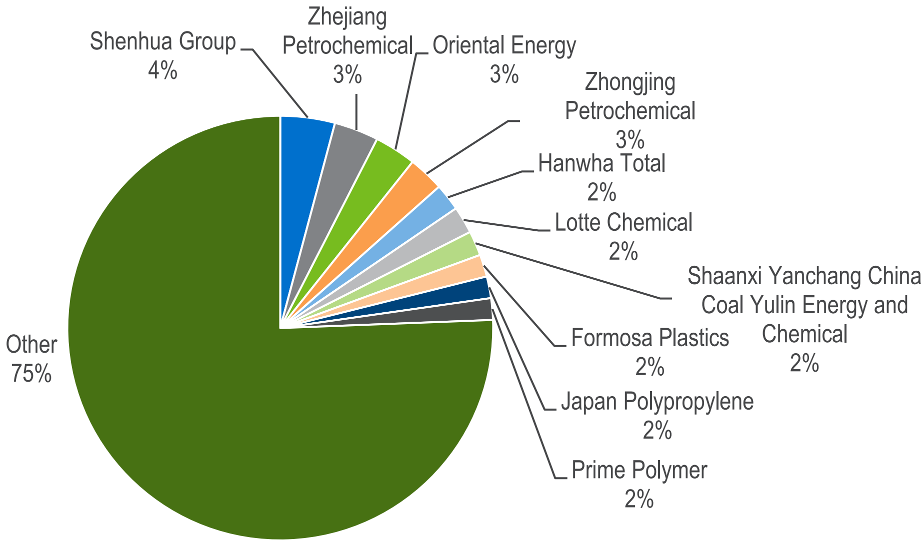
The South Korean petrochemical business was in expansion mode with steam cracker and derivative expansions. Polypropylene capacity grew sharply in 2021 with no other expected expansions in the near term while supply-demand normalizes. The capacity expansion in 2021 are as follows:

- Hanwha Total Petrochemical, a joint venture of Hanwha Chemical and Total Petrochemical expanded its Daesan integrated refining and petrochemical complex in South Korea. A 400 000 tons per year polypropylene plant came onstream in March 2021.
- Ulsan PP, a 50:50 joint venture between PolyMirae Company and SK Advanced, started operation a 400 000 tons per year polypropylene in March 2021. The company utilised LyondellBasell's SPHERIPOL technology.
- Hyundai Chemical, a joint venture between Lotte Chemical and Hyundai Oilbank, plans to invest around US$2.5 billion to build heavy feed-based petrochemical complex in Daesan. Mechanical completion is aimed in the second half of 2021. The Polypropylene capacity was commissioned in October 2022. Hyundai Chemical has chosen WR Grace's UNIPOL PP (polypropylene) technology for the 500 000 tons per year polypropylene plant at the site.
- S-OIL previously conducted a feasibility study into building a mixed feed cracker with the size of 1.5 million tons per year ethylene capacity. In a second phase this project is planned to include 400 000 tons per year polypropylene capacity.

Taiwan

There are three producers in Taiwan: Formosa Chemical Fibre Corporation (FCFC), Formosa Plastics (FPC) and LCY Chemical. In 2019, FPC debottlenecked all units and total capacity has increased by 50 000 tons per year. In 2017, FCFC underwent debottlenecking and increased capacity by 120 000 tons. There is no firm plan for capacity addition in the near to medium term.

Figure 4.48 Polypropylene Capacity Share by Producer – North-East Asia, e-2023



4.4.8.3 Supply, Demand and Trade

The recent commercialization of new polypropylene plants in China and South Korea has led to a drop in regional operating rates to 80 percent in 2022. This decrease can be attributed to the significant increase in capacity and poor demand growth rates. As a result of the new capacity additions in China and South Korea, there has been a sharp decrease in import requirements from other regions, leading to a reduction in net import volume.

In 2020, imports increased due to strong Chinese downstream demand and the need for more virgin material after a spectacular recovery in the second half of the year. North-East Asia is currently a net exporter of polypropylene. The operating rates in this sub-region remained relatively stable as the lower demand was offset by an increase in exports.

Moving forward, it is projected that the operating rates in Asia Pacific and North-East Asia will continue to decline to below 80 percent due to various factors such as the commercialization of new polypropylene plants, poor global economy, slowdown demand growth rate, and poor product margin. This decline will be further intensified by the massive addition of capacity in China, India, South Korea, and South-East Asia, which will result in increased inter-regional competition in Asia Pacific. Countries that are in need of exporting to China to support their operating rates will suffer from the increasing Chinese self-sufficiency. It is expected that some older plants with a small scale will be pushed out of the market. Countries with small domestic capacity that are depending on imports could benefit from the influx of more competitively priced material. However, it will take several years before the market absorbs this additional capacity, and operating rates can rebound.

Figure 4.49 North-East Asia Polypropylene Supply, Demand and Trade

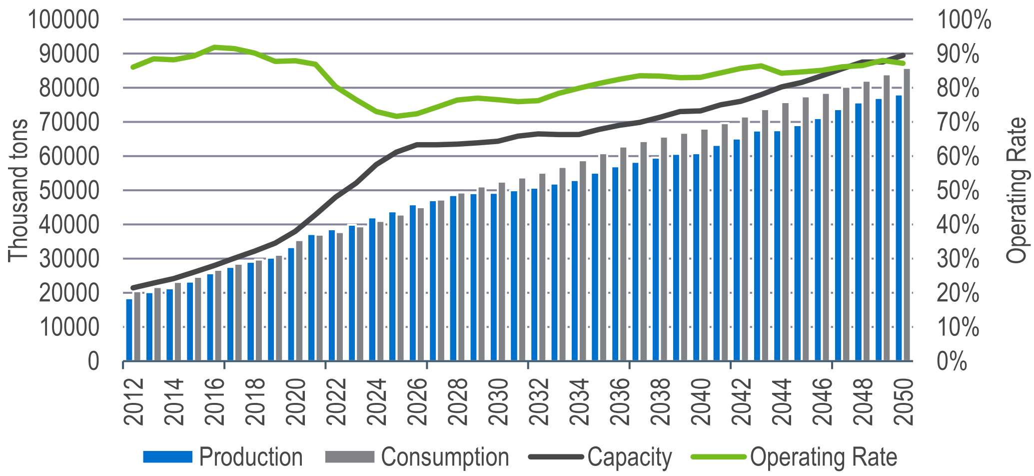


Table 4.47 North-East Asia Polypropylene Supply, Demand and Trade

(thousand tons)

	Actual			Estimate	Forecast								Average Annual Growth Rate, %		
	2012	**2017**	**2022**	**2023**	**2024**	**2025**	**2026**	**2030**	**2035**	**2040**	**2045**	**2050**	**2012-2023**	**2023-2030**	**2030-2050**
Firm Capacity	21 412	30 157	47 977	52 105	57 534	61 146	62 855	62 855	62 855	63 027	62 855	62 855			
Speculative	-	-	-	-	-	-	500	1 500	5 000	10 228	18 700	26 700			
Total Capacity	21 412	30 157	47 977	52 105	57 534	61 146	63 355	64 355	67 855	73 255	81 555	89 555	8.4	3.1	1.7
Operating Rate	86%	92%	80%	77%	73%	72%	72%	76%	81%	83%	85%	87%			
Production	18 434	27 602	38 547	39 870	42 044	43 796	45 892	49 223	55 140	60 880	69 063	78 066	7.3	3.1	2.3
Net Export	(1 995)	(889)	838	469	1 023	912	872	(3 317)	(5 710)	(7 203)	(8 422)	(7 727)			
Consumption	20 429	28 491	37 709	39 401	41 022	42 884	45 019	52 540	60 849	68 083	77 485	85 793	6.2	4.2	2.5

China

In 2022, the import of polypropylene decreased by six percent. This was mainly due to the squeezed PP margin caused by high raw material prices and poor downstream demand. In June 2022, Brent crude prices reached above US$120 per barrel due to the Ukraine/Russia conflict, and naphtha also hit a ten-year high in March. In the second quarter, US ethane prices doubled compared to the average of 2021. End-users operated at reduced rates due to poor margin.

China's polypropylene exports decreased by 8.5 percent in 2022 year-on-year, but still reached almost 1.3 million tons. In 2022, the four leading polypropylene supplying countries to China were South Korea, Singapore, United Arab Emirates, and Taiwan. The current capacity addition in China will continue to reduce the deficit volume in the short term, but net imports of polypropylene will grow again in the long term due to strong projected demand compared to other regions. In 2022, domestic capacity addition and the poor polypropylene margin resulted in an operating rate reduction to 80 percent, with a production increase of six percent while capacity increased by 13 percent.

Japan

Operating rates fell by nine percent to 78 percent with the net export position turning into an import position of 92 000 tons per year in 2022.

The slowing domestic demand growth has had a significant impact on operating rates in Japan. As demand for polypropylene has slowed, producers have been forced to reduce their production. The increase in new capacity in the Middle East, China, and Southeast Asia has also had an impact on operating rates in Japan. These countries have been investing heavily in new polypropylene plants, which has increased the global supply of polypropylene. The poor cost position in Japan has made it difficult for Japanese producers to compete.

The operating rates are projected to drop to around 75 percent in the medium term. The massive slate of additional capacity coming onstream in China will further erode Japanese exports. Despite stagnating demand, global oversupply will move Japan again to its position as a net importer in the forecast period.

South Korea

South Korea production increased in 2022 to 5.2 million tons per year with new capacity online in the country. This also led to a decrease in operating rates of six percent. Net exports increased slightly in 2022 with the increase in capacity but there was not a major change unlike previous years. South Korea is a major net exporter of polypropylene with a large export-oriented capacity base.

The export volume to China remains significant despite additional capacity in the country. South Korea is currently the biggest polypropylene exporter to China because large volumes of more specialised polymer are traded. About 40 percent of South Korea’s output is polypropylene copolymer which experienced stronger growth compared to homopolymer. Vietnam, Turkey and United States are the next largest destinations for exports.

With stagnant domestic demand and several capacity expansions, South Korea will maintain its current position as a large net exporter. Additional capacity is not expected in the near term due to increased competition and operating rates are expected to reduce below historical averages due to new Chinese capacity.

Taiwan

The rate at which polypropylene is produced in Taiwan is heavily influenced by the amount of the product that is exported. Taiwan is a major exporter of polypropylene, but the export volume decreased by 22.5 percent in 2022 due to high raw material prices and weak demand caused by a struggling global economy. In 2021, Taiwanese producers took advantage of production disruptions in the United States and exported a high volume of polypropylene to North and South America. Compared to other countries, Taiwanese producers typically operate their polypropylene plants at high rates. The majority of the exported polypropylene from Taiwan is homopolymer, with around 65 percent of exports being shipped to mainland China. Other major markets for Taiwanese exports include Hong Kong, Peru, Vietnam, and Bangladesh. In 2021, the operating rate was at 97 percent due to strong domestic demand and slightly higher export volume. However, in 2022, the temporary drivers that helped increase production in 2021 were not present, resulting in a decrease in production of almost 28 percent, a reduction in domestic demand of 21.5 percent, and a drop in operating rates to 71 percent.

4.4.9 South-East Asia

4.4.9.1 Consumption

Indonesia

Indonesia's polypropylene demand has undergone rapid growth over the last few years, finding applications in various applications such as include housewares, food packaging, electrical/electronics, and automotive parts due to its high versatility. Demand has recovered moderately with a year-on-year growth of 4.5 percent in 2022, reaching 2.04 million tons. In 2022, the polypropylene demand growth was mainly driven by packaged food products and automotive sector. Demand for applications in the agricultural, electrical appliances and construction sectors continues to remain muted mainly due to the rise in living costs, impacting consumer spending.

Film is the largest end-use application of polypropylene in Indonesia, accounting for approximately half of the total demand. Polypropylene-based films such as BOPP, CPP, and IPP are used widely as flexible packaging for food, cigarettes, and garments. Increasing food deliveries, takeaways, and e-commerce activities were observed during the partial lockdown, leading to increased consumption of plastic packaging materials. Flexible film demand improved as grocery shopping, social event and tourism activities have fully resumed, especially in traditional markets, which remains as a staple of trade activity in Indonesia. Micro, small, and medium enterprises (MSMEs) represent almost 95 percent of business units in the country and contributed roughly 60 percent of national GDP.

This is followed by the consumption of fibre, representing a quarter of the total polypropylene demand in Indonesia. In general, polypropylene fibre has excellent heat-insulating properties, highly resistant to chemicals, easy to process, and inexpensive compared to other synthetic fibres. Common end-uses of polypropylene fibre in Indonesia including hygiene & medical (e.g., mask, gown, cap, drape), automotive (e.g., carpet backing, seat cover), and agriculture (e.g., rice & fertilizer sacks). Strong growth in the fibre application is observed in 2022, supported primarily by the demand in the automotive and agricultural sectors, while the usage in medical sector has decreased as COVID-19 resurgences are no longer posing significant threat to the public health. The demand for polypropylene fibre in hygiene supplies and self-protective products have gradually plateaued as supplies for PPEs are readily available compared to in 2020 where the infection required extra protective gear. The ban on single use HDPE bags supports an increase in demand for medium/heavy duty non-woven polypropylene in Indonesia, however the overall impact on demand in minimal.

The remaining segments including injection moulding, extrusion coating, other extrusion, and blow moulding, account for 25 percent of total demand. Injection moulding for thin wall packaging and flocked swab for COVID-19 test, extrusion coating for Personal Protective Equipment (PPE), and other extrusion for thermoforming packaging have displayed positive growth due to the COVID-19 pandemic. This is also supported by the recovering in manufacturing and construction activity. Unlike the strong restriction during PSBB (Pembatasan Sosial Berskala Besar or Large-Scale Social Restrictions), factories are allowed to operate during PKMM (Pemberlakuan Pembatasan Kegiatan Masyarakat, or Community Activities Restrictions Enforcement). Moreover, sales and demand cars have seen positive growth with the relaxation of sales tax on luxury goods (PPnBM) for motor vehicles.

Overall Indonesian polypropylene demand is projected to achieve stronger growth in 2022 along with the reopening of international borders. The market is projected to grow above GDP growth over the next few years. Demand growth is expected to be driven by expansion in film and fibre applications. The fibre sector will continue growing supported by step-up in production yield as advanced machinery is being adopted by converters in manufacturing fibre-based products such as woven bags, tarpaulins, geotextile rope, and carpet backing. Other growth potential sectors for polypropylene consumption include thermoforming applications for manufacturing disposable food and beverage packaging products, and injection moulding applications, driven by expanding automotive industry with support from government policies to promote electric vehicles (eVs) manufacturing. The electronics industry will also drive propylene consumption as more foreign electronic companies have relocated their manufacturing plants to Indonesia. Additionally, the relocation of capital is also expected to drive polypropylene consumption in the construction industry.

Malaysia

Malaysia’s polypropylene demand reached 543 000 tons in 2022, representing a steady recovery of 3.8 percent since the ease of COVID-19 restrictions. Its good barrier properties, high strength, good surface finish, and relatively low cost make polypropylene the second-largest polyolefin consumed in Malaysia. the overall impact on polypropylene as compared to other polyolefin was not particularly significant as the reduction in non-essential sectors such as construction and automotive was absorbed by an increase in consumption in packaging, medical and electronic sectors.

In Malaysia, polypropylene is predominantly used in injection moulding applications, representing almost half of the demand. It is used to manufacture packaging material, household, electric appliances, and housewares. Despite the reduced consumption in the automotive and construction sectors, injection moulding has contracted moderately as compared to other applications, this is mainly supported by the growth in the packaging, medical and electronic sectors. Based on the data published by the Malaysian Automotive Association (MAA), the total production and sales of passenger cars have shown a strong recovery trend in 2022. Polypropylene is used in this application in moulded articles such as front and rear bumpers, internal and external trim, instrument panels, and body panels. E-commerce industry will continue to drive demand of polypropylene as most consumer behaviours have shift preferences from retail to online shopping.

The food manufacturing industry in Malaysia has also recovered which in turn drive the consumption of thin-wall injection moulding in packaging applications such as plastic dairy containers, ready meal packaging, etc.

Fibre and film are the two next largest end-use applications in Malaysia, together accounting for approximately 42 percent of polypropylene demand. Fibre is mainly utilised in strapping, filament and staple fibres whereas film is used in food and non-food packaging. However, fibre consumption for face mask and medical protective jumpsuit have eventually plateaued as the COVID-19 infection risks have significantly reduced since most of the population is vaccinated. Film demand into medical supply has slowly declined but is offset by demand into food packaging into BOPP film. Along with the recovery in national economy, overall polypropylene demand into fibre and film registered a moderate growth in 2022.

The remaining 12 percent is split between blow moulding, extrusion coating, and other applications. Blow moulding for bottle and container manufacturing, extrusion coating for medical supplies, and other extrusion for thermoforming packaging continues to grow in 2022. Demand for other sectors such as automotive have also returned to growth as the production of passenger cars in Malaysia increased by 45 percent in 2022.

The polypropylene market will continue to grow over the short term as most of the local polypropylene converter companies have placed orders for film, extrusion and injection moulding machines. These orders typically have a lead time of two to three years. With the added capacity by the converters, it is expected to drive the polypropylene consumption further in Malaysia in the short term. Overall polypropylene demand in the short-term period is forecast in line with the country’s forecast GDP growth. This is expected to be primarily driven by injection moulding applications, particularly the manufacturing of household and electrical appliances due to its rigid property. Extrusion coating and other extrusion have upswing potential as it increasingly finds use in paper and plastic coating, particularly in food packaging for biscuits, snacks, confectionaries, and dried foods.

Philippines

Polypropylene demand in the Philippines recovered in 2022, growing close to four percent to 403 000 tons. As the country's economy recovered, the overall demand for polypropylene similarly grew as mobility restrictions eased in 2022, supporting business activities.

Film and fibre are the largest end-use sectors, driven predominantly by packaging applications. Film is used in various types of flexible packaging except those used in freezing temperatures, whereas fibre is used in strapping to secure products together during transport and storage.

Injection moulding displayed growth in 2021 due to increased consumer demand for general household items and electric appliances, as well as rigid packaging such as containers and lids for sauces and hot liquids used in food takeaways. Growth in injection moulding is also supported by the automotive sector, specifically in battery cases and trays, bumpers, fender lines, interior trim, instrumental panels and door trims. According to the International Organization of Motor Vehicle Manufacturers (OICA), the automotive industry in the Philippines recovered in 2021 as motor vehicle production rose by over 25 percent from the previous year, following a 35 percent drop in 2020.

The remaining segments include extrusion coating for the lamination of paper and plastic products, as well as other extrusion for sheet, pipe and wire and cable. In particular, the demand growth for other extrusion is estimated at double-digits in 2021, following the recovery of the construction sector and resumption of activities which had been halted during the pandemic.

In the near term, polypropylene demand growth is forecasted to continue its recovery, growing at slightly below GDP level as consumers gradually return to normal consumption habits. This recovery, however, is dependent on the appearance of new COVID-19 variants and resurgence of infections. Demand is expected to be driven mainly by film and fibre packaging applications. The continued adoption of e-commerce and food delivery services is expected to drive the use of polypropylene film in applications such as food packaging, parcel packaging, tapes, and labels. Polypropylene is also largely used in the production of cement bags and laminated and non-laminated woven fabric, as well as woven bags for agricultural products. The growth in injection moulding is underpinned by demand for houseware products and food containers.

Singapore

Singapore has a small polypropylene market, which recovered by over three percent from the previous year to 38 000 tons in 2022. Polypropylene in Singapore has been predominantly used in injection moulding applications, followed by usage in film applications. Injection moulding is mainly used for household products, appliances, and rigid food packaging, whereas film is used in flexible packaging such as food wraps and parcel packaging.

Polypropylene demand was supported by higher purchase of household products and an increase in food deliveries and e-commerce activity during the lockdown period. In the near term, consumption growth is projected to grow in tandem with GDP level, following the lifting of COVID-19 restrictions and easing of foreign travel requirements in April 2022 due to a drop in daily cases. Injection moulding and film applications are expected to continue driving domestic demand growth, as consumer spending is expected to increase stronger economy.

Thailand

In 2022, the demand for polypropylene in Thailand increased by two percent to just over 1.4 million tons. However, this growth was lower than expected due to the overall slowdown of the economy and the reluctance of converters to restock their high inventory levels. This was mainly caused by the slow end market and the increase in raw material prices, inflation, and decrease in consumer spending. Despite this, the demand for food packaging remained present due to the rise of food deliveries and work from home policies implemented by some companies.

The polypropylene market in Thailand is dominated by homopolymer polypropylene, accounting for around three quarters of total demand. Film for food packaging and fibre for agricultural and cement packaging are the main markets for this type. Impact copolymer polypropylene represents around ten to 15 percent of local demand, primarily for injection moulding and fibre. Meanwhile, random copolymer polypropylene has around ten percent share of total demand, mainly used for film, coating, and blow moulding grades. The market for terpolymer is relatively small. Commodity products drive the demand in the market as consumers cut down on their expenses due to the increasing cost of living. The demand for copolymer polypropylene film accounts for the remaining film demand. Despite campaigns to reduce plastic usage, polypropylene remains an essential material for the packaging industry. Concerns over hygiene have also preserved polypropylene demand into film, as recycled polypropylene is still viewed as unhygienic by consumers.

In the injection moulding sector, consumer products support around half of the demand, while automotive and electrical & electronic industries share the remaining parts. However, the growth of these sectors was slow in 2022 due to consumers being affected by the high inflation rate, which led to an increase in the cost of living. Consumer products growth was lower than expected but remained stable throughout the year. Automotive and E&E market, on the other hand, experienced low growth as consumers refrained from buying big-ticket items. The market growth was hampered by the increase in raw material and production costs. For 2023, the government will continue implementing policies to invigorate consumer spending and increase income for the population to boost overall economic activity. Demand is expected to grow along with GDP, mainly driven by industrial applications and household spending.

In the fibre market, woven fibre accounts for approximately three quarters of the demand, while non-woven fibre accounts for the remaining part. Demand into woven fibre recovered in 2021 and 2022 as consumers and the government increased spending after the pandemic. This has driven the demand in downstream sectors, including construction, agriculture, and industrial. Demand into raffia has also recovered, driven by the return of construction and opening export channels. Non-woven applications were stable in 2021 and 2022 as the population continues to wear masks in public. The three major spun bonds converters in Thailand are Asahi Kasei, Mitsui Hygiene, and CNC International. Asahi Kasei has started production at their new spun bond capacity, which was expanded by 15,000 tons at the end of 2021. Fitesa, a major shareholder of CNC International, also invested in a new spun bond production line in Rayong in 2022. These expansions will drive stronger demand for spun bonds in Thailand in 2022 and beyond.

The market for extrusion coating was growing along with an increase in bags, flexible packaging, and raffia production. Other extrusion mainly includes thermoform applications, mainly consumed for consumer packaging, food packaging, and appliance parts, such as washing machine drums. This end-use market is expected to be preserved as disposable income has decreased due to the high inflation rate. Polypropylene food boxes have been replacing polystyrene foam boxes for food delivery, as the use of foam containers was banned before the pandemic. Demand for food delivery and take-away remained substantial in 2022, as consumers grew accustomed to the convenience of delivery. Food delivery continued to be the major driver for polypropylene demand into food tray in 2022. In the medium term, penetration through food packaging will contribute above-GDP growth for this sector.

Vietnam

In 2022, Vietnam saw an increase in demand for polypropylene, reaching 1.8 million tons, which was a seven percent increase from the previous year. This growth was largely driven by the manufacturing sector, which helped Vietnam maintain a strong position in exporting goods. Countries that import from Vietnam have been faced with higher costs of raw materials and production, making polypropylene from the Vietnamese market more attractive due to its affordability. China, on the other hand, struggled to meet domestic market demand due to the zero-case policy imposed by the government. As a result, Vietnam saw a significant amount of polypropylene imports from China, mostly for commodity and domestic use goods. However, due to quality concerns, converters have largely preferred using polypropylene from other countries for their exported products.

More than half of the total demand for polypropylene in Vietnam is for fibre applications, which are mostly used in producing woven and jumbo bags for agriculture products, fertilizers, and animal food packaging. About 70 percent of polypropylene fibre is consumed in the agricultural sector, with the remaining 30 percent used in industrial applications. The increase in demand for agricultural goods from export markets led to higher productivity in this sector. Meanwhile, demand for polypropylene for cement bags was also influenced by the growth in the construction industry. As the government increased infrastructure project spending and the real estate sector picked up after the pandemic, this sector experienced growth. Demand for fibre applications is expected to grow at a modest pace in 2023, driven by slow growth in exports of agricultural and commodity products.

Woven bag production accounts for over 90 percent of the total demand for polypropylene fibre, with the remaining used in non-woven applications. Plastic bags represent the majority of non-woven polypropylene fibre demand, followed by wet napkins and hygiene products. The demand in this sector continues to grow at a strong rate, with face mask production being a significant contributor. The arrival of face mask manufacturing machines in Vietnam in the second half of 2020 increased demand for non-woven polypropylene fibre. As neighbouring countries continue to wear masks even after the pandemic subsides, face mask production maintained its production rate in 2022.Injection moulding is the second largest application, with usage mainly in household products, appliances, and automotive parts. Demand in automotive was driven mainly by motorcycle parts which dominated the vehicle market in Vietnam. Demand for car parts emerged after VinFast launched the first Vietnam-made car manufacturing site in Haiphong in 2019. VinFast plans to launch Electric Vehicles (EVs) which contain more plastic parts than combustion engine vehicles. But this did not directly increase polypropylene demand in Vietnam as VinFast mainly imported automotive parts from another countries including Thailand and Indonesia. Polypropylene consumption into injection moulding is forecast to grow robustly as an influx of investment in the electrical/electronics industry is anticipated, which will serve both healthy domestic demand and export markets. A continued shift of household products manufacturing bases toward Vietnam is projected to support strong growth of polypropylene in injection moulding applications.

Polypropylene demand for film applications is mainly for flexible packaging for food packaging. Biaxially oriented polypropylene film (BOPP) is the largest market end-use, representing over 80 percent of total consumption in the film sector. More than half of film is captively consumed. Cast polypropylene film (CPP) accounts for around 15 percent of film demand and the remaining is for inflated polypropylene film (IPP). Vietnamese film converters benefitted from export demand as packaging for exported goods increased. Film demand is not projected to grow strongly in the economic recovery period. In the medium term, demand is projected to grow slightly above GDP, driven by downstream film converter capacity expansions.

In the extrusion coating sector, approximately 70 percent of polypropylene is used for lamination of woven, while the remaining 30 percent is used in non-woven fabric/packaging. The growth is linked to polypropylene woven bags production and polypropylene film coating.

Homopolymer accounts for three quarters of total polypropylene consumption. Homopolymer is primarily used in raffia and fibre applications, followed by injection moulding for houseware applications. Impact copolymer has the second largest demand, representing nearly 15 percent of the total market. It is mainly consumed in injection moulding applications (i.e. motorcycle parts, household products, paint pails, battery covers), and to a lesser extent, blow moulding. Random copolymer is mainly used in film and extrusion coating and partly in some injection moulding applications. Major suppliers are Borouge, LyondellBasell, and SABIC. Terpolymer demand is small and it is primarily consumed by CPP film producers. Supply is dominated by TPC, Honam, Lotte, and Samsung Total. During the forecast period, homopolymer and impact copolymer are anticipated to lead polypropylene market growth due to their various applications.

Figure 4.50 South-East Asia Polypropylene Consumption by End-Use, e-2023

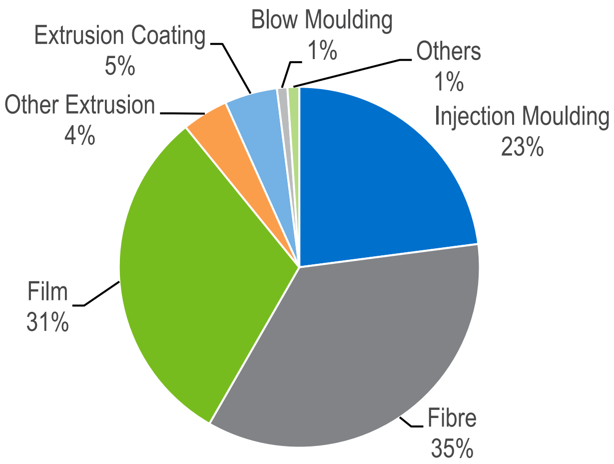


Table 4.48 South-East Asia Polypropylene Consumption by End-Use
(thousand tons)

	Actual			Estimate	Forecast								Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Injection Moulding	970	1 232	1 441	1 513	1 584	1 667	1 766	2 114	2 482	2 786	3 202	3 560	4.1	4.9	2.6
Fibre	1 237	1 734	2 202	2 333	2 444	2 573	2 726	3 273	3 889	4 432	5 179	5 827	5.9	5.0	2.9
Film	1 221	1 638	1 942	2 036	2 128	2 237	2 368	2 856	3 456	4 039	4 860	5 570	4.8	5.0	3.4
Other Extrusion	153	207	263	273	285	299	315	378	454	526	624	710	5.4	4.8	3.2
Extrusion Coating	181	245	296	312	326	343	364	435	515	584	682	766	5.0	4.9	2.9
Blow Moulding	46	55	60	61	63	66	69	80	92	102	117	129	2.7	3.8	2.4
Others	57	64	68	70	72	74	78	88	100	110	124	136	1.8	3.5	2.2
Total	**3 865**	**5 175**	**6 270**	**6 598**	**6 902**	**7 260**	**7 685**	**9 224**	**10 989**	**12 580**	**14 788**	**16 697**	**5.0**	**4.9**	**3.0**

Table 4.49 South-East Asia Consumption by Country
(thousand tons)

	Actual			Estimate	Forecast								Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Indonesia	1 168	1 708	2 042	2 147	2 256	2 382	2 531	3 108	3 854	4 635	5 720	6 663	5.7	5.4	3.9
Malaysia	381	503	543	572	594	621	655	774	914	1 035	1 205	1 351	3.8	4.4	2.8
Philippines	310	355	403	425	440	459	482	564	651	720	817	900	2.9	4.1	2.4
Singapore	31	38	39	41	42	43	45	50	55	59	65	70	2.6	2.9	1.7
Thailand	1 201	1 352	1 453	1 493	1 542	1 602	1 676	1 923	2 204	2 435	2 769	3 055	2.0	3.7	2.3
Vietnam	775	1 220	1 789	1 921	2 028	2 152	2 297	2 806	3 310	3 697	4 212	4 659	8.6	5.6	2.6
Total	**3 865**	**5 175**	**6 270**	**6 598**	**6 902**	**7 260**	**7 685**	**9 224**	**10 989**	**12 580**	**14 788**	**16 697**	**5.0**	**4.9**	**3.0**

4.4.9.2 Supply

Indonesia

In 2022, total polypropylene capacity in Indonesia was 935 000 tons per year. Chandra Asri Petrochemical (Chandra Asri) is the largest producer and has a nameplate capacity of 590 000 tons per year from three production lines. Polytama Propindo is the second-largest producer with 300 000 tons per year of polypropylene capacity from two production lines, followed by Pertamina with 45 000 tons per year of capacity.

Several announcements have been made to further increase polypropylene capacity in Indonesia. Net firm capacity additions in the next decade are expected to be around a million tons per year, which include the following projects:

Polytama Propindo has plan to build a new polypropylene plant – the Balongan Polypropylene Project. The Project is Polytama's second polypropylene plant construction project with an installed capacity of 300 000 tons per year. Polytama officially appointed Basell Poliolefine Italia Srl (LyondellBasell) as the license provider for the Project.

Lotte Chemical Indonesia (LCI) is building a new petrochemical complex in Cilegon under the Lotte Chemical Indonesia New Ethylene (LINE) project. The project will include a naphtha cracker and potentially producing 250 000 tons per year of polypropylene. Lotte Chemical has signed the key work contracts for LINE Project and is expected to be completed by 2026.

Chandra Asri has included polypropylene production as part of its second petrochemical complex in Indonesia. The plant will be operated through its subsidiary Chandra Asri Perkasa (CAP2), with a capacity of 450 000 tons per year in its second petrochemical complex. The new polypropylene plant is expected to commence its operation in early 2027 and will be based on LyondellBasell technology.

Indonesia's state-owned Pertamina has announced plans via its subsidiaries to add new polyolefin production in Tuban. The first project is the new olefin project carried out by PT Trans-Pacific Petrochemical Indotama (TPPI), which includes a naphtha cracker with downstream units of polypropylene. This project is currently under development and considered as speculative.

Separately, Pertamina has officially set up a joint venture with Russia's Rosneft Oil Company, called Pertamona Rosneft Pengolahan dan Petrokimia (PRPP) to develop a grass root refinery and petrochemical project (NGRR). The project is planned to include polypropylene; however, the timeline remains speculative.

Additional, state-owned coal company PT Bukit Asam Tbk (PTBA) is committed to developing a coal gasification project in Tanjung Enim, Palembang. The project is expected to include olefin production and subsequent downstream polyolefin production. Currently, the project is in the EPC preparation stage and remains speculatively at this stage.

Malaysia

Before the start-up of the new production capacity by Pengerang Refining and Petrochemical (PRefChem) in Pengerang, Lotte Chemical Titan was the largest polypropylene producer in Malaysia, with a total polypropylene capacity of 640 000 tons per year. PRefChem was started up in late 2019, containing two new polypropylene plants, each with a capacity of 450 000 tons per year. The plant was shut down in March 2020 following an explosion at the complex and restarted back in 2022. However, there was another explosion in October 2022, which reduced propylene capacity in 2022. The company has restarted the complex in March 2023, with more stable operations in June 2023.

Another large-scale refinery/chemicals complex was announced in Malaysia in 2019. The sponsor is Beijing Beca Sci-Tech Co, which together with Sinopec Engineering plans to build both a steam cracker and deep catalytic cracker (DCC). The project is likely to include downstream polyolefin capacity to fully utilise its olefin production, however this remains speculative.

Philippines

In the Philippines, JG Summit Petrochemical and Philippines Polypropylene Inc. (PPI) are the only two polypropylene producers. PPI restarted its unit in January 2022 following a two-year shutdown period, supported by higher petrochemical margins and demand growth. Additionally, the expansion of its production capacity from 160 000 tons to 225 000 tons per year was completed in 2022. It was expected to start operations in second half of 2023. So far NexantECA have not seen confirmation that this facility has started up. Together, both companies have a combined polypropylene capacity of 525 000 tons per year.

Singapore

There are currently two polypropylene producers in Singapore with a total combined capacity of over 1.6 million tons per year. ExxonMobil is the largest polypropylene producer with an overall capacity of 930 000 tons per year that is split between two production lines. TPC Singapore is the other polypropylene producer with a total production capacity of 680 000 tons per year. Production plants for both companies are located in Jurong Island. There are no planned polypropylene capacity additions over the near term.

Thailand

There are three polypropylene producers in Thailand with total nameplate capacity around 2.3 million tons per year since 2019. The three producers are HMC Polymers, Thai Polypropylene, and IRPC, ranked in order of large capacity. HMC Polymers is 40 percent owned by PTT, and Thai Polypropylene is wholly owned SCG subsidiary. HMC Polymer have invested in a new polypropylene plant with a capacity of 250 000 tons per year. Production came online in December 2022. The plant employs the Spherizone process from LyondellBasell, one of its major shareholders. With this complex process, the plant is expected to produce specialty grade of polypropylene. Because of that, this new plant is not expected to be pressured by another polypropylene projects in several countries around.

Vietnam

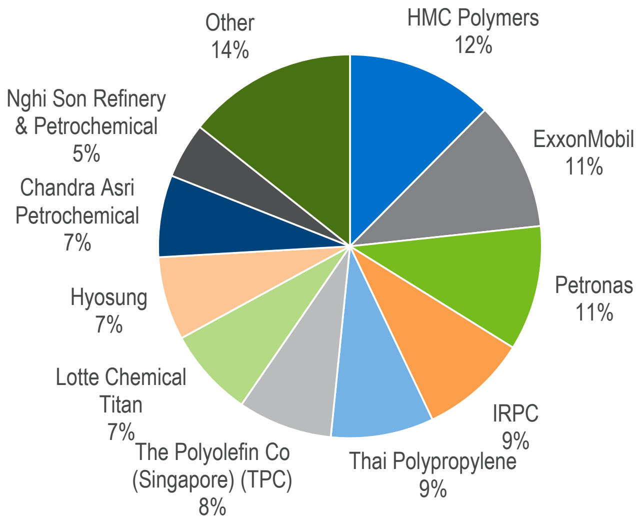
There are currently three polypropylene producers in Vietnam: Binh Son Refinery (BSR), Nghi Son Refinery and Petrochemical (NSRP), and Hyosung. In 2019, NSRP ramped up the production after start-up, increasing propylene consumption by around half. Hyosung commissioned its first polypropylene production line in February 2020. Hyosung's second polypropylene production line and upstream propane dehydrogenation was brought on-stream in August 2021. Production at Hyosung was ramped-up in 2022, and even though running at a reduced rate it boosted the consumption of propylene in the country. This brought the total polypropylene capacity to 1.15 million tons per year. Construction of the petrochemical complex by Long Son Petrochemical is now fully completed. Collectively, polypropylene capacity in Vietnam will reach 1.6 million tons in 2024 when the production at Long Son is able to operate for a full year.

With rapid development after getting approval, Hyosung has already started up the first line of its 300 000 ton per year polypropylene unit in Vietnam in the first quarter of 2020. The start-up is the first phase of PDH-PP project. The second phase consists of a propane dehydrogenation unit with the second line of polypropylene. In total, polypropylene capacity by Hyosung will reach 600 000 tons per year. The second phase came onstream in the second half of 2021. Propylene is fed through the propane dehydrogenation unit integrated at the project. Both units employ Spheripol process from LyondellBasell. The plants are capable to produce all grades, both homopolymer and copolymer. In the early stage, Hyosung offered mainly fibre (both woven and non-woven types), film, and injection moulding grades.

The Long Son project that consists of a 500 000 ton per year polypropylene came on-stream in mid-2023. The project is wholly owned by SCG. First batch of products have been distributed for trial with converters in the domestic market to penetrate the market.

Phu My Plastics have also announced to set up polypropylene plant integrated with propane dehydrogenation unit. The company already signed a long-term agreement with PetroVietnam for the supply of propane. LyondellBasell's Spheripol process has been selected for this planned 300 000 tons per year polypropylene unit by Phu My Plastics. However, it is still considered speculative as there is no firm timeline announced for this project.

Figure 4.51 Polypropylene Capacity Share by Producer – South-East Asia, e-2023



4.4.9.3 Supply, Demand and Trade

Indonesia

Indonesia is currently a major net importer of polypropylene in Asia, after China and Vietnam. The imports levels increased to above one million tons in recent years. Imports are mainly sourced from South-East Asia, South Korea, and the Middle East. Indonesia has been a net importer over the past decade and is expected to maintain this trade position in the future due to increasing consumption growth from its large domestic market which will outpace additional capacity from existing producers.

The operating rate is forecast to drop in the near term as new capacities come online. In the longer term, the operating rate is forecast to range between 75 to 80 percent.

Malaysia

Malaysia is a small net importer of polypropylene over the past decade. The country became a net exporter in 2019 after the commencement of Lotte Chemical Titan's new polypropylene production unit in September 2018. The trade position remained relatively balance in 2021, with exports channelling to countries including China, Indonesia and Vietnam while receiving imports from imports from Singapore and the Middle East.

As the only polypropylene producer prior to PRefChem opening in late-2019, Lotte Chemical Titan had operated its plant at high operating rates of above 90 percent in recent years. Polypropylene operating rate declined in 2022 as a result of high feedstock costs, despite gradual re-opening of the domestic and global economies.

Longer-term operating rates are forecast to range between 75 to 80 percent, with the exception of 2022 as PRefChem was forced to shut down due to the fire incident in October 2022. Upon resuming normal operations, the 900 000 tons capacity addition from PRefChem is expected to further strengthen Malaysia's net export position.

Philippines

The Philippines is a net importer of polypropylene. Since 2020, JG Summit Petrochemical was the sole domestic propylene producer in the country. Import volumes were around 77 000 tons in 2022, as Philippines Propylene Inc restarted its facility. Fuelled by demand growth and higher petrochemical prices, PPI restarted its unit in January 2022 after a two-year shutdown since 2020. It has also completed the expansion of its polypropylene capacity from 160 000 tons to 225 000 tons per year in 2022. The Philippines is forecasted to continue its status as a net importer even after PPI's expansion and unit restart. Imports are sourced from countries such as Malaysia, Singapore, and Thailand.

Singapore

Singapore is a major exporter of polypropylene at around 1.4 million tons in 2022, with most exports heading to Saudi Arabia. Exports to China slightly increased in 2022 coupled by higher exports to Japan, United States and South Korea. A series of turnarounds at polyolefin complex led to a shortage of supply in Middle East which have shifted polypropylene exports from Singapore to the Middle East.

Average operating rates remained relatively high, ranging between 88 and 96 percent over the last five years. Operating rates declined in 2022 as ExxonMobil shut down its No. 1 cracker with propylene production capacity of 490 000 tons per year for one to two months in April 2022 due to weak downstream margins. In the near term, Singapore's polypropylene operating rate is expected to range between 75 to 77 percent due to weak market demand. The country has been a net exporter over the past decade and is expected to maintain this trade position due to its limited domestic market for polypropylene.

Thailand

Thailand is a net exporter of polypropylene, in 2022 exports came down to around 640 000 tons from 860 000 in the previous year. The major reason for the lower export number was because of the global trade slow-down stemming from slow consumer markets. About two-third of exports are homopolymer polypropylene and the remainder is copolymer polypropylene (mainly impact copolymer). Thailand exports mainly to China, Indonesia, Vietnam, Japan, and India. Volumes to China have gradually declined since 2021 as China required less import volume from domestic capacity additions and slow domestic demand.

It's worth noting that in 2022, China implemented a COVID-19 zero-case policy that affected market demand. However, this policy was lifted in late 2022, which may result in an increase in net export volume from Thailand going forwards. Expectations are high for demand to return in China. Thailand is expected to maintain its net export position throughout the forecast period, but the volume may be lower in the short term due to increased regional competition. Net trade balance is projected to improve once new capacity comes online. The startup of the new unit from HMC is not expected to reduce operating rates by a significant amount, as the focused grades are mainly specialty.

Vietnam

In Vietnam, the operating rates for polypropylene have decreased due to the launch of new capacity at the Long Son location in 2023. This is due to the competitive position of exporters from South Korea, China, and the Middle East. However, operating rates and production are likely to increase in the near future as new capacity ramps up and demand growth continues. Although the net deficit will decrease in the short term, the lack of new capacity over the next decade will cause the deficit to increase in the medium term.

Vietnam is a net importer of polypropylene, with a net volume of around one million tons in 2022. Polypropylene shipments to Vietnam mainly come from South Korea, Saudi Arabia, and Thailand, with material from the Middle East transhipped in Singapore to reduce lead time. South Korea mainly supplies copolymer polypropylene while China mainly supplies homopolymer polypropylene. Vietnam has a small export market, with three polypropylene producers exporting around 400 000 tons to South Korea, Malaysia, and other Asian countries.

The government previously introduced a one to three percent import tariff on homopolymer polypropylene from the Middle East, which returned to three percent in January 2018. However, this had little impact as Middle East producers are highly competitive. With the launch of new capacity, the net deficit of polypropylene in Vietnam is expected to decline.

Figure 4.52 South-East Asia Polypropylene Supply and Demand

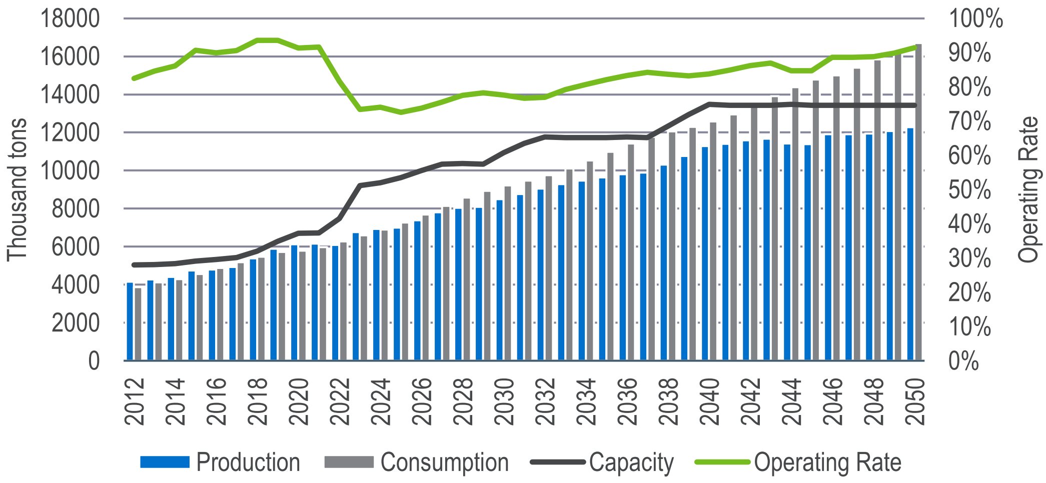


Table 4.50 South-East Asia Polypropylene Supply, Demand and Trade

(thousand tons)

	Actual			Estimate	Forecast								Average Annual Growth Rate, %		
	2012	2017	2022	2023	2024	2025	2026	2030	2035	2040	2045	2050	2012-2023	2023-2030	2030-2050
Firm Capacity	5 040	5 433	7 473	9 211	9 361	9 635	9 998	10 335	10 335	10 363	10 335	10 335			
Speculative	-	-	-	-	-	-	-	600	1 400	3 108	3 100	3 100			
Total Capacity	5 040	5 433	7 473	9 211	9 361	9 635	9 998	10 935	11 735	13 472	13 435	13 435	5.6	2.5	1.0
Operating Rate	82%	91%	82%	73%	74%	73%	74%	78%	82%	84%	85%	91%			
Production	4 158	4 921	6 096	6 756	6 929	6 993	7 380	8 488	9 631	11 289	11 383	12 282	4.5	3.3	1.9
Net Export	292	(254)	(174)	158	28	(267)	(305)	(736)	(1 358)	(1 291)	(3 405)	(4 416)			
Consumption	3 865	5 175	6 270	6 598	6 902	7 260	7 685	9 224	10 989	12 580	14 788	16 697	5.0	4.9	3.0

Section 5

Marketing Plan

5.1 PROPOSED TARGET MARKETS

This section analyses the sales plan for the Project based on plant capacities provided by the Client.

Based on the supply, demand and trade balances supplied in Section 4 of this report, NexantECA has prepared a high-level sales plan for polypropylene sales for the Project. NexantECA has considered the net trade position as well as the overall market size and consequent penetration into the major target markets. Furthermore, NexantECA has also considered the competitiveness of the Project compared to other international producers supplying the products into the target markets in its analysis.

From a commercial perspective, it may sometimes be advisable to supply products to the local markets first, due to lower logistic costs. For domestic sales, road transport is widely used, while rail is the most economical way of transportation to neighbouring countries. Saudi Arabia is the largest producer of polypropylene in the Middle East with 5.5 million tons of capacity and many existing big plants. The Project envisages to build an integrated polypropylene plant with an annual production capacity of 500 000 tons per year. The local demand for polypropylene is healthy, but Saudi Arabia is a globally leading exporter of polypropylene. Given a number of large local producers, the Project will have a significant export programme, and the Project's marketing strategy will be based mainly on international sales. Such international sales will include exports to other countries in the Middle East region.

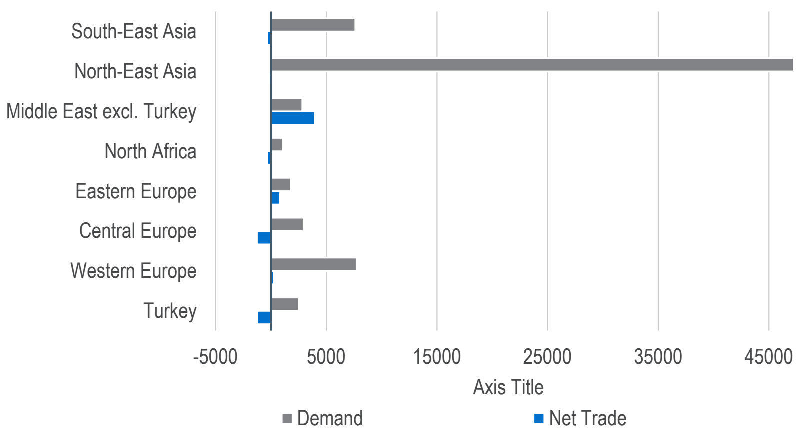
It is not common for a new entrant into an existing market to gain significant market share upon start-up, given competition from established producers, historic market dynamics and product quality considerations. A diversified market entry strategy is therefore recommended, whereby export volumes are periodically increased or decreased to gain market share within regions that return the highest netback values.

5.1.1 Polypropylene

It is assumed that the nameplate capacity of PP for the Project is 500 000 tons of polypropylene per year. The marketing plan considers 100 percent of produced polypropylene to be placed in target regions.

The graph below summarises key demand and net-trade data presented in the Market Analysis (Section 4) of this report.

Figure 5.1 Projected Regional Demand and Net Trade
(Forecast in 2027)



Note: The positive net trade indicates the net export position, whereas the negative net trade indicates the net import position.

NexantECA has conducted a review of trade balances in the regions highlighted in the market dynamics section above. The forecasted trade balance indicates that certain regions are likely to continue experiencing a deficit in their trade positions, positioning them as potential export destinations for polypropylene.

For the target market analysis, NexantECA has taken into consideration regions which are projected to maintain a net-importing position over the forecast period, as well as the regions with a significant domestic market.

In 2027, the total polypropylene output from the Project, at 500 000 tons per year, represents only 0.5 percent of global consumption of polypropylene in that year.

Western Europe as a whole is fairly balanced in polypropylene. This reflects a surplus of polypropylene in some Western European countries (particularly Benelux and Germany) and a shortage in some others (notably Italy) which is projected to remain a net importer. Currently trade with Russia is expected to reduce, as this country is increasingly impacted by the ever-mounting sanctions imposed on both individuals and companies. This may be an opportunity for producers in other regions, and notably for the Project, to make up for the loss of trade. It is also noted that Western European polypropylene production has a higher proportion of advanced grades (e.g., copolymer) which are exported globally, while there is a deficit of commodity homopolymer grades.

Central Europe heavily relies on imports for both polypropylene homopolymer and copolymers. Around 75 percent of the polypropylene produced is exported outside national borders but remains within the region. Almost 50 percent of the imports come from Western Europe, another 25 percent from intraregional manufacturers, while approximately 25 percent are supplied from Middle East, Korea and Russia. Russian polypropylene exports to the region fell significantly in 2022 due to the conflict in Ukraine. This may represent an opportunity for the Project, as Central Europe will remain a net importer of polypropylene homopolymer and copolymer.

Eastern Europe was a net importer of polypropylene over the last decade but in recent years polypropylene investment in Russia, and across several countries has changed the market considerably. There is sufficient capacity now to cover total demand. Following the contraction in demand across the region due to the conflict in Ukraine, there will be an increased drive to find export opportunities from new capacity additions. Russia’s proximity to China will ensure its exports will continue. Other important export destinations for polypropylene from Eastern Europe are Turkey and Central Europe, as the new exports are set to displace supplies from Western Europe. No long-term export opportunity to this region is considered for the Project.

In the Middle East, Saudi Arabia is the largest exporter of polypropylene, while the largest polypropylene market in the region is Turkey, with Iran being a distant second, and the ‘Other Middle East’ following behind in the third place. Turkey is anticipated to remain a significant net importer over the forecast period. Although there is a new PDH/PP plant under development (at Ceyhan) with capacity of 450 000 tons per year (start-up 2024), this only accounts for approximately 20 percent of the current deficit and is therefore unlikely to particularly disrupt trade flows. Increased export capacity in Saudi Arabia (from the SK Gas/AGIC JV) may lead to increased competition for markets in Turkey, although the tariff-free access should be maintained giving them an advantage over GCC-based exporters.

The demand and the net import position of North-East Asia will grow considerably over the forecast period, beginning from 2027. Although currently North-East Asia is a net exporter of polypropylene, it is expected to import more than 3 000 thousand tons per year from 2030 and more than 7 000 thousand tons per year from 2040, with consumption doubling between 2025 and 2045. China in particular shows strong projected demand.

In the South-East Asia, the largest net importers are Vietnam and Indonesia. The regional consumption is projected to grow considerably over the forecast period, with the production lagging behind from 2030, and the needs in polypropylene imports are anticipated to increase.

Africa is a large net importer of polypropylene, and this will continue throughout the forecast period with more limited capacity additions when compared to other regions. Africa's net import requirement continues to grow. All African countries rely on polypropylene imports, with the exception of South Africa which is a net exporter. The two largest net importers are Algeria and Egypt. These countries source their requirements in great part from Saudi Arabia.

Table 5.1 Marketing Plan for Polypropylene per Target Region
(Forecast, 2027)

Region	Regional Market		Product Placement	
	Demand	Net Trade	Sales	Sales
			(ktpa)	*(percent)*
Western Europe	7 732	260	50	10%
Central Europe	2 952	(1 273)	75	15%
Eastern Europe	1 790	813		
North Africa	1 067	(342)	50	10%
Turkey	2 511	(1 237)	125	25%
Middle East excl. Turkey *	5 340	5 203	50	10%
North-East Asia	47 260	(153)	50	10%
South-East Asia	7 634	(333)	100	20%
Total			500	100%

*The Middle East placement refers to product being distributed as local sales in Saudi Arabia, in line with Alujain's comments. The product placement volumes align with the base case of the Financial Model, with the option to adjust volumes sold to each target market based on current market conditions.

The disruption of shipping in the Red Sea due to attacks attributed to the Houthis in Yemen, aimed at supporting Hamas in its conflict with Israel, has significantly impacted global chemical industry supply chains. This escalation of hostilities has led major shipping companies to avoid the Red Sea route for safety reasons.

The necessity to divert shipping routes away from the Red Sea has introduced substantial delays and increased costs for the chemical industry. Normally, a significant portion of the world's ocean carrier traffic passes through the Red Sea. However, the current situation has forced rerouting around the Cape of Good Hope at the southern tip of Africa, extending transit times by up to several weeks. This shift not only affects shipping rates but also the efficiency of global supply chains in the chemical sector, underscoring the broader economic implications of geopolitical conflicts on international trade.

When COVID-19 emerged a few years back, the chemical industry faced sudden and significant price hikes across the board, with container rates soaring from US$3 500 to US$20 000, for instance. However, the recent disruptions have not uniformly affected all shipping lines; the attacks by the Houthis have specifically targeted vessels bound for Israel.

Currently, logistics costs have not reverted to the peak levels experienced during the COVID-19 pandemic, yet, the financial impact on shipping and the broader supply chain depends on the duration and intensity of these disruptions.

The polypropylene market, similar to other polyolefin markets, is dynamic and fluctuates with typical petrochemical cycles. For instance, the current market tightness in Asia, following China's transition to a net importer, is a direct result of recent capacity expansions. As these new capacities integrate into the industry, they are expected to rebalance market dynamics. This shift presents an opportunity for polypropylene producers like the Project to redirect their volumes to other markets where higher netbacks are achievable.

Furthermore, the Financial Model (FM) identifies additional markets beyond those proposed in the marketing plan and covers greater regions. This expands the Project's options to explore regions that could enhance the Project's returns. In particular, two additional regions are considered in the FM: North America and South America.

North America as a whole is balanced in polypropylene, with the United States being a net exporter and Mexico and Canada (to a lesser degree) being net importers. However, new polypropylene capacities in Canada and Mexico will reduce their net import position in the medium term. The automotive sector is anticipated to be a significant driver of polypropylene demand, and the polypropylene market is projected to experience continued growth at the rate of approximately 2 percent over the forecast period.

South America is a fairly significant net importer of polypropylene, with around 620 000 tons per year in 2023. The main producers (Brazil and Argentina) are reasonably balanced but supply product to other South American countries which have limited production capacity. Over the forecast period it is expected that the consumption of polypropylene in South America will continue to grow steadily at the rate of 3.8 percent during 2023-2030 and at 2.7 percent in 2030-2045.

The Project's export volumes could be placed in the target regions, given the size of the markets and their net trade positions; however, a careful consideration should be given to evaluate feasible PP netback to each of the target markets.

The following table summarizes the ports selected which in NexantECA's opinion are reasonable representatives for selected target markets in Tables 5.1 or 5.2.

Table 5.2 Summary of Selected Polypropylene Target Market Port Locations

Region	Target Port
Western Europe	Rotterdam, Netherlands
North America	Houston, USA
Middle East	Yanbu, Saudi Arabia
North-East Asia	Shanghai, China
South America	Santos, Brazil
South-East Asia	Singapore, Singapore
North Africa	Alexandria, Egypt
Turkey	Mersin, Turkey
Central Europe	Gdansk, Poland

Based on the assessment of target markets, netbacks to the Project have been developed in Section 6 of this report. Netbacks to the Alujain plant gate at Yanbu were calculated for each of the key destination markets of Western Europe, U.S.G.C and North-East Asia.

Table 5.3 Comparison of Calculated Netbacks

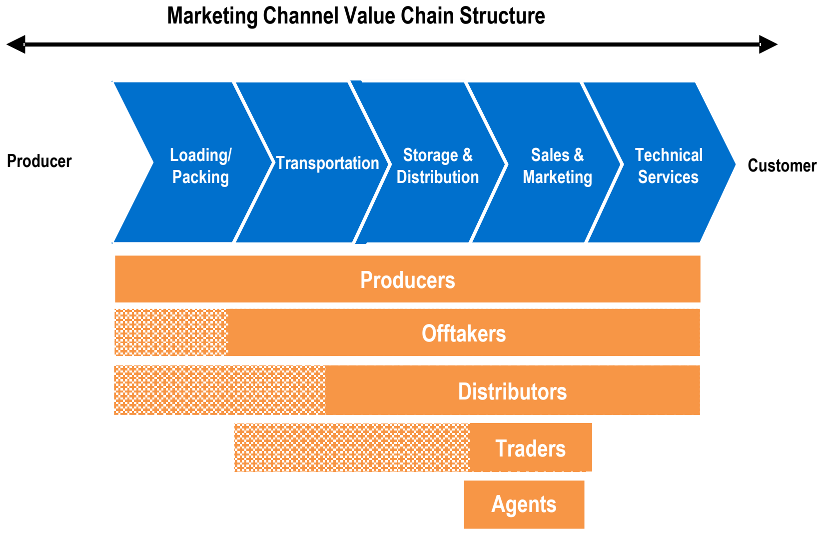
Target Port	Average Annual Netback, 2026 - 2050	
	USD per Ton	
Houston, USA	1299	Highest
Rotterdam, Netherlands	1267	↑
Shanghai, China	921	Lowest

Diversification of the customer base is considered in the proposed marketing plan. Over the forecast period, shifts in global supply, demand and trade will vary the attractiveness of sales to specific target markets slightly. The largest targeted sales volumes should therefore be directed towards those regions where demand and net import position is greater, and where the netback is the highest.

5.2 MARKETING AND DISTRIBUTION CHANNELS

In order to serve the scale of customers in an efficient and cost-effective manner, producers use a variety of logistics and marketing channels. Marketing channels are covered by producers, off takers, traders and distributors, each of which follows a different business model. Long established producers typically work across the entire set of channels and use traders and distributors in addition to direct selling to customers.

Figure 5.2 Marketing Channels and Players



The borders between these channels are not well defined and the markets may overlap due to the inter-relation of the players and their activities, for example a distributor may sell product to other distributors or source from agents to supply a customer. Customers buy from all parts of the supply chain, depending on material types/grades, locations, price and whether technical service is required. Offtakers, traders and direct sales are the three most common routes, which are profiled at high level in the following sub-sections.

5.2.1 Direct Sales

Some producers, in particular those with decades in the business, sell directly to customers. The proportion of direct sales is influenced by factors such as the proximity of customers, size of the market opportunity and the capability/experience of the producer. This option is recommendable when the producer has wide experience and marketing capabilities as well as technical services.

It is required to invest in developing in-house sales and marketing capability to sell the products directly to consumers and offer technical services if so required.

The key objectives for marketing and selling product are:

- to maximise net-back prices to the Project Owner
- to sell all available plant output
- to minimise transaction costs
- to provide good customer support.

The first two items are key to the delivery of a financially successful project. In a capital intensive business, the achievement of high plant utilisation and maximum margins are critical success factors. A low cost, logistics chain and the maintenance of a satisfied customer base are essential factors in achieving the two key goals.

The establishment of a new sales and marketing department is challenging, time-consuming and costly, and may be viewed as risky by potential lenders as the potential impact of failing to sell all the output could jeopardise their investment. The Project would need to weigh up the benefits of this strategy.

5.2.2 Offtakers

Product offtakers are defined here as those marketers offering long-term offtake agreements to producers. The term of the offtake agreement could be equal to or longer than the term of the loan for the new project which can assist in securing financing from lenders. The offtaker may lift all production volume or an agreed volume managing all aspects of marketing, sales and distribution, for the term of the agreement. The offtaker could be a polypropylene producer with trading activities or a trader.

A good offtaker of product will demonstrate the following key attributes:

- Extensive experience in selling polypropylene
- Good understanding of the propylene markets
- Strong global presence (especially important given the wide ranging target markets for this project)
- Supply chain network, including distribution centres
- Financial strength and credibility with lenders

5.2.3 Distributors

An independent distributor is a company offering products from various manufacturers to sell to its customers and which is not back integrated into production or owned by a supplier. Distributors often receive a margin both from their suppliers and customers.

5.2.4 Traders

Traders work for the producers and are paid a commission by the producer, which is normally a percentage of the FOB price of two to five percent and the commission depends on sales volumes.

5.2.5 Agents

Agents act on behalf of suppliers and tend to work on a commission basis; they do not normally take ownership of the product themselves. Agents tend to have excellent local market knowledge and contacts, particularly with small customers.

The sales contract will be between the supplier and the customer at the price negotiated by the agent, net of commission. An agent may arrange product delivery through third party logistics or with the customer.

Table 5.4 Marketing Options Summary

	Advantage	Disadvantage
Direct Marketing	Knowledge of the market and branding. Optimal price achievable	Costly, risky and takes time to develop
Offtake Agreement	Low cost and security to lenders	Modest contact with consumers
Sales via Traders	Global coverage	No volume guarantee and lower product quality or poorer product performance perceptions

5.3 CONCLUSIONS

It is anticipated that the placement of polypropylene within the selected target markets is realistic and achievable. The global polypropylene market is very large and commoditised and the Project's location is well-placed to supply both the western and eastern hemispheres. The selected target markets should secure sufficient offtake opportunities.

The analysis in this section provides an initial view of a possible marketing plan for the Project. The proposed plan could be refined as the Project advances further.

Section 6
Pricing

6.1 INTRODUCTION

This section presents NexantECA's price forecasts for propane, propylene and polypropylene (PP) (homopolymer) in the following countries/locations:

- Western Europe – Spot CIF North-West Europe
- US Gulf Coast – Spot US Mont Belvieu FOB
- Middle East – Contract Saudi Arabia FOB
- North-East Asia (China) Spot FOB

Prices are presented on an annual average basis between 2012 and 2050.

Netback pricing at the project gate have been developed for propylene and PP sales to the target markets defined from the Market Dynamics analysis presented in Section 4.

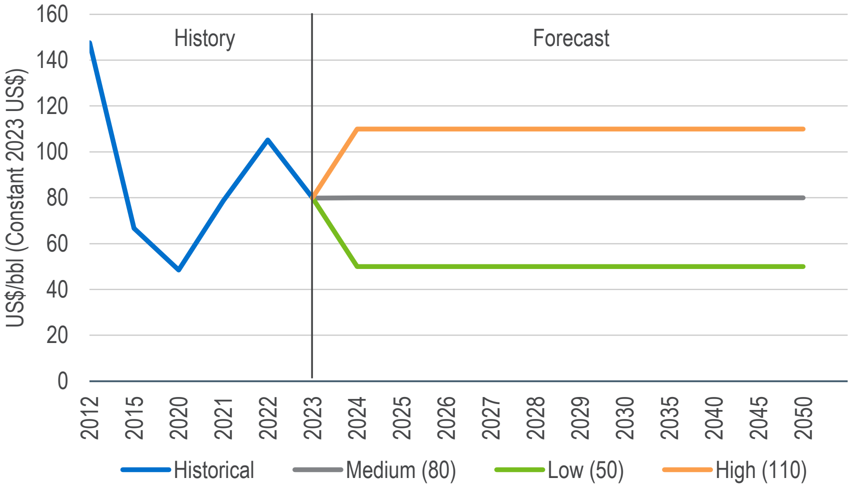
6.1.1 Crude Oil Price Scenarios

NexantECA develops product price forecasts for different crude oil price scenarios to demonstrate how product prices are expected to behave depending on the prevailing crude price at the time. The crude oil price scenarios provide the financial advisor with the flexibility to run various sensitivities in the financial model to see how the project will behave depending on crude oil price levels.

The crude oil price scenarios are based on various levels of Brent Crude FOB pricing over the forecast period. For the purpose of this study, three crude oil price scenarios were considered:

- **Low (US$50):** Brent crude prices over the forecast period are set at US$50 per barrel in constant 2023 dollar terms
- **Medium (US$80):** Brent crude prices over the forecast period are set at US$80 per barrel in constant 2023 dollar terms
- **High (US$110):** Brent crude prices over the forecast period are set at US$110 per barrel in constant 2023 dollar terms

Figure 6.1 Crude Oil Price Scenarios
(Constant 2023 US$)



For the purpose of this report, the medium oil scenario is considered as the **Base Case** – this is the scenario depicted in any figures unless otherwise stated.

6.1.2 Product Pricing Methodology Overview

The product pricing outlooks presented in this report are developed based on three methodologies:

- **NexantECA Marker:** NexantECA records historical pricing and develops pricing forecasts for key products in key trading hubs on a quarterly basis. Prices are forecast based on a comprehensive view of industry profitability, the forecasts for which are prepared using a proprietary simulation model of the global petroleum and petrochemicals industry. Industry outlooks draw on more than 50 years of knowledge and experience of the global industry to develop algorithms to simulate petrochemical business dynamics. The forecast methodology relates market demand drivers to petrochemical consumption, which is compared to the ability to supply based on a database of global capacity. Basic commodity theory suggests market tightness, indicated by average operating rates, is a primary driver of profitability. Production costs are built up from a detailed database of archetype plant techno-economic models, heavily influenced by assumptions of crude oil and energy prices. Petrochemical product prices are determined by adding projected production costs to the margin outlook. Inter-regional competition and inter-material competition add further constraints and complexity to shape the pricing dynamics.
- **Actual Historical/NexantECA Forecast:** Through subscriptions to price publishing agencies (e.g., Platts, Argus, ICIS), NexantECA has access to actual historical pricing. The forecasts for the prices for which actual historical pricing was available were based on a comparison of the actual historical pricing to a relevant NexantECA Marker price, with the differential between the two over the forecast period set by the observed historical differential as well as NexantECA's expectations of any potential future narrowing/widening of the differential based on market dynamics.
- **Netback Calculations:** Pricing assessments in countries where actual historical pricing is not available is developed through netback calculations from relevant price setting countries/regions, taking into consideration trade flows and elements such as customs/tariffs and freight costs.

Prices for 2023 shown in this report, reflect the average 2023 year-to-date (YTD) prices.

All prices are shown in constant 2023 US$ terms for the medium crude price scenario, unless specified otherwise in the title or in the axis's labels.

6.1.3 Port and Freight Assumptions

Where freight and port fee calculations were involved, NexantECA has used the following ports for each country/region in the pricing assessment:

Table 6.1 Port Assumptions in each Country/Region

Country / Region	Port of Destination
Saudi Arabia	Yanbu
Middle East	Jubail, Saudi Arabia
Western Europe	Rotterdam, Netherlands
US Gulf Coast	Port Houston, Texas
North-East Asia	Shanghai, China

Freight rate forecasts were based on actual historical freight rates observed over the routes in question or suitable proxy freight rate quotes between other ports in the same regions as the ports in question, pro-rated to account for sea distances and adjusted for port fees and customs/tariffs, as available and applicable. Forecasted freight rates are flat in constant 2023 US$ terms, and different freight assumptions were made in each crude oil price scenario to reflect the generally lower freight rates when crude, and hence bunker fuel, prices are low.

It is important to note that freight rates are notoriously volatile and depend not only on macro-factors such as the prevailing fuel prices but also on local, micro-trends such as the cargo sizes, fleet availability, sea conditions as well as regional trading strategies. Nevertheless, for both propylene and polypropylene freight rates represent on average five to eleven percent of the market prices and hence volatility in freight rates should not have an overly significant impact on Alujain's financial performance.

6.2 PROPANE PRICING

6.2.1 Pricing Drivers

Propane is primarily used as a fuel with secondary use as a feedstock into the petrochemicals industry. As a fuel, propane (as a component of LPG) typically competes with natural gas, heating gas oils, electricity, and residual fuel oils. Increasing demand for propylene in the global petrochemical industry has also driven petrochemical producers to catalytically dehydrogenate propane to produce propylene. Propane prices are thus influenced by pricing of competing fuels, and the prices of the principal steam cracker feedstocks, naphtha and ethane.

The main factors that influence propane pricing are:

- The propane supply / demand balance
- Its value relative to butane for blending into LPG
- Its value to a steam cracker operator compared to alternative feedstocks
- The price of natural gas

Propane Supply / Demand Balance

Since propane is primarily sourced as a by-product from natural gas production and crude oil refining, production of propane ultimately is not dictated by propane demand.

Over the course of a year, propane prices follow a highly seasonal pattern, reflecting the seasonality of propane demand. Higher relative prices are achieved during the winter (in the northern hemisphere) when propane's use as a residential heating fuel peak. The propane price assessment provided is based on an annual average, masking seasonal fluctuations.

Price of Natural Gas

As a competing fuel, floor prices for propane will be those of natural gas on an energy equivalence basis. LPG is used as a heating and cooking fuel in regions that do not have access to mains gas and so substitution is limited. Hence, the high natural gas prices (in Western Europe) because of the Russia-Ukraine conflict resulted in increased propane prices in 2022, but as natural gas price has fallen in 2023, so has the price of propane.

6.2.2 Key Trends and Correlations

Propane prices are bound by value of competing fuels, and the price of the principal petrochemical feedstock, naphtha.

Propane prices have broadly tracked naphtha over the long term, reflecting competition as petrochemical feedstock. Turbulence in natural gas markets has driven shorter term trends in the value of propane relative to naphtha, in many cases reflecting evolving competitiveness of gas relative to crude oil. Lengthening supply and easing natural gas prices in many markets opened a widening discount on propane in the last decade. The United States has typically defined the floor to global propane prices, with a structural surplus regularly exported.

A structural deficit in Asia typically sets global price ceiling. Global prices realigned with the lower price point in the United States by 2015 as new infrastructure connected demand with the previously isolated surplus in the United States.

Propane is typically refrigerated and shipped as a liquid in large tankers. Frequent global trade in large volume cargoes closely ties propane prices across global markets. Global propane supply is projected to be driven by natural gas production and refining activities. The COVID-19 outbreak has introduced substantial supply-side pressure, but the influence was temporary, with a return to more normal business conditions driven by economic recovery in 2021 and continued growth over the next few years.

From 2022, the deteriorating political climate between Russia and Ukraine in Central and Eastern Europe caused huge turbulence in the global gas market, especially in the Eastern Europe, EU, Eastern/Central Asia and the US. The deepening conflict between Russia and Ukraine led gas prices to swiftly increase to post new record high from opening months of 2022. European producers are particularly exposed to gas supplies from Eastern Europe while Russia supplies approximately one-third of Europe’s natural gas. EU has introduced several rounds of sanctions on Russia which included a ban on imports of fossil fuels as well as Russia registered vessels entering EU ports along road transportation. Factors such as high transportation costs, supply chain disruptions, and increase demand for propane exports to Asia resulted in the propane price to continuously increase throughout 2021. The sanctions have caused great pressure on the already tight market and has introduced great uncertainty to the global supply/demand, pricing and trade balance.

The geopolitical tension caused by the Russia-Ukraine crisis, coupled with the sanctions imposed by the United States and European countries on Russia, and Russia’s countersanctions, have aroused concerns in the international energy market that oil and gas supplies may be interrupted and is currently at a state of high volatility. Additionally, the recent increase in oil prices have had a knock-on effect on propane prices. This is because propane is a by-product of oil and natural gas production.

The United States has typically defined the floor to global propane prices, with a structural surplus regularly exported. Asia has typically defined the ceiling to global prices, reflecting the structural deficit. The U.S. will continue to set the floor to global prices, reflecting its strong export position. Asian pricing will define the higher end of the spectrum, reflecting its position as the driver of global demand growth, strong import requirement, and higher freight costs to reach Asian markets relative to European markets.

Due to the surge in U.S. supply and low heating demand in Europe due to the mild winter, propane prices did not spike to the same extent as those of ethane, and propane cracking remained advantageous relative to naphtha for significant parts of 2022. Recently, some major Asia propane buyers have signed multi-year take-or-pay contracts to lift around one million tons per year each of propane through new coastal terminals in the United States. This has supported growth in U.S. propane exports, although during periods of extremely low propane pricing buyers have occasionally opted to pay the charge for not taking cargo, and instead sourced propane from the Middle East. China propane prices dropped by over 16 percent in quarter three 2023 over previous quarter while those in the United States were only around four percent lower.

6.2.2.1 Saudi Aramco CP

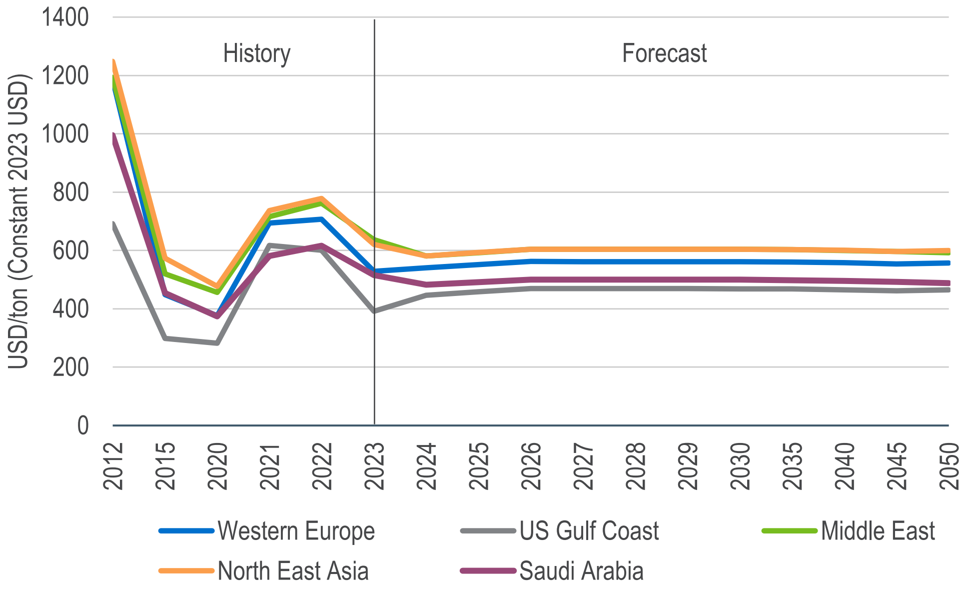
The pricing in Saudi Arabia is formulated based on the Saudi Aramco Contract Price (CP) for propane and butane. Saudi Aramco updates the CP monthly, serving as a benchmark export price primarily for key Asian markets. The methodology for determining propane and butane prices in Saudi involves subtracting freight costs from the Japanese propane/butane price and then applying a 20 percent discount. These prices are significantly influenced by the anticipated LPG import demand from China and South-East Asia.

NexantECA has taken note of Saudi Aramco's recent announcement regarding the hike in prices for certain feedstocks and fuel, communicated to various petrochemical and cement companies. Notably, domestic ethane prices have seen a 43 percent increase from US$1.75/MMBtu to US$2.50/MMBtu, and methane prices have climbed by 40 percent from US$1.25/MMBtu to US$1.75/MMBtu, with these adjustments taking effect from 1 January 2024. This escalation in feedstock and fuel prices is expected to compress margins.

However, it's important to note that there have been no adjustments in the prices or discounts for LPG feedstock, including propane and butane. Unless the Saudi government devises short or long-term strategies to amend LPG pricing, the PDH/PP projects will likely remain unaffected. Such projects usually involve final prices being negotiated and approved by the Ministry of Energy. NexantECA understands that the Project secured propane as a feedstock from the Ministry of Energy to cover Project’s requirements of the PDH/PP complex. However, the commercial details of the propane supply were not made available for the benefits of the Study. As such, NexantECA assumed the propane price to be based on the Saudi Aramco CP price described above.

Figure 6.2 Global Propane Prices, 2012 – 2050

(Constant 2023 US$, Medium oil scenario)



The Saudi Aramco CP price began to track the decline in global oil prices from February 2020 onwards, although it remained at a premium to Brent crude. The sudden spike in crude prices due to the Russia/Ukraine conflict shows propane prices have had increased volatility over the last few years. This, however, is not expected to persist over the forecast period, as the completion of the various refinery and petrochemical plant turnarounds have already increased the supply of both propane and propylene available for the Asian market.

Table 6.2 Propane Price Forecasts

(Constant 2023 US$ per ton, medium oil scenario)

		History					Estimate	Forecast										
		2012	**2015**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2035**	**2040**	**2045**	**2050**
Western Europe	*CIF NWE Spot*	1 187	448	376	694	707	528	541	551	562	562	562	562	561	560	558	554	557
US Gulf Coast	*FOB Spot*	691	299	282	617	601	392	446	458	469	469	469	469	469	468	465	462	464
Saudi Arabia	*Saudi Contract*	995	454	375	581	616	515	483	492	500	500	500	500	500	498	495	492	488
Middle East	*Contract*	1 194	520	456	716	761	637	581	592	604	604	604	604	604	603	600	597	593
North East Asia	*FOB Spot*	1 249	574	477	737	778	620	582	593	604	604	604	604	604	603	600	597	600

6.3 PROPYLENE PRICING

6.3.1 Pricing Drivers

Propylene is the second most important olefin feedstock to the petrochemical industry (after ethylene), being used as a petrochemical feedstock in a variety of chemical processes – approximately two-thirds of global demand is used for polypropylene production, with the remainder into other derivatives including propylene oxide, cumene/phenol, acrylonitrile and acrylic acid.

The key source of propylene supply is from the steam cracking of naphtha, where it is produced as a by-product to ethylene. It is also commonly produced in refineries as a by-product in the fluid catalytic cracking (FCC) of vacuum gasoil (VGO). On-purpose propylene production is becoming more prevalent since the 2000s primarily through the development of numerous propane dehydrogenation (PDH) plants, which became economical particularly as the increasing availability of lighter steam cracker feedstocks (such as ethane from shale gas, which yields virtually no propylene) has reduced the use of naphtha in steam crackers and hence decreased propylene supply.

Propylene is a highly flammable gas which requires a high pressure and/or low temperature to be converted into a liquid for transport. Propylene freight rates therefore tend to be high, and the majority of propylene production facilities convert it into one of its derivatives on-site instead of selling it on the merchant market. Nevertheless, propylene is still a globally traded commodity, albeit in smaller volumes than many other base chemicals.

Propylene is typically traded in three different grades, dependent upon the purity of the product:

- **Polymer-grade** is the purest material, with a minimum propylene content of 99.5 percent, and very low concentrations of inorganic trace elements. This high-grade material is required for production of polypropylene, without impairing catalyst performance.
- **Chemical-grade** is of lower purity, with a minimum of 94 percent propylene. This material can be used directly in production of most derivatives except polypropylene.
- **Refinery-grade** is the lowest quality, with minimum propylene content of 60 percent. Refinery propylene can be used directly in cumene/phenol production or fed to a splitter to remove the propane and upgrade to higher purity chemical- or polymer-grade material.

The main factors that influence propylene pricing are:

- The pricing of propylene derivatives
- The production economics and competitiveness of naphtha crackers versus other feedstocks
- Its value to a petrochemicals producer compared to alternative uses in a refinery
- The price of propane

6.3.1.1 Pricing of Propylene Derivatives

Propylene supply is largely dictated by demand, particularly since on-purpose production via PDH became more prevalent. As such, propylene prices are heavily influenced by the pricing of its key derivatives, and polypropylene in particular. Widespread global trade in polypropylene has bound regional propylene prices through the value of contained monomer. Polypropylene prices are also governed by the relative cost of polypropylene production versus competing polymers (most notably high-density polyethylene), as consumers have the opportunity to substitute polypropylene. Prices of both resins, and the associated cost of feedstocks, must remain closely bound to preserve consumption of both products in competing markets.

6.3.1.2 Competitiveness of Naphtha Crackers

The increasing availability of lighter steam cracker feedstocks has significantly boosted the competitiveness of ethane crackers over naphtha crackers for the production of ethylene. While standard severity naphtha crackers produce approximately 0.5 tons of propylene per ton of ethylene, ethane crackers do not produce any propylene, hence a continued availability of light steam cracker feedstocks will likely limit the potential for any new naphtha cracker projects and may force further conversions of current naphtha crackers to allow them to process light feedstocks instead, which would reduce the supply of propylene and hence increase the prices.

6.3.1.3 Value for Petrochemicals vs. Refining

Refinery-grade propylene produced in refineries is often consumed on-site in the production of alkylate, a high-value gasoline blend component, or blended into LPG and either sold or consumed internally as a fuel. The petrochemical industry must therefore offer a sufficient premium over the value of propylene in refinery streams to attract volumes of propylene away from the competing uses within the refinery.

The alkylation value of propylene in the refinery used to define a strong floor to propylene prices in the United States, with refinery propylene prices dropping to alkylation values in weak markets. Extraction of propylene from refineries was frequently the swing source of production, with the other principal source of propylene supply from steam crackers commonly constrained by production of ethylene. Refiners have the option of extracting refinery grade propylene for chemical use or directing it to alternative uses within the refinery such as alkylate production. In periods of high propylene demand, prices for refinery grade propylene increased above the highest alternative value within the refinery, incentivizing further recovery. The higher refinery grade prices added pressure to chemical- and polymer-grade prices to allow the splitters to maintain margins. The sharp decrease in isobutane prices since 2010 has strengthened alkylation values, regularly lifting them above the price point the petrochemical industry could bear for refinery- and polymer-grade prices. With little investment in refinery operations in the United States, and the sharply lower cost of isobutane, surplus alkylation capacity has been absorbed. Removal of this key marginal source of propylene has withdrawn the previously strong influence of alkylation values from propylene prices in chemical markets. Increasing availability of on-purpose propylene increasingly acted as the marginal supply source.

6.3.1.4 Price of Propane

Propane dehydrogenation was once viewed as a marginal source of supply; however, units are now required to run continually as ethylene market dynamics and migration towards lighter feedstocks restricts propylene co-product supply. The price of propane feedstock directly dictates the profitability of a PDH plant and hence the potential supply of propylene.

6.3.2 Key Trends and Correlations

Since propylene is mainly produced in naphtha steam crackers, refinery FCC units or from propane in PDH units, propylene prices are closely linked to crude oil prices. The link is not as well-defined as the link between propane and crude oil, with more pronounced fluctuations observed in historical propylene-crude price differentials, as propylene pricing is also influenced by the pricing for the key propylene derivatives, which are more demand-driven.

The return to normal operations for the three PDH units in the U.S. and further propylene capacity additions globally resulted in an oversupplied market in 2019, which put pressure on propylene prices and resulted in a decrease in global operating rates. This, coupled with the decline in crude oil prices, and hence propane feedstock prices, led to a drop in propylene prices across the globe. Propylene prices continued to trend downwards in 2020 due to the COVID-19 pandemic and in early 2021 the propylene prices were relatively low due to weak demand and oversupply.

By the end of 2021, propylene prices reached record highs due to some regions experiencing shortages in supply. As the economic activity achieved a brisk recovery, the propylene market was squeezed tight into 2021. Prices remained elevated in 2022, reflecting ongoing supply demand imbalances along with other factors such as ongoing supply chain disruptions.

Unprecedented margin gains were abruptly surrendered as markets reverted to their equilibrium position into 2022 with supply levels in the US achieving record high volumes as observed in 2018. Global capacity growth accelerated to its fastest for more than a decade, approaching six percent in 2023. Mounting competition in global propylene markets led by rapid expansion in China will depress profitability, with PDH margins settling at the lower end of the range earned in commercial operations through 2026. Although Europe will regularly define the ceiling to global prices, increasing competition in global markets will cap prices, holding propylene at a discount to ethylene. Investment in new on purpose propylene capacity will reduce the volatility seen in recent years. Weaking domestic markets in the United States coupled with deepening competition for propylene derivatives in global markets capped U.S. propylene prices as upstream costs firmed through quarter three. The lower price point in China was a further burden on prices.

Figure 6.3 Global Propylene Prices, 2012 – 2050

(Constant 2023 US$, Mid (80) Crude Price Scenario)

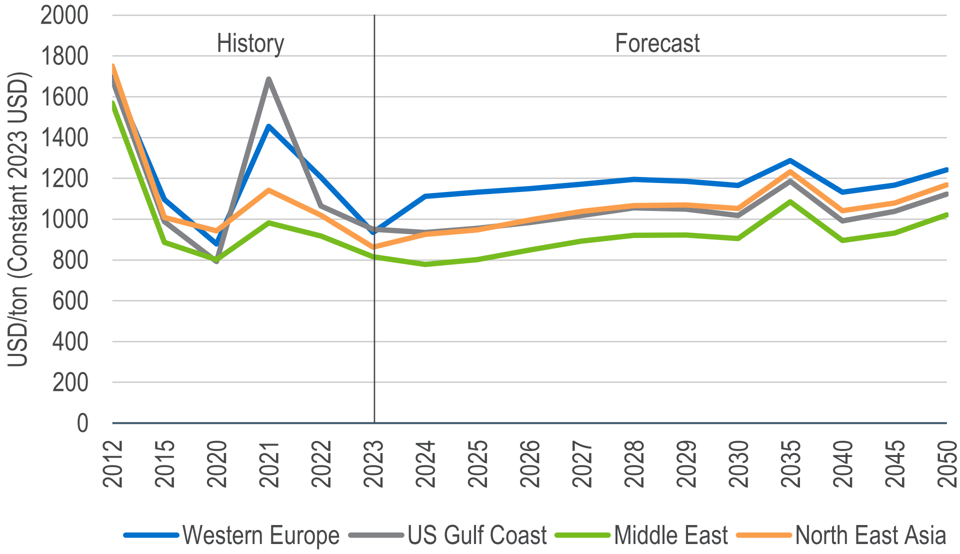


Table 6.3 Propylene Price Forecasts

(Constant 2023 US$ per ton, medium oil scenario)

		History					Estimate	Forecast										
		2012	2015	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2035	2040	2045	2050
Western Europe	*CIF NWE Spot*	1 700	1 096	878	1 454	1 205	935	1 112	1 131	1 149	1 172	1 195	1 186	1 165	1 287	1 132	1 167	1 242
US Gulf Coast	*FOB Spot*	1 685	988	793	1 687	1 065	951	935	955	983	1 018	1 055	1 049	1 017	1 186	992	1 039	1 124
Middle East	*FOB Spot*	1 569	887	801	982	918	816	779	801	849	892	920	923	905	1 086	895	932	1 021
North East Asia	*FOB Spot*	1 751	1 009	942	1 142	1 019	863	926	948	996	1 039	1 067	1 070	1 052	1 233	1 042	1 079	1 168

6.3.3 Target Market Pricing Assessment

Prices for the target markets considered in this report were developed on the following basis:

- Western Europe, USGC and North-East Asia prices are recorded and forecast by NexantECA on a regular basis.
- The price in Saudi Arabia and the Middle East is set by the prices in the key export market of South-East Asia, which is also regularly updated by NexantECA. South-East Asian pricing is directly linked to the prices in the single-biggest market, China. The price assessments for Saudi Arabia and the Middle East were therefore based on netback calculations from South-East Asia

Table 6.4 Propylene Pricing Methodology

Country / Region	Basis	Pricing Methodology	Reference Price
Middle East	Spot FOB	Netback	South-East Asia
Western Europe	Spot CIF	NexantECA Reference	N/A
USGC	Spot FOB	NexantECA Reference	N/A
North East Asia	Spot FOB	NexantECA Reference	N/A

6.3.4 Alujain Netbacks

Netbacks to the Alujain plant gate at Yanbu were calculated for each of the key destination markets of Western Europe, U.S.G.C and North-East Asia. The netback calculations take into consideration all the key costs associated with bringing propylene product from the Alujain plant to the destination markets, such as tariffs/customs duties, sea freight costs, and port and handling fees at both Yanbu and the destination port, dependent on the basis of the market price.

Tariffs/Customs Duties

Saudi Arabia has free trade agreements with the EU, United Kingdom and the US which cover propylene, hence there are no tariffs or customs duties that need to be paid on imports from Saudi Arabia. China, on the other hand, has tariffs with Saudi Arabia for propylene at 2%. However, this tariff is not factored into the netback assessment provided below, as the market price basis for China is CFR, in which the tariff falls onto the buyer, not the seller. Additionally, there is a supplementary fee of US$4 per ton for transiting through the Suez Canal, applicable to shipments bound for the US and Western Europe.

Freight and Port Costs

The key price component in netback calculations is the freight cost between Yanbu and the destination port. These have been included in the netback calculations as per NexantECA understanding of freight costs between countries/regions.

Port and handling fees in the regions have been based on published port fees and NexantECA's assumption on additional handling fees incurred at each port, dependent on the basis of the market price i.e. for a CFR price, port and handling fees is are only taken into account in the origin country; conversely, for a FD price, port and handling fees are taken into account in both the origin and destination country.

Propylene freight cost was assumed to be similar to the propane freight cost. The estimated freight costs were used to determine the Middle East price from South-East Asia by subtracting freight from the CFR price.

Netback Freight Assumptions

For the netback calculations, the following freight rate assumptions were made. These have been based on the average historical freight rates observed between the relevant countries/regions. Rates to Saudi Arabia have been calculated to the Port of Yanbu.

Table 6.5 Propylene Freight Assumptions – 2027
(Constant 2023 US$, Mid (80) Crude Price Scenario)

Region	Port Basis	USD / ton
WE - KSA	Rotterdam - Yanbu	76
USGC - KSA	Houston - Yanbu	119
NEA - KSA	Shanghai - Yanbu	122

Netback Prices Calculations

The tables below show the netback calculation to Alujain for sales of propylene into the target markets based on the year 2027 – planned operation start date of the Project.

Table 6.6 Western Europe Propylene Alujain Netback Pricing, 2027
(Constant 2023 US$, Mid (80) Crude Price Scenario)

Price Element	Basis	Units	Price
Western Europe	FD Contract	$/ton	1 231
Inland Freight	Rotterdam	$/ton	30
Tariffs & Customs	Rotterdam	$/ton	0
Port Fees & Handling	Rotterdam	$/ton	13
Freight	Rotterdam - Yanbu	$/ton	76
Use of Suez Canal		$/ton	4
Port Fees & Handling	Yanbu	$/ton	20
Saudi Arabia	Plant Gate	$/ton	1 088

Table 6.7 USGC Propylene Alujain Netback Pricing, 2027
(Constant 2023 US$, Mid (80) Crude Price Scenario)

Price Element	Basis	Units	Price
USGC	FD Contract	$/ton	1 094
Inland Freight	Houston	$/ton	10
Tariffs & Customs	Houston	$/ton	0
Port Fees & Handling	Houston	$/ton	25
Freight	Houston - Yanbu	$/ton	119
Use of Suez Canal		$/ton	4
Port Fees & Handling	Yanbu	$/ton	20
Saudi Arabia	Plant Gate	$/ton	916

Table 6.8 North-East Asia Alujain Netback Pricing, 2027
(Constant 2023 US$, Mid (80) Crude Price Scenario)

Price Element	Basis	Units	Price
North-East Asia	CFR Spot	$/ton	1 059
Tariffs & Customs	Shanghai	$/ton	0
Port Fees & Handling	Shanghai	$/ton	0
Freight	Shanghai - Yanbu	$/ton	122
Port Fees & Handling	Yanbu	$/ton	20
Saudi Arabia	Plant Gate	$/ton	917

Figure 6.4 Alujain Propylene Netback Pricing, 2012 – 2050
(Constant 2023 US$, Mid (80) Crude Price Scenario)

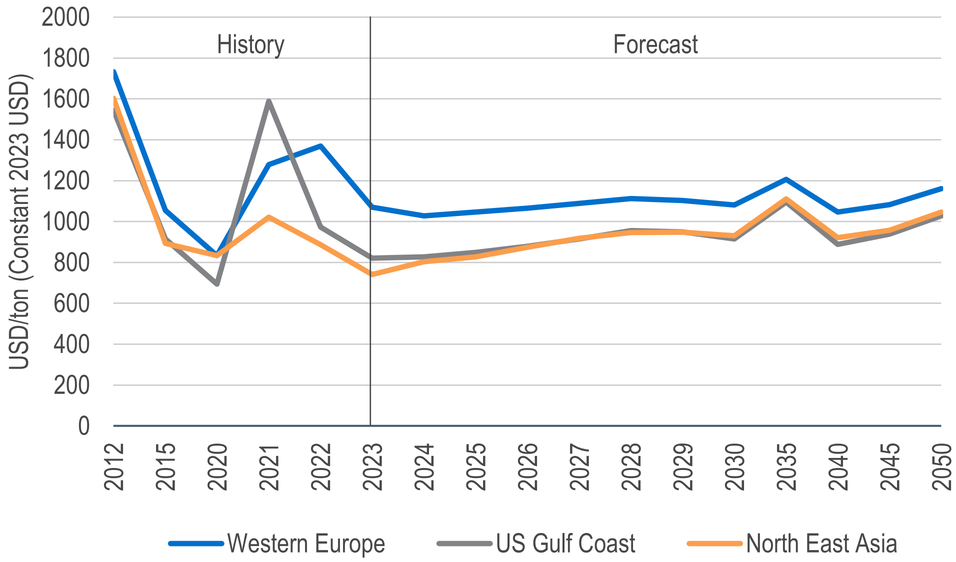


Table 6.9 Propylene Plant Gate Netback Pricing to Target Markets
(Constant 2023 US$ per ton, Mid (80) Crude Price Scenario)

		History					Estimate	Forecast										
		2012	**2015**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2035**	**2040**	**2045**	**2050**
Western Europe	*Plant Gate*	1 733	1 055	833	1 278	1 369	1 071	1 027	1 047	1 065	1 088	1 113	1 103	1 081	1 207	1 047	1 083	1 160
US Gulf Coast	*Plant Gate*	1 544	915	694	1 589	972	821	827	849	878	916	956	949	915	1 095	888	938	1 028
North East Asia	*Plant Gate*	1 603	893	833	1 021	887	742	804	826	874	917	946	949	931	1 111	920	957	1 047

6.4 POLYPROPYLENE PRICING

6.4.1 Pricing Drivers

Polypropylene prices are generally set by direct negotiation between major producers and convertors, in a similar manner to polyethylene. Prices settle at a balance between the value of the resin to convertors on the demand side, and the costs of production on the supply side. Transparent prices for polypropylene are widely reported for most of the principal regional petrochemical markets.

Polypropylene resins are broadly categorised into two generic grades:

- **Homopolymer** resins are general purpose resins produced almost exclusively from propylene monomer.
- **Copolymer** resins typically incorporate between 5 and 15 percent ethylene co-monomer, improving impact resistance.

This report specifically analyses production economics of homopolymer injection moulding commodity grade resin.

Factors which are frequently analysed in negotiation of price settlements include:

- Production economics for polypropylene (most notably propylene feedstock costs)
- The price of competing polymers (most notably HDPE, PVC and polystyrene)
- The supply/demand balance for polypropylene
- Prices for polypropylene in other regions, and projected trade flows
- Profitability of convertors and plastics processors

6.4.1.1 Propylene Feedstock Costs

Feedstock costs represent approximately 90 percent of the total cash cost of production of polypropylene, and hence have the single biggest influence on polypropylene pricing. Due to the high costs of transportation of propylene, purchasing propylene on the merchant market leads to a much higher cost of production when compared to polypropylene plants integrated with propylene production. Polypropylene producers integrated with propylene production therefore have a significant price advantage over those purchasing propylene.

6.4.1.2 Competitiveness of Polypropylene versus Other Polymers

For most applications, the competitiveness of polypropylene relative to ethylene-derived polymers is mostly dependent on their respective prices, as there are many similarities between polypropylene and polyethylene properties that allow these products to be used interchangeably. The competitiveness depends mostly on the price of propylene relative to ethylene, as the cost of acquiring the feedstock monomer is the largest component of production costs.

6.4.1.3 Polypropylene Supply / Demand Balance

The polypropylene market is driven by demand – during times of lower demand, propylene feedstock can be diverted away from polypropylene and used for the production of the other propylene derivatives. Many major producers have this optionality onsite, providing them with a significant advantage in being able to tailor their production to the pricing achievable for the various propylene derivatives. Furthermore, in certain regions, some PDH-PP plants act as marginal suppliers which operate intermittently depending on market conditions. For example, this used to be the case in the US, however in recent times the plant economics were favourable, and these marginal suppliers have been operating at full capacity.

6.4.1.4 Global Pricing and Trade

Polypropylene is a commodity product regularly traded across the globe. The pricing of polypropylene in different regions is therefore closely linked, as any arbitrage opportunities are quickly exploited by traders. It is also a relatively transparent market, meaning pricing is generally efficient and based on market fundamentals, i.e., in a particular market/region the price is set by the marginal supplier of polypropylene to the market.

6.4.1.5 Profitability of Convertors and Plastics Processors

Although currently still in early-stage development, the recycling industry is expected to have increased influence over polypropylene pricing over the long term, as virgin polypropylene producers will have to compete with recycled polymers for market share.

6.4.2 Key Trends and Correlations

Polypropylene prices are linked to crude oil prices due to the significance of propylene feedstock costs, which typically account for 90 percent of total polypropylene production costs. However, polypropylene pricing is also heavily influenced by competition against other polymers and other demand/consumer-driven dynamics, hence the link to crude oil pricing is much less direct than that of propylene and propane.

At the beginning of 2021, polypropylene prices were relatively low due to weak demand and oversupply. However, a sharp rise in prices was observed when propylene supply chains were disrupted in the U.S due to winter storms. This was coupled with supply chain issues related to COVID-19 pandemic, including shipping delays and labour shortages.

Continued lockdowns in China where zero COVID-19 policy resulted in lower demand for the material. Capacity expansions approaching 10 percent across Asian markets lengthened markets against subdued demand. This compounded with high feedstock cost burden due to escalated crude oil prices put pressure on margins. The transient downturn in margins suffered against increasingly turbulent markets through 2022 was swiftly revered.

Asian spot CIF prices have generally set the floor to regional prices, despite the frequent deficit of Asian capacity drawing in imports. The disconnection between pricing gradient and trade flows reflects the different basis of regional prices. Asian prices represent material imported into Asian CFR spot markets, before application of duty and delivery to customer. Prices in Europe and the United States represent resin fully delivered to the customer. The start-up of export focused capacity in the Middle East has supplied most Asian imports since 2010. The ability of export dominated producers in the Middle East to supply either market ensures that, over the long term, prices in Asia and Europe must be interlinked, and most times offer similar netbacks. Weak market demand and over- supplied markets continued to depress Western Europe PP prices. Further reduction of PP prices outpaced a more modest drop in monomer prices as a renewed upturn in oil prices lent some inertia to propylene prices.

Petrochemical pricing is inherently cyclical due to a fundamental misalignment between investment in incremental capacity addition and demand growth as they have different drivers. Strong economic growth leads to higher petrochemical consumption and after a lag of a few years, leads to tightening markets and higher profitability. The higher profitability stimulates investment in new plants. With petrochemical projects taking up to five years from funding approval to start-up, capacity often lags the demand profile. The Middle East will enhance its position as the world’s largest exporter of polypropylene, with capacity doubling by 2030.

Figure 6.5 Global Polypropylene Prices, 2012 – 2050
(Constant 2023 US$, Medium oil scenario)

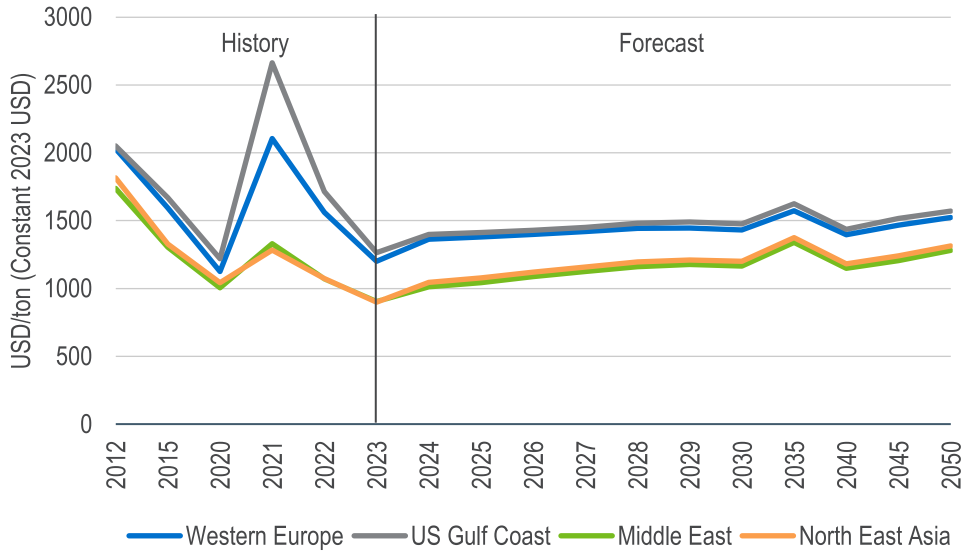


Table 6.10 Polypropylene Price Forecasts
(Constant 2023 US$ per ton, medium oil scenario)

		History					Estimate	Forecast										
		2012	**2015**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2035**	**2040**	**2045**	**2050**
Western Europe	*CIF NWE Spot*	2 030	1 594	1 126	2 106	1 562	1 201	1 363	1 380	1 398	1 419	1 444	1 445	1 432	1 574	1 396	1 467	1 523
US Gulf Coast	*FOB Spot*	2 050	1 670	1 219	2 662	1 713	1 264	1 397	1 411	1 429	1 451	1 482	1 490	1 475	1 624	1 435	1 515	1 571
Middle East	*FOB Spot*	1 737	1 303	1 005	1 329	1 072	903	1 011	1 043	1 087	1 125	1 161	1 177	1 166	1 340	1 148	1 206	1 280
North East Asia	*FOB Spot*	1 814	1 328	1 043	1 283	1 072	898	1 045	1 077	1 121	1 159	1 195	1 211	1 200	1 374	1 183	1 240	1 315

6.4.3 Target Market Pricing Assessment

Prices for the target markets considered in this report were developed on the following basis:

- Western Europe, USGC and North-East Asia prices are recorded and forecast by NexantECA on a regular basis. Forecast price is based on the production economics of homopolymer injection moulding commodity grade resin as well as the balancing of projected production costs (dominated by propylene feedstock cost), and projected margins against the need for continued competitiveness with other polymers (including HDPE, PVC and polystyrene).
- The price in Saudi Arabia and the Middle East is set by the prices in the key export market of South-East Asia, which is also regularly updated by NexantECA. South-East Asian pricing is directly linked to the prices in the single-biggest market, China. The price assessments for Saudi Arabia and the Middle East were therefore based on netback calculations from South-East Asia.

Table 6.11 Polypropylene Pricing Methodology

Country / Region	Basis	Pricing Methodology	Reference Price
Middle East	Spot FOB	Netback	South-East Asia
Western Europe	Spot CIF	NexantECA Reference	N/A
USGC	Spot FOB	NexantECA Reference	N/A
North-East Asia	Spot FOB	NexantECA Reference	N/A

6.4.4 Alujain Netbacks

Netbacks to the Alujain plant gate at Yanbu were calculated for each of the key destination markets of Western Europe, U.S.G.C and North-East Asia. The netback calculations take into consideration all the key costs associated with bringing polypropylene product from the Alujain plant to the destination markets, such as tariffs/customs duties, sea freight costs, and port and handling fees at both Yanbu and the destination port, dependent on the basis of the market price.

Tariffs/Customs Duties

Export regions, including the EU, United Kingdom, the US, and China, impose a 6.5 percent tariff on polypropylene, payable in addition to the market price. The tariff is factored into the netback assessment provided below, excluding China, where the basis for the market price is CFR, in which the tariff burden is on the buyer, rather than the seller. Additionally, there is a supplementary fee of US$4 per ton for transiting through the Suez Canal, applicable to shipments bound for the US and Western Europe.

Freight and Port Costs

The key price component in netback calculations is the freight cost between Yanbu and the destination port. These have been included in the netback calculations as per NexantECA understanding of freight costs between countries/regions.

Port and handling fees in the regions have been based on published port fees and NexantECA's assumption on additional handling fees incurred at each port, dependent on the basis of the market price i.e. for a CFR price, port and handling fees is are only taken into account in the origin country; conversely, for a FD price, port and handling fees are taken into account in both the origin and destination country.

Netback Freight Assumptions

For the netback calculations, the following freight rate assumptions were made. These have been based on the average historical freight rates observed between the relevant countries/regions. Rates to Saudi Arabia have been calculated to the Port of Yanbu.

Table 6.12 Polypropylene Freight Assumptions, 2027
(Constant 2023 US$, Mid (80) Crude Price Scenario)

Region	Port Basis	USD / ton
WE - KSA	Rotterdam - Yanbu	59
USGC - KSA	Houston - Yanbu	95
NEA - KSA	Shanghai - Yanbu	105

Netback Prices Calculations

The tables below show the netback calculation to Alujain for sales of polypropylene into the target markets based on the year 2027 – planned operation start date of the Project.

Table 6.13 Western Europe Polypropylene Alujain Netback Pricing, 2027
(Constant 2023 US$, Mid (80) Crude Price Scenario)

Price Element	Basis	Units	Price
Western Europe	FD Spot	$/ton	1 459
Inland Freight	Rotterddam	$/ton	40
Tariffs & Customs	Rotterdam	$/ton	95
Port Fees & Handling	Rotterdam	$/ton	13
Freight	Rotterdam - Yanbu	$/ton	59
Use of Suez Canal		$/ton	4
Port Fees & Handling	Yanbu	$/ton	20
Saudi Arabia	Plant Gate	$/ton	1 228

Table 6.14 USGC Polypropylene Alujain Netback Pricing, 2027
(Constant 2023 US$, Mid (80) Crude Price Scenario)

Price Element	Basis	Units	Price
USGC	FD Contract	$/ton	1 491
Inland Freight	Houston	$/ton	40
Tariffs & Customs	Houston	$/ton	97
Port Fees & Handling	Houston	$/ton	25
Freight	Houston - Yanbu	$/ton	95
Use of Suez Canal		$/ton	4
Port Fees & Handling	Yanbu	$/ton	20
Saudi Arabia	Plant Gate	$/ton	1 210

Table 6.15 North-East Asia Polypropylene Alujain Netback Pricing, 2027
(Constant 2023 US$, Mid (80) Crude Price Scenario)

Price Element	Basis	Units	Price
North-East Asia	CFR Spot	$/ton	1 179
Tariffs & Customs	Shanghai	$/ton	0
Port Fees & Handling	Shanghai	$/ton	0
Freight	Shanghai - Yanbu	$/ton	105
Port Fees & Handling	Yanbu	$/ton	20
Saudi Arabia	Plant Gate	$/ton	1 053

Figure 6.6 Alujain Polypropylene Netback Pricing, 2012 – 2050

(Constant 2023 US$, Mid (80) Crude Price Scenario)

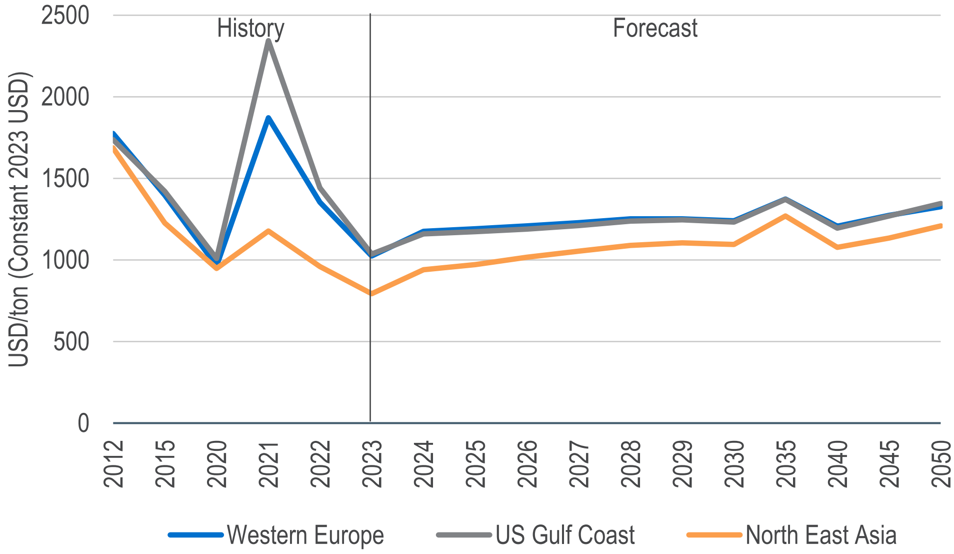


Table 6.16 PP (Homopolymer) Plant Gate Netback Pricing to Target Markets

(Constant 2023 US$ per ton, medium oil scenario)

		History					Estimate	Forecast										
		2012	**2015**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2035**	**2040**	**2045**	**2050**
Western Europe	*Plant Gate*	1 776	1 396	964	1 871	1 353	1 024	1 176	1 192	1 208	1 228	1 251	1 252	1 240	1 372	1 206	1 273	1 326
US Gulf Coast	*Plant Gate*	1 737	1 421	1 008	2 343	1 443	1 035	1 160	1 173	1 189	1 210	1 239	1 246	1 232	1 371	1 195	1 270	1 347
North East Asia	*Plant Gate*	1 687	1 227	948	1 178	959	792	940	972	1 016	1 053	1 089	1 106	1 095	1 268	1 077	1 134	1 209

Section 7

Technology Overview

7.1 INTRODUCTION

The recent developments, background, and process descriptions for the process technologies selected for the Project are discussed in this section. The section also includes commentary on the key differences between the selected technologies and other technologies provided by licensors on the market.

CATOFIN® PDH technology, licensed by Lummus Technology, has been selected for the Project's PDH plant. The scope of this award includes the technology license and basic engineering. With a name plate capacity of 600 000 tons per year, the PDH plant is in the middle of the range of Lummus CATOFIN® technology based plants, with 750 000 tons per year capacity demonstrated in other projects.

SPHERIZONE™ polypropylene technology, licensed by LyondellBasell has been selected for the Project's polypropylene unit. With a nameplate capacity of 500 000 tons per year, this capacity has been demonstrated in other licensed projects before. Alujain has confirmed that the PP (polypropylene) plant is capable of operating at a capacity of 550 000 tons per year. This operational capacity has been incorporated into the Financial Model, allowing for increased PP availability for sales. Adjustments for the required propylene and propane supply have also been taken into account.

7.2 PROPANE DEHYDROGENATION

7.2.1 Introduction

PDH (propane dehydrogenation) systems are on-purpose, stand-alone propylene production facilities and do not require integration with upstream or downstream plants. As such, a PDH project focuses an investment specifically on propylene capacity. A PDH unit provides a high yield of propylene and is usually installed where propylene is needed as opposed to where the feedstock is cost effective. Although they are most economic where there is a low-cost supply of propane (e.g., Middle East and the U.S. Gulf Coast), they are also appropriate where there is a need for propylene or a need to diversify a producer's petrochemical portfolio.

The basic reaction in the propane dehydrogenation process is shown in the following equation:

$$\underset{\text{Propane}}{CH_3CH_2CH_3} \rightarrow \underset{\text{Propylene}}{CH_3CH{=}CH_2} + \underset{\text{Hydrogen}}{H_2}$$

This reaction is highly endothermic and the conversion of propane to propylene is dependent both on low partial pressure and high temperature, resulting in generally large reactor vessels and high energy consumption. Several technologies have been commercialised for propane dehydrogenation and are offered for license, which are discussed in the subsequent sections.

7.2.2 Licensors

Several technologies have been commercialized for propane dehydrogenation, including Honeywell UOP's Oleflex™ process, Lummus Technology's CATOFIN® process, and thyssenkrupp's STAR process®, along with new offerings such as Dow's UNIFINITY™ fluidized catalytic dehydrogenation process and KBR's K-PRO™ process have also emerged in recent years.

There are three basic types of PDH technology available today: fixed bed, moving bed, and fluidized bed. The Lummus Technology CATOFIN® process and Thyssenkrupp STAR process are examples of fixed bed technology. The CATOFIN® process has a heritage that goes all the way back to the Houdry process that was developed in 1936. This catalytic cracking process was developed for the selective conversion of crude petroleum to gasoline and was a semi-batch, fixed bed process. In the 1940s, the process was adapted for the production of butadiene and later of isobutylene. It wasn't until 1992 that CATOFIN® was commercialized in PDH service. The ThyssenKrupp STAR process are based on tubular reactors and steam reformer furnace technology. The STAR process was commercialized in 2010. These technologies are semi-batch in nature and utilize multiple reactors operating on a cyclical basis to achieve continuous production. While one or more reactors are on-line processing propane, one or more other reactors are off-line in catalyst regeneration and when the on-line reactors have reached their conversion capacity, feedgas is switched to the regenerated reactors while the spent reactors are regenerated.

Moving bed technology is offered by UOP's Oleflex process. The process is based on UOP's continuous catalytic regeneration (CCR) technology. The process consists of four radial flow moving bed reactors in series wherein a small amount of catalyst is continuously removed from the bottom of the last reactor, while an equivalent amount of regenerated catalyst is added to the top of the first reactor. The catalyst removed from the reactor system is regenerated in a separate section of the process and regenerated catalyst is directed back to the reactors creating a dynamic moving catalyst bed through the reactors. UOP commercialized its Oleflex PDH process in 1990.

Both Dow and KBR offer PDH processes based on fluidized bed technology. This latest development in PDH technology is based on fluidized catalytic cracking technology developed in the 1940s for gasoline production. Dow's UNIFINITY™ fluidized catalytic dehydrogenation process consists of one reactor and one regenerator. In the UNIFINITY™ process, the incoming feed propane fluidizes fresh or regenerated catalyst in the fluid bed reactor and lifts the catalyst through riser tubes up the reactor. At the top of the reactor, catalyst is disengaged from product gas in a series of cyclones and spent catalyst is directed to a regenerator where the catalyst is reactivated. The regenerator is also a fluid bed design where hot air and combustion gas both regenerate and lift the catalyst upwards where cyclones separate the catalyst from hot flue gas and the catalyst is directed back to the reactor section. This process has not yet been commercialized but is being actively promoted by Dow.

KBR's K-PRO process is based on KBR's 70+ years of technology development in the areas of refinery FCC and catalytic olefins technology where the K-PRO process utilizes the same proven FCC reactor technology. The K-PRO reactor uses KBR's Orthoflow design which is a stacked reactor/regenerator for fluid catalytic applications where incoming feed propane is mixed with hot regenerated catalyst and flow upwards through risers wherein the PDH reaction takes place. Product and catalyst are separated in a series of cyclones and spent catalyst is discharged into the stripper where it is regenerated. The following table summarizes the major PDH technology licensors.

Table 7.1 Propane Dehydrogenation Technology Licensors

Licensor	Process	Catalyst	Reactor Type	Experience
UOP	Oleflex™	Platinum-tin on alumina	Moving bed	▪ Commercialized in 1990 ▪ Leading licensor with over 27 plants in operation ▪ Over 10 million tons per year of capacity ▪ Largest operating plants include two 750 000 ton per year plants
Lummus Technology	CATOFIN®	Chromium oxide + aluminum oxide on alumina	Fixed bed	▪ Commercialized in 1992 ▪ Ten PDH plants in operation with capacity of over 6 million tons per year ▪ Technology also used in over 50 projects worldwide in mixed propylene/isobutylene and butadiene production ▪ Largest plant at 900 000 tons per year capacity started up in 2021
ThyssenKrupp	STAR process®	Platinum + tin on zinc aluminate	Fixed bed, tubular, reformer design	▪ Commercialized in 2010 ▪ One plant in operation with 350 000 tons per year of capacity ▪ Engineered a 545 000 ton per year capacity plant, and two 450 000 ton per year plants but all projects currently on hold ▪ Experience in over 70 reformer unit installations
Dow	UNIFINITY™	Gallium oxide and platinum on alumina	Fluid bed	▪ First plant commissioned at end of 2022 ▪ Licensed a 500 000 ton per year plant in 2019 ▪ Technology research and development reaches back to 2000 ▪ Based on proven FCC technology
KBR	K-PRO	Zinc oxide on titania	Fluid bed	▪ Announced new process offering in late 2018 ▪ Leverages over 70 years of experience in refinery FCC and catalytic olefins technology (K-COT) ▪ Three license awards as of end 2021

7.2.3 Lummus Technology CATOFIN® Process

Lummus Technology is a provider of technology and associated catalysts for technologies used in petrochemical facilities, oil refineries and gas processing plants.

It consists of over 800 staff across five key global offices and offer over 90 proprietary processes for license. In the area of on-purpose propylene production, Lummus offers two technologies: Olefins Conversion Technology (OCT) which is based on metathesis technology, and CATOFIN® propane dehydrogenation (PDH).

7.2.3.1 PDH Plant Experience

Lummus Technology currently has twelve CATOFIN® PDH plants in operation (10 PDH and 2 PDH plus BDH plants that include world's largest dehydrogenation plant) producing more than 6 million tons per year of propylene. CATOFIN® operating plants range in capacity from 250 000 tons per year to 900 000 tons per year of propylene with a maximum offered capacity of one million tons per year.

Lummus Technology's experience in dehydrogenation also includes applications of CATOFIN® technology in more than 50 projects worldwide. Many are commissioned in the production of isobutylene and propylene, as well as several units in butadiene production.

7.2.3.2 Recent Developments

In 2022, there were several developments and/or start-ups related to the CATOFIN® propane dehydrogenation (PDH) plants from Lummus Technology. For example, Lummus Technology and its catalyst partner Clariant announce the start-up of the world's largest operating CATOFIN® PDH plant in Qingdao Jinneng New Material Co., Shandong Province, China, with a capacity of 900 000 tons per annum. The CATOFIN process combines Lummus' technology with Clariant's custom-made catalysts and heat generating material to convert propane to propylene. The process operates at thermodynamically advantaged reactor pressure and temperature to maximize conversion of propane to propylene, while reducing investment and operating costs. Another CATOFIN® PDH plant was commissioned at Shandong Ruize Chemical Technology Co., Ltd.'s complex in Zibo City, Shandong Province, China, with a capacity of 300 000 tons per annum. The plant is part of Shandong Ruize's plan to transition its complex from refining to petrochemicals.

In March 2023, Lummus Technology announced an integrated technology award from SP Chemicals and its subsidiary SP Olefins in Jiangsu Province, China. SP Chemicals will license Lummus' CATOFIN® PDH technology for a new 800 000 ton per annum plant. SP Olefins will license Lummus' Novolen® technology for a new 400 000 ton per annum plant polypropylene (PP) unit. Lummus' scope includes the process design package and technology licenses for the CATOFIN and Novolen technologies, plus technical services, training and catalyst supply. Novolen PP technology has been the most licensed PP technology globally since 2020. It features the Novolen ComPPact™ gas-phase reactors which are the most efficient reactors for the PP industry, resulting in the smallest volume, lowest cost, and enabling simple and efficient product discharge. The technology is highly flexible, robust, energy efficient and allows production of a full grade slate of leading PP products of all product families, including homopolymers, random copolymers, impact copolymers and reactor thermoplastic olefin (RTPO).

7.2.3.3 Catalyst

Clariant is the exclusive supplier of a proprietary CATOFIN® catalyst. From literature and patent research the CATOFIN® catalyst is a chromium oxide/alumina catalyst consisting of activated alumina pellets impregnated with 18 to 20 percent chromium, or a mix of chromium oxide and aluminium oxide on alumina pellets.

A recent improvement to the CATOFIN® process is the addition of HGM to the catalyst mix. This catalyst improvement was developed by Clariant and addresses the endothermic nature of the dehydrogenation reaction. The typical operating temperature of propane dehydrogenation is high (500 to 700 °C) due to the endothermic chemistry involved in the dehydrogenation reaction. The CATOFIN® reaction process operates in the range of 600 °C. Literature suggests that a temperature decrease in the CATOFIN® reactor can be as high as 50 to 100 °C which reduces the conversion of propane to propylene. This reduction in reactor bed temperature is addressed in the process by purging the reactor vessel and regenerating/reheating the catalyst with hot air.

HGM is a heat-generating metal oxide material that generates heat upon exposure to reducing reaction conditions. The metal oxide can be any of a broad range metal oxides, but the CATOFIN® process uses a form of copper or manganese oxide on an alumina carrier. The HGM is comprised of 5 to 15 percent (by weight) of the metal and during the reduction step of the CATOFIN® process when hydrogen is introduced to the regenerated catalyst bed (prior to introducing feed propane), the HGM generates heat as the metal oxide is reduced. This exothermic reaction provides a temperature increase of up to 150 °C in the reactor which aids in increasing propane conversion to propylene. Similarly, during hot-air regeneration of the catalyst bed, the HGM aids in providing heat to the catalyst bed as the metal component of the HGM is oxidized to the metal oxide.

$$\text{Reduction of HGM:} \quad MeO_x + H_2 \rightleftharpoons Me + H_2O \qquad \Delta H < 0$$

$$\text{Oxidation of HGM:} \quad Me + O_2 \rightleftharpoons MeO_x \qquad \Delta H < 0$$

In practice, HGM is typically mixed with CATOFIN® catalyst and this mixed catalyst comprises a section of a multi-layer catalyst bed within each CATOFIN® reactor.

Since 2011, HGM has been used in Lummus Technology's isobutylene production units, and in 2014 it was introduced into PDH service at the Ningbo Haiyue 600 000 ton per year plant in China with notable success. HGM and its benefits are now an integral part of CATOFIN® PDH technology.

The CATOFIN® process achieves propane conversion of approximately 45 percent per pass with propylene selectivity of 87 weight percent or higher based on their latest catalyst and HGM design. The more efficient conversion has led to a reduction in fuel firing for PDH units utilising the CATOFIN® technology, also due to lower heat input required from the hot air system.

7.2.3.4 Process

The Lummus Technology CATOFIN® process is a cyclic catalytic dehydrogenation process that uses an adiabatic, fixed bed, multi-reactor system. The process allows for continuous uninterrupted flow of the major process streams. Propane is converted to propylene while passing through the fixed catalyst bed in CATOFIN® reactors and unconverted propane is recycled to extinction. In one compete cycle, propane is dehydrogenated to propylene, the reactor is then purged with steam and blown with hot air to reheat and reactivate the catalyst. The reaction cycle time is not driven by catalyst deactivation, but more so by the need to provide heat to the reactors in order to maintain high conversion of propane to propylene in the highly endothermic dehydrogenation reaction.

The dehydrogenation catalyst for propane is activated alumina pellets impregnated with chromium and is supplied by Clariant. The catalyst is very robust and easily tolerates trace impurities encountered in LPG feeds that could poison a noble metal catalyst. It can also easily tolerate moderate amounts of C_4's in the feed.

Operating conditions for the process are selected to optimize selectivity, conversion, and energy consumption. The operating temperature is in the range of 600 °C and the operating pressure is under vacuum at about 0.5 bar absolute (approximately 7 psia).

The reactor system usually consists of a single train of three to ten reactors (depending upon capacity). The Project will consist of a single train of five parallel fixed bed reactors and a regeneration air system. The horizontal fixed bed reactors are connected in parallel and operated cyclically to produce continuous flow of all major process streams. At any time in the cycle one or more reactors are on-stream, one or more reactors are on reheat/regeneration, and other reactors are on evacuation, steam purge, air re-pressurization, catalyst reduction, or valve changes. For a given reactor size, a 10-bed system has around three to four times the production capacity of a three-bed system. Lummus Technology's current offering ranges from 300 000 to one million tons per year in capacity, but this can be scaled down as needed by decreasing the reactor size or scaled up by either increasing reactor size or adding more reactors and making appropriate operating cycle time updates.

- One complete cycle for a reactor includes the following key steps: feed or reaction, steam purge, air reheat, evacuation, and reduction.
- **Feed or Reaction.** Fresh propane feed is combined with recycle feed from the bottoms of the product splitter and the net overhead product from the de-oiler, vaporized, and fed into the reactor to produce propylene. Propane feed flows from the top to the bottom of the reactor vessel.
- **Steam Purge.** After a preset amount of time in the reaction step, the reactor is purged with steam while still under vacuum. The steam purge strips residual hydrocarbons from the catalyst and reactor into the recovery system.
- **Air Reheat.** Following the steam purge, the catalyst is reheated to operating temperature with a hot air stream.
- **Evacuation.** After the air reheat is complete, the reactor vessel is evacuated in preparation for the next on-stream period.
- **Reduction.** Prior to the introduction of the propane feed, hydrogen-rich gas is introduced into the reactor to remove any adsorbed oxygen and to reduce the HGM (if used). Both of these actions provide additional heat to the reactors and brings the reactor temperature up to 600 °C.

Each reactor goes through this same cycle in a defined automated sequence. The sequence logistics result in continuous, uninterrupted flow of hydrocarbon and air through the unit. A complete cycle will take 25 minutes. In the case of the Project's single train of five parallel reactors, at any one time there will be:

- Two reactors are onstream.
- Two reactors are on reheat/regeneration
- One reactor is on evacuation, steam purge, air repressuring, catalyst reduction, or valve changes.

A simplified flow schematic for the CATOFIN® process is shown in the following figure.

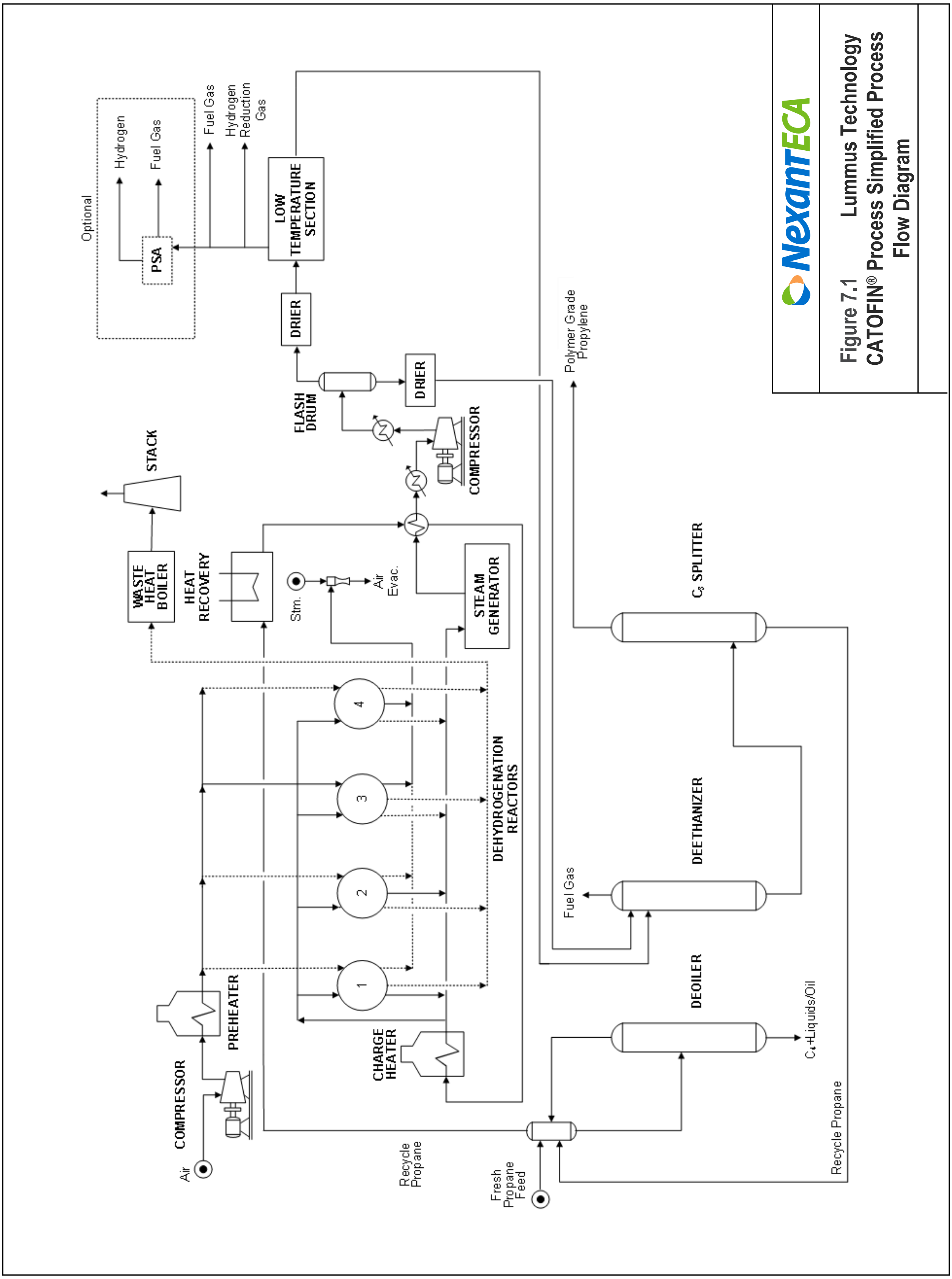


Figure 7.1 Lummus Technology CATOFIN® Process Simplified Process Flow Diagram

Reaction Section

In a typical operation, fresh propane feed is combined with recycle propane from the bottoms of the product splitter in the deoiler. The purpose of the deoiler is to remove butane and heavier materials from the propane feed and the bottoms stream from the deoiler can be burned as fuel in the reactor charge heater or used as fuel in other integrated facilities. If desired, the deoiler bottoms can be further processed to recover a C_4 stream and a C_5+ stream containing a mix of aromatics. The net overhead from the deoiler is the reactor feed. The current PDH unit design utilizes a low-pressure deoiler which eliminated the need for a cooling water condenser and reduces reboiling temperatures and process duty requirements.

A small amount of dimethyl disulfide or other sulfiding agent is then added to the total reactor feed to passivate the feed heater. The feed is then preheated to around 450 °C by heat exchange with feed-effluent heat exchangers and a fired heater. The feed temperature is maintained below the thermal cracking temperature of propane prior to entering the reactors. Feed flows to the on-stream reactors which have been preheated to 600 °C where it contacts the catalyst bed under vacuum conditions of about 0.5 bar absolute. The reactors have a relatively large cross section to minimize pressure drop through the reactors.

Once-through conversion of propane is approximately 45 percent and selectivity to propylene is 87 weight percent or higher. The simultaneous high conversion and high selectivity is achievable because of a combination of the favourable thermodynamics of the vacuum operation and the introduction of HGM to the most recent CATOFIN® design. There is no need for hydrogen recycle or steam dilution to reduce the partial pressure of reactants to achieve high conversion and selectivity. Side reactions that occur in the reactor alongside the main propane dehydrogenation reaction result in the formation of some light and heavy hydrocarbons as well as coke deposition on the catalyst. The coke is burned during the regeneration cycle, providing heat to the catalyst bed.

Since the reaction is endothermic, the temperature of the catalyst bed decreases over the course of the reaction. Preheated air in the regeneration cycle along with the burning of a small amount of coke provides all the heat required to return the reactor to the desired temperature for the reaction phase. In effect, the heat provided during the regeneration step is stored in the catalyst bed to be absorbed during the on-stream period. Because the reactors are fixed bed, there are no attrition losses and no catalyst make-up between turnarounds. For systems designed with HGM, the CATOFIN® PDH process can be optimized based on the additional heat from HGM that is provided during both the hydrogen reduction step and the air regeneration steps of the cycle. In the initial design, the optimization of the amount of heat required by the air reheat step is achieved by adjusting the air to hydrocarbon (feed propane) ratio. Early CATOFIN PDH plant designs were based on an air to hydrocarbon ratio 6.6 to 7.5 on a weight basis. For systems designed with HGM, the air to hydrocarbon ratio is effectively reduced, to 4.5, since the HGM in the reactors provides heat for the endothermic dehydrogenation reaction. This optimized air rate results in lower air compression power requirements, regeneration air heater firing requirements and approximately a 35 percent reduction in heat loss from the waste heat boiler stack.

The hot reactor effluent is cooled by routing through a waste heat steam generator, the feed-effluent exchanger, and a cooler before flowing to the compressor section of the plant.

Compressor Section

The cooled reactor effluent is then compressed to 10 to 16 bara, cooled, and dried before being sent to the low-temperature recovery section, for separation of the light ends. Design of the product compressor is critical in order to keep the compressed gas temperature low to minimize the formation of polymer. Interstage knockout drums are utilized to separate any condensed water. Lummus Technology uses a 3-stage centrifugal compressor. The compressor driver can vary depending on project utility availability. A common design was to utilize a steam turbine which balances heat recovery and steam production and use within the process. The compressor discharge vapor is then cooled and separated in a low temperature recovery flash drum. In efforts to reduce the carbon footprint of the PDH unit, Lummus has pioneered the use of all electric drivers for the major process compressors, allowing power to be sourced from green and high efficiency power generation units. Lummus now has eight plants in operation where compressors are driven by electric motors.

Recovery Section

In the recovery section of the plant, inert gases, hydrogen, and light hydrocarbons from the compressed reactor effluent are removed. Propane, propylene, and heavier components are sent to the product purification section.

The reactor effluent condensate from the low temperature recovery flash drum downstream of the compressor section of the plant is dried and sent to the deethanizer to remove light hydrocarbons such as methane, ethane, ethylene, and inert gases from the stream. The uncondensed reactor effluent from the flash drum is also dried and then sent to the low temperature recovery (LTR) section of the plant where the stream is further cooled to condense and recover any remaining propane and heavier hydrocarbons. The propane and heavier hydrocarbons are also sent to the deethanizer.

The light ends stream from the LTR section is hydrogen rich and can be sent to a hydrogen recovery unit (pressure swing adsorption or PSA) if the project site has an off-taker for high purity hydrogen. CATOFIN does not require high purity hydrogen for process reasons. For the case that a PSA is not included in the process, the hydrogen rich light ends stream is typically split. A small amount of the hydrogen rich gas is sent to the reduction gas surge drum and is consumed by the process in the reduction step of the cycle. The remaining portion of the light ends gas is sent to the fuel header.

The deethanizer separates the ethane and lighter hydrocarbons from the propane, propylene, and heavier streams from the reactor effluent. The uncondensed vapor from the deethanizer overhead is sent to the fuel gas header, while the bottoms liquid is sent to the product purification section of the plant.

Product Purification Section

In the product purification section, the deethanizer bottoms liquid enters a propylene splitter which produces high purity propylene stream that is 99.5 percent (by weight) or higher as an overhead product (polymer grade propylene product). Residual sulfur is removed from the propylene product in a sulfur removal unit to produce the final high purity propylene product.

Current PDH plant design use a medium-pressure splitter tower in a stand-alone heat pump compressor configuration, Compared the previous design of a low-pressure splitter integrated into the propylene refrigeration system, a decrease of seven to ten percent in refrigeration compressor power has been achieved. Lummus has also developed proprietary high-pressure splitter tower design if steam turbines are more economically suitable for the project.

The bottoms from the propylene splitter are recycled to the CATOFIN® reactor section of the plant as recycle propane.

Reheat Air Compressor

The hot air used in the air reheat step of the process cycle is typically provided by a reheat gas turbine or air compressor that is heated in a fired heater prior to passing through the reactors. The hot reheat air, preheated to 420 °C, serves to burn residual coke off of the catalyst and to restore the temperature of the reactor beds in preparation for the next feed step of the cycle. Some additional heat can also be added during the hot reheat air step by injecting fuel gas into the system to be combusted within the catalyst bed. The resulting flue gas from the reactors is subsequently used to generate steam in a waste heat boiler and then to preheat boiler feed water. Steam that is produced in the effluent cooling process is utilized within ISBL of CATOFIN® as a utility (no import or export steam).

Heat Exchange Improvements

Improvements made by Lummus to the heat recovery in the system, compared to early CATOFIN PDH plant designs, to lower specific energy are as follows:

- Tempered water system: The tempered water system collects heat from the low level heat sources in the PDH Unit, such as the product gas compression aftercoolers or the waste heat boiler and transfers it for use to the deoiler tower system, or allows it to be exported as a heat source elsewhere, thereby lowering the energy consumption.
- Recovery of heat from the reactor evacuation ejector: The early CATOFIN PDH plant designs were based on sending the reactor evacuation ejector exhaust continually to the stack resulting in an energy loss. Current PDH plant designs now use HP steam instead of LP steam to improve the efficiency of the ejector operation. Also, there are two options for recovering the heat from the ejector exhaust; the first being to send the exhaust directly to the WHB to allow heat to be recovered efficiently. Lastly, the heat can be recovered in the tempered water loop if very large amounts of low level heat are required within the complex.
- Optimization of refrigeration temperature levels: The refrigeration levels in both the propylene and ethylene refrigeration systems have been optimized to reduce refrigeration power requirements, thus lowering energy consumption.

Automatic Process Control

As previously mentioned, the reactor system consists of a single train of parallel reactors operating in a cyclic manner so that at any one time some reactors are on-stream, some reactors are on reheat/regeneration, and some reactors are on evacuation, steam purge, air repressurization, catalyst reduction, or valve changes.

The process streams to the individual reactors are controlled by hydraulically-operated valves. The operation of these valves is actuated by centralized cycle timing instrumentation. Mixing of air and hydrocarbon streams is prevented by electrically interlocking the valve operators on both valve positions and on a check of reactor pressures. The hydraulically-operated valves are of a special design, permitting the cyclic operation in a highly reliable manner.

7.2.4 Comparison of PDH Technologies

The process characteristics of the five licensed propane dehydrogenation technologies are summarized in the table below.

Table 7.2 Propane Dehydrogenation Process Characteristics

Licensor	**Lummus Technology**	**UOP**	**ThyssenKrupp**	**Dow**	**KBR**
Process	CATOFIN®	Oleflex™	STAR process®	FCDh	K-PRO
Commercial	Yes	Yes	Yes	Yes (licensed)	Yes (licensed)
Catalyst	Chromium oxide + aluminium oxide on alumina	Platinum-tin on alumina	Platinum + zinc and calcium aluminate	Gallium oxide and platinum on alumina	Zinc oxide + modifiers on titania support
Pressure	~0.5 bara	1.05 bara at last reactor	2-6 bara	1.3-1.7 bara	1.5 bara
Temperature	600 °C	600-650 °C	550-590 °C	600-650 °C	550-650 °C
Partial Pressure Control	Vacuum (no hydrogen or steam dilution)	N/A	Steam	N/A	N/A
Coke Control	None	Hydrogen recycle	Steam injection	Short residence time	Short residence time
Reactor Type	Fixed-bed	Moving-bed	Fixed-bed	Fluid-bed	Fluid-bed
Reaction Catalyst Residence Time	7-15 minutes	5-8 days	11 hours reaction 1 hour regeneration	< 2 minutes	minutes
Catalyst Life	4 years	4 years	5 years	2-3 years turnover rate	N/A
Heat Method	Furnace preheat of process stream, cyclic, coke burn-off	Furnace reheat of the process stream and coke burn-off	Heat recovery, top-fired reformer, steam injection, coke burnoff	Heat recovery, coke burnoff, supplemental fuel in regenerator	Heat recovery, coke burnoff, supplemental fuel in regenerator
Regeneration Method	Cyclic (in-situ)	Continuous Catalyst Regeneration (CCR)	Cyclic (in-situ)	Fluid bed	Fluid bed
Conversion, %	45	30-40	29-31.5	43-48	45
Selectivity, wt%	87+	85.5-88	87.6-92.	88-92	87-90
Fresh Propane (95 wt%) per ton of Propylene	1.2021 tons	1.1725 tons	1.1833 tons	1.1782 tons	1.2199
Fresh Propane Requirement for 600 000 tons per year of Propylene	721 263 tons per year	710 905 tons per year	710 000 tons per year	706 941 tons per year	731 920 tons per year

7.3 POLYPROPYLENE

7.3.1 Introduction

A commercially viable route to polypropylene was discovered by Giulio Natta in 1954, using catalysts that had recently been invented by Karl Ziegler for manufacturing polyethylene. The first commercial production of polypropylene began in 1957. Polypropylene is produced from the polymerisation of propylene, with certain grades also consisting of a comonomer, typically ethylene. Polypropylene (PP) is one of a number of polyolefins that are commodity plastics, which are used globally in a wide range of market segments including packaging, consumer products, automotive, and building and construction.

Polypropylene is a linear polymer that is very versatile and can be used for injection moulding, fibre, film, and other extrusion processes. Polypropylene product can be broadly grouped into three categories, as shown below; applications for each category are discussed in Section 4:

- **Homopolymer:** propylene monomer is polymerised without comonomers. Homopolymer is the most commonly produced and is a general-purpose grade used in a range of applications.
- **Impact resistant block copolymer:** ethylene co-monomer constituting around 5-15 percent of total polymer mass is arranged in blocks within the polymer chain, improving the impact resistance compared to polypropylene homopolymer.
- **Random copolymer:** ethylene comonomer constituting around 1-7 percent of total polymer mass is randomly arranged within the polymer chain, giving a more malleable, clearer product.

Approximately 198 million tons of polyolefins were produced and consumed globally in 2022, making them by far the largest plastic type. Polypropylene accounted for around 83 million tons, or 42 percent of the total, with the three types of polyethylene accounting for the remainder. Polypropylene is the largest type of polyolefin. The market for polyolefins in the United States and Western Europe is large, but mature, while consumption in Asia Pacific (especially China) has grown rapidly and is providing the engine for global consumption growth.

7.3.2 Licensors

The processes can be grouped into three main categories: gas phase, bulk, and slurry/improved slurry. This generally refers to the first reactor system, as all state-of-the-art processes employ either a gas phase or bulk reactor system to produce homopolymer and random copolymer, followed by a gas phase reactor system for the sequential production of impact copolymer. Several of these processes are capable of producing metallocene-based resins.

Gas phase technologies include:

- INEOS' INNOVENE PP process, which is no longer available for licensing.
- Japan Polypropylene's HORIZONE process, which is available for licensing.
- Lummus Novolen Technology's NOVOLEN process, which is available for licensing.
- LyondellBasell's SPHERIZONE process, which is available for licensing.
- Sumitomo's polypropylene process, which is available for licensing.
- W. R. Grace's UNIPOL PP process, which is available for licensing.

Bulk technologies include:

- Borealis' BORSTAR PP process, which is available for venture-based licensing.
- ExxonMobil's polypropylene process, which is no longer available for licensing.
- LyondellBasell's SPHERIPOL process, which is available for licensing.
- Mitsui's HYPOL II process, which is available for licensing.

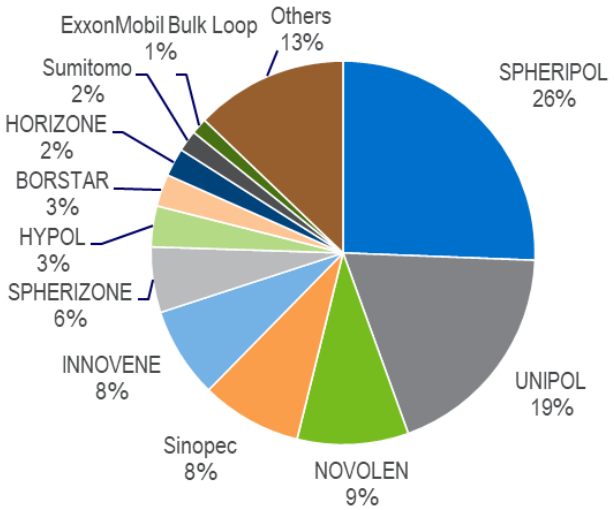
The technology licensing market has changed over the years. With industry consolidation, the number of participants has been reduced and the major players are more likely to have access to in-house technology, thus reducing the number of third-party licenses. Also, merged companies may decide not to license one of their technologies in favour of another technology. In addition, some technologies are no longer made available for third-party licensing and are only used by the technology holder and joint venture partners. Other companies have decided to only selectively license, and most recently, INEOS decided to stop actively pursuing third-party licensing. Another factor affecting licensing is that as plant scale grows and/or demand growth slows, the number of individual licenses required is reduced. The major licensors that produce polypropylene are presented in the figure below.

Figure 7.2 Polypropylene Licensors

Process Type (Homopolymer Reactor)		
Gas Phase	**Bulk**	**Slurry**
Grace UNIPOL	Borealis BORSTAR	Amoco/Chisso
INEOS INNOVENE PP	ExxonMobil	Hercules
JPP HORIZONE	LyondellBasell SPHERIPOL	Mitsubishi
Lummus Novolen Technology NOVOLEN	Mitsui HYPOL II	Montedison
LyondellBasell SPHERIZONE	Sinopec ST-PP	Sumitomo
Sumitomo	HFEC SPG/ZHG	Others

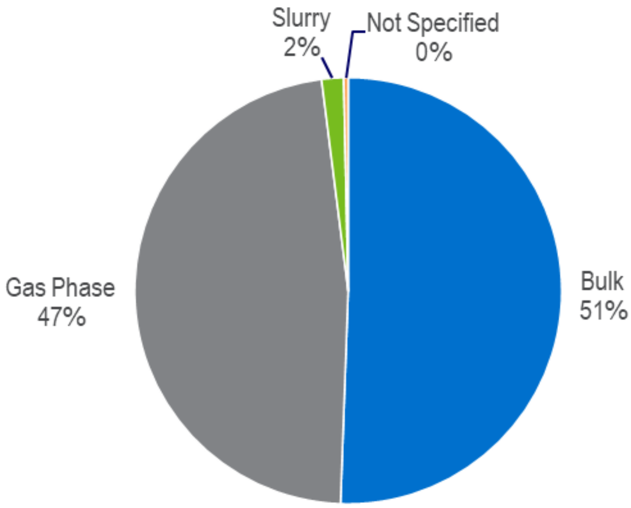
The installed capacity by process technology is illustrated in below. The top three technologies (SPHERIPOL, UNIPOL, and NOVOLEN) accounted for about 54 percent of the market in 2022. With the addition of three more technologies (Sinopec, INNOVENE, and SPHERIZONE), about 76 percent of global capacity is accounted for, while three additional technologies (HYPOL, BORSTAR, and HORIZONE) bring the total to about 84 percent of global capacity. The Others category includes bulk processes developed by Shell, Sumitomo, Appryl, Chevron Phillips, Lotte, Total, and local Chinese companies (including HFEC), Idemitsu's gas phase process, and slurry processes developed by Amoco/Chisso, Sumitomo, and local Chinese companies.

Figure 7.3 Installed Polypropylene Capacity by Technology, 2023



The bulk and gas phase processes lead the production of PP. In 2023, global polypropylene capacity was 108 million tons per year, with bulk and gas phase processes each accounting for more than 45 percent of the total. The once dominant slurry process accounted for only two percent of capacity. (Note that the process listed refers to the first reactor(s) for each technology, as the copolymer reactor is always a gas phase reactor.)

Figure 7.4 Installed Polypropylene Capacity by Process Type, 2023



including licensor announcements that may not be considered firm, an additional 30 million tons per year of polypropylene capacity could be brought onstream by 2027, an increase of 31 percent over the capacity in 2022. While most of the top licensors will add significant capacity, NOVOLEN and UNIPOL are expected to experience the largest share increases, while UNIPOL, SPHERIPOL, NOVOLEN, and SPHERIZONE will add the most tons per year. Bulk processes are expected to lose share, while gas phase processes will increase their share, to 51 percent of installed capacity. There are multiple planned plants that have not made an official announcement of the technology that will be employed.

Many of the major global producers are also technology holders, and due to the numerous acquisitions and joint ventures over the years, many use different technologies, as listed in the following table.

Table 7.3 Polypropylene Technology Holders and Major Marketers

Technology Holders and Major Marketers	Technology Owned and Used	Comments (based on 2022)
Borealis	Owned: BORSTAR PP Used: BORSTAR PP, SPHERIPOL, Slurry	Technology available for selective licensing; #9 global marketer (including share of Borouge jv)
Braskem	Owned: None Used: SPHERIPOL, UNIPOL PP, Shell Bulk, Slurry	#3 global marketer
ExxonMobil	Owned: ExxonMobil PP Used: ExxonMobil PP, NOVOLEN, SPHERIPOL, UNIPOL PP, Sumitomo Bulk	Technology no longer licensed; #10 global marketer
Grace	Owned: UNIPOL PP Used: None	Technology actively licensed
INEOS	Owned: INNOVENE PP Used: INNOVENE PP, UNIPOL PP, BP Amoco Bulk, Sumitomo Slurry	Technology no longer licensed; marketer (not top 10)
Japan Polypropylene	Owned: HORIZONE Used: HORIZONE, UNIPOL PP, Amoco/Chisso Slurry, Mitsubishi Bulk	Technology actively licensed; marketer (not top 10)
Lummus Novolen Technology	Owned: NOVOLEN Used: None	Technology actively licensed
LyondellBasell	Owned: SPHERIPOL, SPHERIZONE Used: SPHERIPOL, SPHERIZONE, NOVOLEN, Shell Bulk	Technology actively licensed; #2 global marketer
Mitsui	Owned: HYPOL Used: HYPOL, NOVOLEN, Sumitomo Slurry, Bulk	Technology actively licensed; marketer through Prime Polymer (not top 10)
PetroChina	Owned: None Used: INNOVENE PP, NOVOLEN, Sinopec, SPHERIPOL, SPHERIZONE, UNIPOL PP, Chinese Bulk	#4 global marketer
Reliance	Owned: None Used: SPHERIPOL, UNIPOL PP, slurry	#8 global marketer
SABIC	Owned: None Used: HORIZONE, INNOVENE PP, SPHERIPOL, SPHERIZONE, UNIPOL PP	#5 global marketer
Shenhua Group	Owned: None Used: INNOVENE PP, NOVOLEN, UNIPOL PP	#6 global marketer
Sinopec	Owned: Sinopec Used: Sinopec, HORIZONE, HYPOL, INNOVENE PP, SPHERIPOL, SPHERIZONE, UNIPOL PP, Chinese Bulk, Slurry	Technology licensing status unknown; #1 global marketer
Sumitomo	Owned: Sumitomo PP Used: Sumitomo PP, Sumitomo Bulk	Technology actively licensed; marketer (not top 10)
TotalEnergies	Owned: None Used: HYPOL, SPHERIPOL, SPHERIZONE, Fina Bulk	#7 global marketer

7.3.3 LyondellBasell SPHERIZONE™ Technology

7.3.3.1 Background

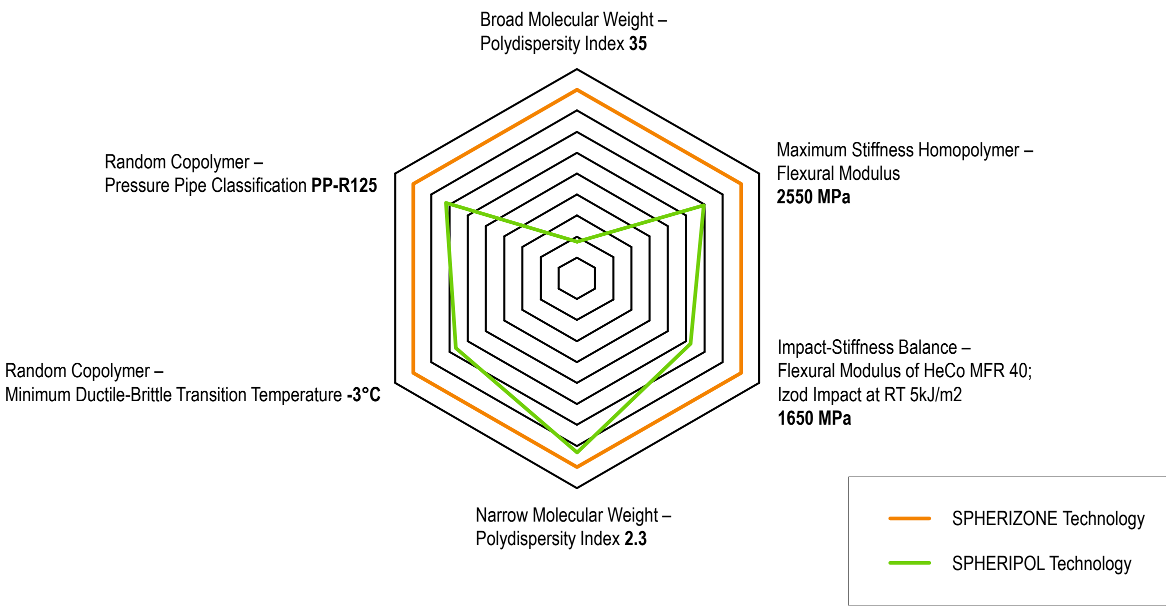
SPHERIZONE™ polypropylene technology is licensed by LyondellBasell (LYB). LyondellBasell and its predecessor companies have been developing new chemical technologies for almost 70 years.

The Basell joint venture (formed October 2000) included the polyolefins assets of Shell and BASF, (i.e., Montell, Targor, and Elenac). Basell merged with Lyondell in December 2007 to form LyondellBasell Industries.

The SPHERIZONE™ process was commercialized by LyondellBasell in 2002 and has been offered for license since 2003. Its introduction was a major fundamental process technology development for polypropylene. SPHERIZONE™ is a mainly gas phase, non-metallocene polypropylene process that features a Multi-Zone Circulating Reactor (MZCR), which can produce a homogenous two-phase polypropylene in one reactor. The principle behind the MZCR is a reactor that offers two reaction zones with different process conditions, specifically temperature, hydrogen, and comonomer concentrations. Growing polymer circulates repeatedly between the two zones, giving the prospect of enhanced homogeneity between the polymer phases. This technology is said to produce more uniform polymers with broader molecular weight distribution and advanced performance capabilities. A single reactor can be used to produce homopolymers (narrow to very broad MWD) and random copolymers with a better property balance than conventional polypropylenes, as well as new families of multiple phase propylene polymers, including twin random copolymers or homo/random grades. According to LyondellBasell, the extension of the polymer properties compared with those achieved with conventional technology is significant, as illustrated in the following figure.

Figure 7.5 SPHERIZONE™ and SPHERIPOL™ Property Envelope

(Source: LyondellBasell)



The commercialization of SPHERIZONE™ involved the retrofitting of an existing 160 000 ton (353 million pound) per year SPHERIPOL™ line at LyondellBasell's Brindisi, Italy facility. The technology was first licensed to joint venture Indelpro in Mexico for its 350 000 ton (772 million pound) per year plant, which started up in 2008. It is also used by a joint venture, Al Waha Petrochemical, formed between LyondellBasell and Sahara Petrochemical in Saudi Arabia. The joint venture built a 450 000 ton (992 million pound) per year SPHERIZONE™ plant that started up in 2009.

Samsung Total and Lotte Daesan in South Korea both licensed 250 000 ton (551 million pound) per year plants. Samsung Total's plant started up in 2007, while Lotte Daesan's started up in 2008. Plants that use or have licensed SPHERIZONE™ technology are listed in the following table.

Table 7.4 SPHERIZONE™ Polypropylene Plants
(Thousand tons per year)

Location/Company[1]	Design Capacity[1]	Start-up Date[1] *(per licensor)*	ICP Capable
ASIA AND PACIFIC			
China			
Sinopec Tianjin Petrochemical, Dagang	450	2010	Y
PetroChina Daqing Refining, Daqing	300	2012	N
CSPC, Huizhou	400	2018	Y
	500	Not specified	Not specified
Sinopec Zhongke, Zhanjiang	200	2020	Y
Shaanxi Yanchang Coal Yulin Energy & Chemical, Yulin	400	2020	Y
Liaoning Bora Petrochemical, Panjin	200	2020	Y
Zhejiang Petroleum & Chemical, Zhoushan	900 (2 lines)	2022	Y
PetroChina Liaoyang Petrochemical & CPMC, Liaoyang	300	2021	Y
Sinopec Zhenhai Refining & Chemical, Ningbo	300	2022	Y
Shandong Chambroad Sinopoly New Materials, Binzhou City	200	Expected 2023	Y
Kaijin Blue Sky Energy (Zhejiang), Wenzhou, Zhejiang	300	TBD	Y
Ningxia Baofeng Energy Group, Yingchuan, Ningxia	500	Expected 2023	Y
Jinneng Chemical (Qingdao), Qingdao, Shandong	450	Expected 2024	Y
Malaysia			
Petronas, Johor	450	2019	Y
South Korea			
Hanwha Total (Samsung Total), Daesan	250	2007	Y
Lotte Chemical (Honam), Daesan	250	2008	Y
Thailand			
HMC Polymers, Map Ta Phut	300	2010	Y
	250	Expected 2023	Y
MIDDLE EAST			
Saudi Arabia			
Al Waha Petrochemical, Al Jubail	450	2009	Y
Advanced Global Investment Company, Al Jubail	400	Expected 2025	Y
NORTH AMERICA			
Mexico			
Indelpro, Altamira	350	2008	N
United States			
Undisclosed	450	TBD	Y
WESTERN EUROPE			
Italy			
LyondellBasell, Brindisi	160/200	2002	Y
Undisclosed			
Undisclosed	300	TBD	Y
Portugal			
Repsol, Sines	300	TBD	Y
UNDISCLOSED			
Undisclosed	200/250	2007	N

[1] Name and capacity of licensee and start-up date may have changed since license taken

7.3.3.2 Recent Developments

The major recent process technology development for polypropylene was the introduction by LyondellBasell of SPHERIZONE™, a mainly gas phase, non-metallocene polypropylene process featuring a Multi-Zone Circulating Reactor (MZCR), featuring a homogenous two-phase polypropylene cascade reaction in one polymerization reactor. The process was commercialized in 2002 and has been offered for license since 2003.

SPHERIZONE™ polypropylene plants that have come on-stream since 2017, are under construction, or recently licensed include:

- Sinopec Zhenhai Refining & Chemical in China, license for 300 000 tons (661 million pounds) per year, started up in February 2022.
- Zhejiang Petroleum & Chemical in China, license for two 450 000 ton (992 million pound) per year lines, started up in January 2022.
- PetroChina Liaoyang Petrochemical and China Petroleum Materials Limited (CPMC) in China, license for 300 000 tons (661 million pounds) per year, started up in August 2021.
- Shaanxi Yanchang Coal Yulin Energy & Chemical in China, 400 000 tons (882 million pounds) per year started up in November 2020.
- Liaoning Bora Petrochemical in China, 200 000 tons (441 million pounds) per year started up in September 2020.
- Sinopec Zhongke in China, 200 000 tons (441 million pounds) per year started up in September 2020.
- Petronas in Malaysia, 450 000 tons (992 million pounds) per year started up in late 2019.
- CSPC in China, 400 000 tons (882 million pounds) per year started up in May 2018.
- HMC Polymers in Thailand, license for 250 000 tons (551 million pounds) per year, expected to have come online in 2023.
- Shandong Chambroad Sinopoly New Materials in China, license for 200 000 tons (441 million pounds) per year, expected to have come online in 2023.
- Advanced Global Investment Company (AGIC) in Saudi Arabia, license for 400 000 tons (882 million pounds) per year, expected in 2025.
- Kaijin Blue Sky Energy (Zheijiang) in China, license for 300 000 tons (661 million pounds) per year, with no start-up date announced.
- Ningxia Baofeng Energy Group in China, license for 500 000 tons (1.10 billion pounds) per year, expected to have come online in 2023.
- Jinneng Chemical (Qingdao) in China, license for 450 000 tons (992 million pounds) per year, expected in 2024.
- Repsol in Portugal, license for 300 000 tons (661 million pounds) per year, with no start-up date announced.
- CSPC in China, license for 500 000 tons (1.10 billion pounds) per year, with no start-up date announced.
- Two confidential licenses, one in the United States for 450 000 tons (992 million pounds) per year and one in Western Europe for 300 000 tons (661 million pounds) per year, with start-up dates to be determined.

Key developments reported by LyondellBasell for SPHERIZONE™ technology include:

- New polymer structures optimized for high processing speed at downstream convertors where requirements for improved properties, purity, and consistency are more stringent.
- Optimization of barrier generation facilities tailored to a stepwise increase in the proportion of specialty families in the licensees' product portfolio, based on licensee needs. This gives the advantage of reduced initial capital investment, scalable to full capability over time.
- New developments in the growing market of butene-1 low SIT (seal initiation temperature) and high clarity grades with SIT lower than 110 °C (230 °F) and differentiated polymer structure, giving lower operating costs and shorter transitions.
- Non-phthalate general-purpose catalyst for all product families under final commercial development.
- Development of new medical grades and soft pipes is ongoing in the areas of random and heterophasic copolymers (hecos).
- Development of ex-reactor high stiffness heterophasic copolymers with higher MFR, giving higher purity products at reduced operating costs.
- Soft hecos development with differentiated structures and enhanced gas phase reactor productivity for a wide family of specialty hecos and TPO (bi-polymer content greater than 30 percent) in a single gas phase reactor without substantial throughput penalty.
- The largest single line plants currently in operation have a nameplate capacity of 450 000 tons (992 million pounds) per year. The largest single-reactor design offered for license for homopolymer/random copolymer is 500 000 tons (1.10 billion pounds) per year. The largest two reactor system for impact copolymer production is also 500 000 tons (1.10 billion pounds) per year in a single train.

7.3.3.3 Process Description

LyondellBasell developed the MZCR design by applying recirculation principles of catalytic cracker technology to their experience in single-zone polymerization reactors. A sketch of the process is presented in the figure below. In the design, as the polymer particles form, they continuously circulate between two interconnected zones, each with a distinct polymerization environment and fluid dynamic regime.

Through the effect of the barrier fluid, the two zones can have different gas compositions, producing different materials. Along with other factors, the number of passes the particles make between the two zones determines the homogenization of the final polymer. The particles typically pass through the zones more than 40 times. The uniformity and homogenization of the polymers produced give them higher melt strength, better impact performance, improved creep characteristics, and improved processing when compared with existing materials. LyondellBasell has suggested that in the future, more than one barrier fluid layer could be used in order to further improve the process. Due to the flexibility of the MZCR and its associated polymerization conditions, a single general-purpose phthalate catalyst can be used to produce a full range of specialty products. A non-phthalate version of this general-purpose catalyst is being developed and is expected to become commercial shortly.

According to LyondellBasell, when compared with SPHERIPOL™, the SPHERIZONE™ process has the following characteristics:

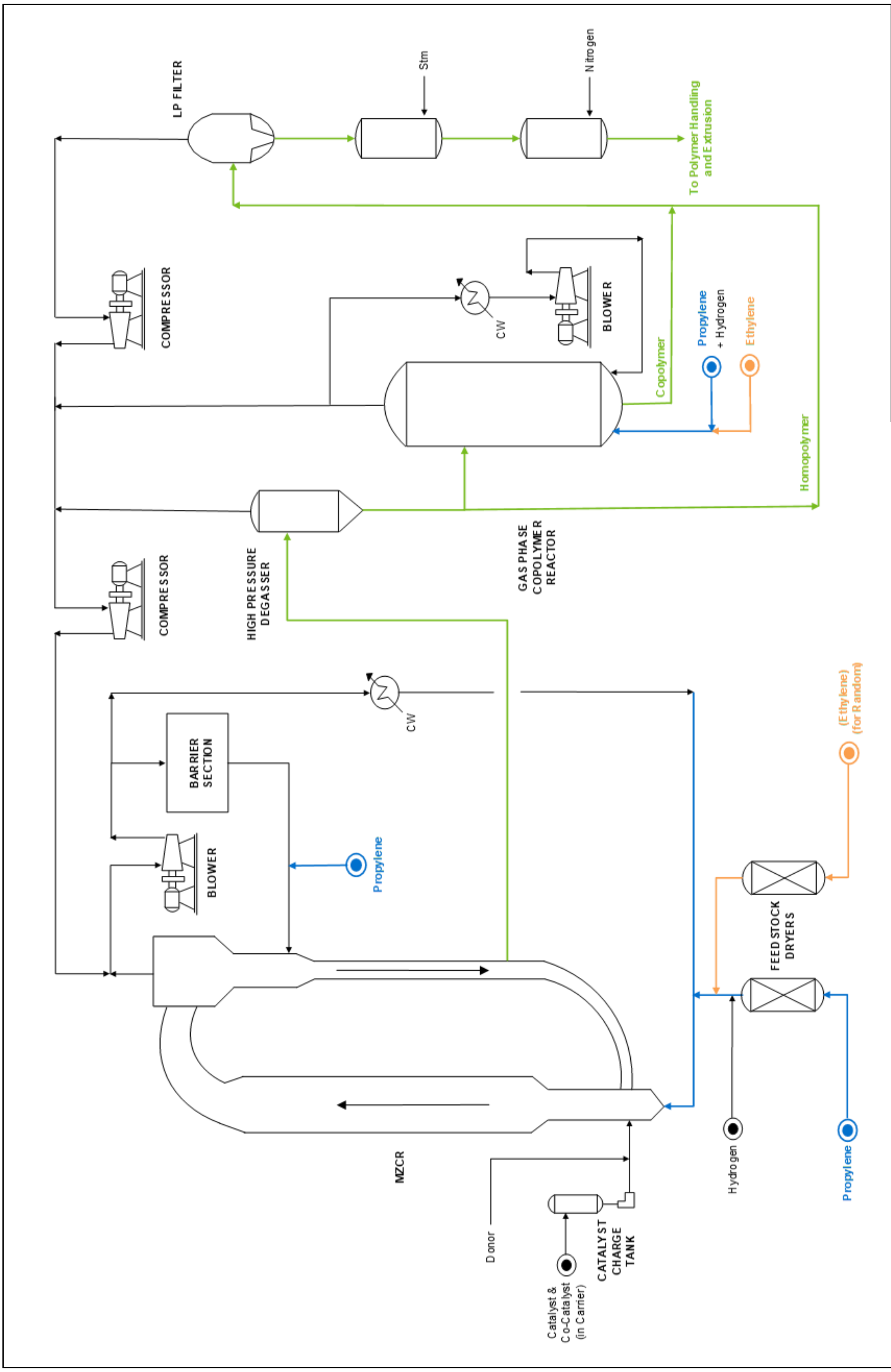
- Capability to produce a broad range of unique polypropylene product families
- Extended operating temperature and gas composition capability
- Approximately 60 percent reduction of propylene hold-up in the polymerization section, giving advantages for very complex transitions.

Slightly higher capital costs enabling the production of a highly differentiated product portfolio with essentially the same operating costs, depending on the actual product portfolio produced.

In the riser, solid particles move upward through a gas stream in a transport mode. In this zone, higher hydrogen and/or comonomer concentration can be maintained. An internal barrier fluid is used to separate the particles from the transport gas, enabling them to cross into the down-comer zone, where they move downward in a packed bed mode. In the downer, an independent reaction environment can be achieved, as hydrogen and/or comonomer concentration can be controlled in a different range.

The two reactor zones in one circulating system should give a cost advantage over existing polypropylene processes that utilize two or more separate reactors. LyondellBasell claims that energy consumption is significantly lower than for conventional processes. According to LyondellBasell, the process produces resins with improved processability, better mechanical performance, and other superior technical characteristics, which should improve the products for traditional market applications such as BOPP film, packaging, fibers, consumer goods, and automotive. It is also believed that the new products will be suitable for new applications, replacing other materials. As with the SPHERIPOL™ process, a gas phase, fluid-bed reactor is added for impact copolymer production, which in the case of SPHERIZONE™, adds the capability of propylene ethylene rubber phase incorporation into the new homopolymer/random copolymer or twin random copolymer matrix structure coming from the MZCR polymerization step. The end products will consist of high-grade polymers for domestic and industrial usage, such as:

- Homopolymers using only propylene
- Random copolymers using propylene and ethylene
- Random copolymers using propylene and butene-1
- Random terpolymers using propylene, ethylene, and butene-1
- Heterophasic impact copolymers consisting of a propylene homopolymer, or random copolymer as defined above and of one or more copolymers of propylene with ethylene.



NexantECA

Figure 7.6 SPHERIZONE™ Gas Phase Polypropylene Process

According to LyondellBasell, an increasing range of new propylene polymer families for various applications are currently available from commercial SPHERIZONE™ plants. These new grades, reported to display excellent properties, are being developed for both specialized and large volume applications and give the potential to explore new applications for polypropylene, such as:

New grades designed for non-woven soft textile applications in high spinning speed machines, which exploit the capability of SPHERIZONE™ technology to control comonomer distribution, combining a low crystallinity component, which contributes to softness, with a high crystallinity component, which gives tenacity.

Clear blown film grades for mono or multi-layer (side layer) structures, displaying an excellent combination of optical properties, high stiffness, low gel and odour levels, plus good sealing performance for food packaging. Potential applications include retortable food pouches, hygienic packaging, and large pet food bags.

High clarity and high stiffness random copolymers with low temperature impact for the thermoforming sheet and blow moulding markets. Main applications are impact-demanding packaging stored at freezer conditions, such as chilled packaging of poultry, meat, ready meals, and fish.

Broad range of low and very low sealing initiation temperature grades for both BOPP and cast film sealing layer.

Pipe grades with outstanding stiffness (flexural modulus above 1 900 MPa) and good impact performance. The high rigidity of the material, combined with excellent processability, allows a significant reduction of wall thickness, while keeping resistance to deformation under pressure.

New polymer structures targeting the improvement of flexible pipe grades for under floor heating.

High stiffness grades specifically designed for high-barrier sheet applications, such as crystal-clear cups and trays for packaging fruit and vegetables, with good dimensional stability in thinner gauges after hot-filling, for microwave reheating and substitution of traditional glass and metal small packs.

New homopolymer/random copolymer structures specifically designed for very high speed production of BOPP films, providing easy film stretchability, improved thickness profile, very good compatibility with the skin layer resin, and excellent optics.

High throughput and very high impact-stiffness balance copolymers for the automotive industry, which can be used pure or further compounded, with significant weight reduction in automotive applications.

Catalyst and co-catalyst preparation

LyondellBasell produces the catalyst as well. The cocatalyst solution is delivered to the catalyst activation in pre-contacting pot and in pre-polymerization reactor by means of metering pumps. Grease and oil both are discharged into a heated tank, mixed, dried of moisture and then transferred into catalyst dispersion drums. The catalyst powder is discharged directly into catalyst dispersion drums. The suspension is agitated into a stable mud at a constant temperature, maintained by continuous cooling in the jacket. The catalyst mud is transferred to the catalyst activation in the pre-contacting pot via loading syringes and metering package, and the catalyst is mixed with the two co-catalysts in pre-contacting pot.

Polymerisation and distillation

In combination with LyondellBasell's catalysts, the SPHERIZONE® process produces spherical polymer particles directly in the reactor.

The catalyst mixture leaving the pre-contacting pot is injected into a stream of propylene cooled down to about 10°C. The reaction takes place for 15-20 minutes in a small loop reactor, full of liquid monomer. The purpose of pre-polymerization is to encapsulate the catalyst particle with a shell of polymer. The reactor is operated at about 30°C, at the same pressure as the Multizone Reactor (MZCR) downstream, plus the head losses of the connecting line. The temperature is controlled by circulating chilled water through the reactor jacket. From the top of pre-polymerization reactor, the prepolymer flows directly into the bottom of the riser of Multizone Reactor (MZCR).

In the MZCR, the polymer is transported upward by the reaction gas in the riser, a fast-fluidized bed, running at the temperature between 72 and 85°C. Then the solids move downward as a packed bed in the downcomer after separation from the riser gas in an internal cyclone. The product is discharged from a valve installed at the lower end of the downcomer. The reaction gas is recycled through an external line by a centrifugal compressor; the heat of reaction is removed by a vertical shell and tube exchanger installed in the gas line. The reactor can be operated with a homogeneous gas composition ('monomodal') or with two separate gas mixtures in the two zones ('bimodal'): the latter condition is obtained by feeding a barrier stream of propylene into the upper part of the downcomer, thereby differentiating the gas compositions of the two legs. The polymer layer above the barrier feed forms a seal between the two reaction environments, enabling the barrier stream to separate the gas mixture coming from the riser via cyclone in a stripping section of the solid bed. Only the barrier gas flows down, dragged by the polymer particles.

This concept is used for bimodal homopolymers (different H_2 concentrations) or random copolymers (different ethylene concentrations).

In the case of bimodal homopolymer, a high hydrogen concentration in the riser produces a high Melt Flow Rate (MFR) polymer, while a low hydrogen concentration into the downcomer produces a low MFR polymer. The hydrogen concentration is differentiated by feeding a hydrogen-depleted propylene stream (the barrier) from the bottom of ethylene stripper to the top of the downcomer to replace the hydrogen-rich gas coming from the riser.

Homopolymer and random copolymer requires different hydrogen and ethylene concentrations in the riser and in the downcomer. High hydrogen and ethylene concentrations in the riser produce high MFR random copolymer, while low hydrogen concentration and no ethylene in the downcomer produce low MFR homopolymer. Hydrogen and ethylene concentrations are differentiated by feeding a hydrogen- and ethylene- free propylene barrier stream to the top of the downcomer. This liquid barrier is generated in the distillation towers; the light ends from the tops of the towers are recycled to the fluidization circuit.

The quality of the barrier stream is an important parameter. For monomodal products, the same composition is required in the two legs; therefore, the barrier is flushed with the same riser gas, filtered in high-pressure bag filters. Conversely, in bimodal campaigns a good “barrier effect” is required by keeping the concentration of hydrogen (or ethylene) in the stream to a minimum; the barrier liquid obtained by condensation is treated in a stripping section to match this requirement.

During monomodal production, the hydrogen concentration in the whole reactor is roughly the same, and therefore so is the reaction velocity. On the other hand, during bimodal production, different H2 concentrations in the two legs give different reaction rates. In the downcomer, a substantial decrease in reaction rate occurs because of the high molecular weight of the component being produced, whereas in the riser reactivity may decrease slightly because of the lower partial pressure of the monomer.

The heat of reaction is removed by circulating jacket water in reactor cooler. The entire cooling system is connected to a nitrogen-blanketed expansion drum located above the highest point of the reactor cooler, which ensures the complete filling of the circuit and provides an expansion volume as the jacket water increases in temperature.

Polymer degassing and monomer recovery

The polymer discharged from MZCR contains a large quantity of hydrocarbons; to recover them, the polymer is conveyed to a medium pressure degasser. The medium pressure degasser is a bag filter, automatically cleaned by reverse-jet action with a gas stream coming from the discharge of recycle compressors after an adequate pressure reduction. The separator bags are made of aramidic fibres. Polymer from medium pressure separator bottom is continuously discharged under level control either to low pressure degasser (for homo- or random polymers) or to gas phase copolymerization reactor (for heterophasic copolymers).

When producing homopolymers or random copolymers, the polymer collected in medium pressure separator is conveyed directly to the second degassing stage low pressure filter, which is maintained at about 0.6 barg in order to separate the remaining un-reacted monomer(s) from the polymer. The recovered monomer is compressed by low pressure recovery compressor and conveyed to the suction of medium pressure separator recovery compressor for recycling to the reaction area.

Polymer grade propylene undergoes purification and then flows to the propylene feed tank which is a small buffer tank providing a minimum supply of propylene in case of feed interruption, which will allow plant operators to bring the plant to a safe shutdown. The propylene feed pumps are high pressure centrifugal pumps that boost the propylene pressure to the level required to enter the reactors.

Gas-phase copolymerisation

To produce heterophasic copolymers, the polymer discharged from medium pressure separator is fed to the fluid bed Gas Phase Reactor (GPR). Ethylene and propylene (plus hydrogen for molecular weight control) are fed at controlled flow rates and in suitable ratios to meet the required product properties. Fluidization in the GPR is maintained by recycling the gas in the reactor through centrifugal compressor. Cooling of the recycle stream via GPR cooler ensures the removal of reaction heat. The polymer is discharged continuously to the low-pressure bag filter. From low pressure bag filter the released monomers are recompressed by recycle compressor and then sent to the ethylene stripper tower, where the unreacted ethylene is stripped from the mixture and recycled back to GPR, while the residual unreacted propylene returns to the propylene feed tank. The ethylene stripper is also used to purge the propane from the MZCR circuit.

Polymer purification

Polymer is discharged by gravity from low pressure filter to steamer drum, where steam is injected to remove the remaining monomers and to deactivate the catalyst residuals. Polymer grade propylene is purified to eliminate water, CO, CO_2 and methanol. From the steamer drum polymer is discharged by gravity to dryer, where removal of condensed water on the polymer is achieved by means of hot nitrogen in a fluidized bed. Dry powder polymer is transferred to intermediate surge silos via a closed-loop nitrogen pneumatic transport system.

Pelletisation and storage

Polymer powder is continuously discharged from intermediate surge silos via screw feeder and weight measuring device onto mixing screw conveyor. Solid additives are directly fed to the screw conveyor through independent feeders. A dedicated system for low melting additives discharges directly into extruder feed hopper. There is also one unit for talc feeding, with dedicated hopper and transport blower. The screw conveyor feeds the extruder by gravity; in the extruder the polymer and the additives are homogenized, extruded and pelletized through an underwater cutter.

After pelletisation, the polypropylene pellets are conveyed by water to the water/pellets separator and dryer. The polymer pellets are separated from coarse and fines in the vibrating classifier, and then are conveyed by the pneumatic transfer system to the homogenizing silos which are used as final storage silos. All silos are equipped with facilities to homogenize the polymer, so that composition of the polymer throughout silo remains fairly uniform. The pellets from all silos can then be transferred to the bagging silos downstream via pellets pneumatic conveying system.

7.3.4 Comparison of Polypropylene Technologies

The table below compares the features of main processes used for polypropylene production.

Table 7.5 Features of Main Industrial Polypropylene Processes

Process Type	Typical Solvent	Typical Temperature Range (°C)	Typical Pressure Range (bar)	Process description
Slurry	Hexane	50-80	8-30	Polymer precipitates to form a slurry.
Bulk	None (propylene)	45-80	18-40	Polymer precipitates in bulk ("liquid pool") propylene to form a suspension
Gas-phase	None	60-80	15-42	Granular polymers form in gas-phase fluidised bed, horizontal stirred bed or a vertical stirred bed

The process characteristics of the main licensed gas-phase polypropylene technologies are summarized in the following table.

Table 7.6 Features of Main Gas-Phase Polypropylene Technologies

Licensor,	LyondellBasell	INEOS	Lummus	Grace
Process	SPHERIZONE™	INNOVENE®	NOVOLEN	UNIPOL
Commercial	Yes	Yes	Yes (licensed)	Yes (licensed)
Reactor	Gas-phase Multi-Zone Circulating Reactor (MZCR)	Condensed gas-phase Horizontal stirred gas phase reactor (HSBR)	Gas-phase Vertical stirred bed reactor (VSBR)	Condensed gas-phase Fluidized bed reactor (FBR)
Catalyst	General-purpose phthalate catalyst Ziegler-Natta and metallocene	Ziegler-Natta and metallocene	Ziegler-Natta and metallocene	Ziegler-Natta
Pressure	25-30 bara	22-30 bara	20-35 bara	25-35 bara
Temperature	70-90°C	60-85°C	50-105°C	60-70°C
C_2 content	Up to 8% wt	22% wt	Up to 22% wt	Up to 19% wt
Residence Time	~ 1 hour	~ 1 hour	~ 1 hour	~ 1 hour
Propylene per ton of Polypropylene	1.001 tons	1.001 tons	1.001 tons	1.001

Section 8

CAPEX and OPEX

8.1 CAPEX

In the process of developing a PDH-PP complex, Alujain supplied estimated capital expenditure (CAPEX), based on the Class 3 estimate (-20 to +30 percent of accuracy), which is summarised in the table below.

Table 8.1 Alujain CAPEX Breakdown
(US$ million)

Budget Items	Value
Building/Infrastructure	111
PDH	780
PP	560
Tie-ins	103
UTOS	575
Initial Working Capital	45
Finance Cost	50
Total	**2 223**

We understand that Alujain is currently working on completing the FEED study for the project with their engineering company. Once the FEED study is completed, this may lead to a revision of the above CAPEX.

NexantECA classified the provided CAPEX values into inside battery limits (ISBL), outside battery limits (OSBL), and other project costs (OPC) categories based on Alujain's estimates, as illustrated in the table below.

Table 8.2 Project CAPEX Allocation
(US$ million)

	Propylene	Polypropylene	Complex
Capacity, thousand tons per year	600	550	
ISBL	780	560	1 340
OSBL	459	329	788
OPC	55	40	95
Total	**1 294**	**929**	**2 223**

8.1.1 Inside Battery Limits (ISBL)

The ISBL portion of a plant can be thought of as a boundary over which are imported raw materials, catalysts and chemicals, and utility supply streams. In a similar manner, main products, by-products, and spent utility return streams are exported over this boundary.

ISBL investment includes the cost of the main processing blocks of the chemical plant necessary to manufacture products. It represents an "instantaneous" investment (i.e., no escalation) for a plant ordered from a contractor and built on a prepared site with normal load bearing and drainage characteristics of a developed country.

Battery limits investment includes the installed cost of the following major items (non-exhaustive):

- Process equipment: vessels and internals, heat exchangers, pumps and compressors, drivers, solids handling
- Major spare equipment/parts (e.g., spare rotor for turbine or compressor)
- Building housing process units
- Process and utility pipes and supports within the major process areas
- Instruments, including computer control systems
- Electrical wires and hardware

The installed cost also includes construction overhead: fringe benefits, payroll burdens, field supervision, equipment rentals, small tools (expendables), field office expenses, site support services, temporary facilities, etc.

8.1.2 Outside Battery Limits (OSBL)

Outside battery limits (OSBL) investment includes the plant investment items that are required in addition to the main processing units within the battery limits. These auxiliary items are necessary to the functioning of the production unit, but perform in a supporting role rather than being directly involved in production. A distinguishing characteristic is the potential for sharing offsite facilities among several production units in a large plant, in which case investment cost would be allocated or prorated.

OSBL investment includes the installed cost of the following major items (non-exhaustive):

- Storage for feeds, products, by-products, including tanks/silos, dikes, inerting, process warehouse, and bagging/palletizing equipment
- Steam generation units
- Cooling water systems, including cooling towers and circulation pumps
- Process water treatment systems and supply pumps
- Boiler feed water treatment systems and supply pumps
- Refrigeration systems, including chilled water/brine circulating pumps
- Heat transfer medium systems, including organic vapor, hot oil, molten salts
- Electrical supply, transformers, and switchgear
- Loading and unloading arms, pumps, conveyors, lift trucks, including those to handle barge, tank/hopper car, and tank/hopper/other truck traffic; weigh scales
- Auxiliary buildings, including all services, furnishings, and equipment

8.1.3 Other Project Costs (OPC)

These costs are very site/project specific and for this project, consist of working capital and financing costs.

8.1.3.1 Working Capital

Working capital includes the following items:

- Inventory of raw material of 5 days for the individual units.
- Inventory of catalyst & chemicals of 180 days for the individual units.
- Inventory of products of 10 days for the individual units.
- Accounts payable of 25 days of variable production and fixed costs for the individual units (total 50 days).
- Accounts receivable of 20 days of net revenue for the individual units (total 40 days).
- Cash in hand of 20 days of fixed costs for the individual units (total 40 days)

8.1.3.2 Financing cost

These costs primarily include interest payments on loans, fees for financial services, and charges related to debt issuance. Companies often secure significant capital through loans, and the interest accrued, along with loan fees and debt issuance costs, constitutes a substantial portion of financing expenses. Additionally, guarantee fees, hedging costs, monitoring and compliance expenses, and opportunity costs contribute to the overall financial burden. Equity financing, if utilized, introduces its own set of costs such as underwriting fees and legal expenses.

8.2 OPEX

Alujain did not provide values for operational expenditure (OPEX), and therefore NexantECA estimated Project OPEX based on internal database for a PDH/PP plant of the similar size. OPEX can be split into variable and fixed costs, and for this Project, the specific values for both components are elaborated upon below. It's crucial to consider these OPEX elements comprehensively to ensure accurate projections and effective financial planning for the project's operational phase.

8.2.1 Variable Cost

Variable costs are directly related to the production volume and dependent on the plant's operating rate. Variable cost consists of raw materials/feedstocks, utility costs, plus credits for any relevant co-products and by-products.

Raw materials costs include the cost of feedstocks, catalysts and auxiliary chemicals. Raw materials are valued into the plant at their purchase price or estimated value in the case of intermediate product streams. Products are credited either at their plant (cost of production) or market price, depending on their final use.

Utilities typically include such items as power, steam, fuel (natural gas, fuel oil etc.), water (cooling water, process water, boiler feed water, etc) and inert gases (nitrogen, etc.). The table below summarises prices adopted for the various inputs used for the project.

Table 8.3 NexantECA Price Estimates for Process Inputs, 2027

Raw Material	Unit	Value
Propane	$/ton	542
Catalyst & Chemicals	$/ton	13
Extruder Addititives	$/ton	11
By Products		
Off-gas	$/ton	580
C4HC	$/ton	518
Hydrogen	$/ton	585
Utilities		
Power	$/MWh	32
Steam (Low Pressure)	$/ton	5
Nitrogen (Inert gas)	$/kton	38
Boiler Feedwater	$/ton	1
Steam (High Pressure)	$/ton	5
Fuel Gas	$/Gcal	6

8.2.2 Fixed Costs

The fixed costs in the project can be split by Direct Fixed Costs and Allocated Fixed Costs. The table below shows the values estimated for the Project.

Table 8.4 NexantECA Annual Fixed Costs Assumptions, 2027

Cost		**Propylene**	**Polypropylene**
Labour	US$/person	38 000	38 000
Foreman	US$/person	48 000	48 000
Supervision	US$/person	143 000	143 000
Factors			
Labour	# person	29	29
Foreman	# person	8	8
Supervision	# person	1	1
Direct Overheads Factor	% of Labour	45.0%	45.0%
General Plant Overheads Factor	% of Direct Fixed Costs	55.0%	55.0%
Maintenance Factor	% of ISBL	2.0%	2.0%
Insurance Factor	% of ISBL+OSBL	0.4%	0.4%
Environmental Factor	% of ISBL+OSBL	0.5%	0.5%
Direct Fixed Costs			
Labour	$ million	1.1	1.1
Foreman	$ million	0.4	0.4
Supervision	$ million	0.1	0.1
Direct Overheads	$ million	0.7	0.7
Direct Employment Cost	**$ million**	**2.4**	**2.4**
Maintenance Cost	$ million	16.9	12.1
Total Direct Fixed Costs	**$ million**	**19.2**	**14.5**
Allocated Fixed Costs			
General Plant Overheads	$ million	10.6	10.6
Insurance/Tax	$ million	4.7	3.4
Environmental	$ million	6.7	4.8
Total Allocated Fixed Costs	**$ million**	**22.0**	**18.8**
TOTAL FIXED COSTS	**$ million**	**41.2**	**33.3**

8.2.2.1 Direct Fixed Costs

Labour costs include the cost of only those people employed to operate the process unit, including operators and supervisors. The estimated number of operators for a process unit is the total number of personnel employed as operators for the plant in question. The number is equal to the number per shift times the number of shift teams. The number of operators per shift is based on NexantECA's in-house information for process units of the size and type in question. The cost per person is the gross salary/wage before deduction of tax and also includes bonuses given as additional months of salary. A representative average wage for a particular country is used.

Maintenance costs include all costs for materials and labour (both company employees and contractors) associated with maintenance. The maintenance cost is the average cost per year and includes costs for major shutdowns that only occur every two to four years. Maintenance costs are estimated as a percentage of the ISBL capital cost. This should not give the impression that the maintenance costs are only for ISBL equipment. The percentage of ISBL is simply a relationship. The maintenance cost reflects the total cost for the facility.

Direct overhead costs are sometimes referred to as the Payroll Burden or Payroll Added Charges and is the difference between the total cost of employing a person and his or her gross basic salary. It includes social costs such as pension, health insurance, employer taxes on salaries etc., directly related to direct labour and covers company contributions for social security, medical and other benefits not directly given as salary.

8.2.2.2 Allocated Fixed Costs

Allocated costs include tax, insurance and general plant overheads. General Plant Overhead includes costs for site administration (not corporate or head office), technical support and royalties where applicable, laboratory facilities, environmental affairs, medical facilities, canteen, fire and safety, security and employee transportation services. Other site costs not specifically associated with the process units in question are also included.

Insurance covers the replacement of the facilities in the event of an accident. The cost of business interruption insurance is not included. Property tax is sometimes known as rates or land charges. This tax is estimated based on the process unit's capital cost.

The costs provided are generic estimates based upon NexantECA understanding of the corporate world, and such estimates are not unique for KSA.

Section 9

Cost Competitiveness

9.1 INTRODUCTION

Delivered cost competitiveness is an important indicator of profitability in the petrochemical industry. Production economics show notable disparities both within and between regions of the world, and such disparities influence market behaviour, investment, and consolidation in the industry. In particular during a cyclical downturn it is producers at the top end of the cost curve who are forced to close if the market price falls below production costs unless operators choose to continue operation for non-economic reasons. The cost competitiveness review for the Project was conducted for the year 2027 under the three assumed NexantECA crude oil price scenarios explained in Section 6.1.1: assuming a Brent price of US$80 per barrel for the base case, US$50 per barrel for the low oil scenario and US$110 per barrel for the high oil scenario. Analysis for the following configurations have been conducted to show the relative ex-works cash cost positioning of the proposed Project compared to Leader plants at other locations:

- The Proposed Project – A 600 000 tons per year PDH plant integrated with a 500 000 tons per year PP unit.
- Middle East Leader PP producer (integrated with PDH).
- West European Leader PP producer (non-integrated, purchasing propylene at the contract price).
- US Leader PP producer (non-integrated and integrated with PDH).
- South-East Leader Asian producer (non-integrated and integrated with PDH).
- North-East Leader Asian producer (non-integrated).

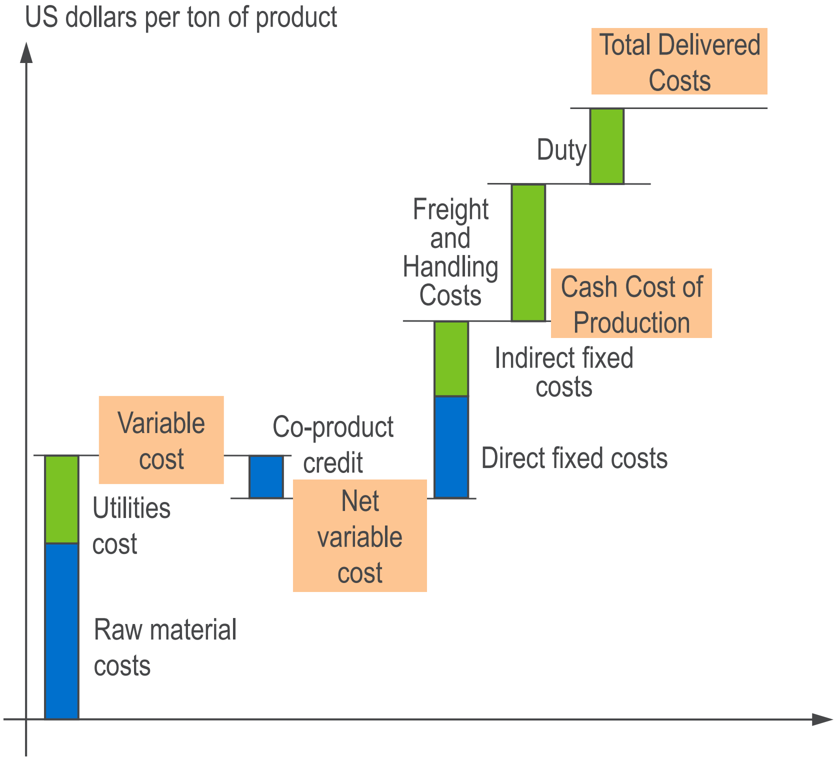
Delivered cash cost competitiveness to China (Shanghai, CFR) and Western Europe (Rotterdam, CFR) have also been developed for polypropylene. Propylene costs and prices are an important determinant of polypropylene competitiveness.

9.2 METHODOLOGY FOR COST COMPETITIVENESS ASSESSMENT

Cost competitiveness is an important determinant of profitability in the petrochemical industry. Production economics may show notable disparities both within and between regions of the world, and such disparities prove to influence market behaviour, investment, and consolidation in the industry.

To perform economic comparisons, NexantECA uses a standard methodology for analysing the costs of production. The production costs are grouped into various categories. Given that terms such as "allocated fixed costs" are open to different interpretations, the following section defines what NexantECA means by these terms. In summary, NexantECA's cost of production estimates, comprise the following elements:

Figure 9.1 Components of Cash Cost of Production



9.2.1 Cash Cost Basis

Cash cost of production is a measure of cost competitiveness that considers a plant's variable and fixed operating costs. The cash cost represents the total expenses required for plant operations and may be considered the minimum production cost. While this measure of a plant's operating costs may not reflect capital–related expenses such as depreciation, interest charges or return on capital, it does provide a meaningful comparison of operating costs related to raw materials, by–products, utilities consumption and labour and maintenance associated costs.

Cash cost does not include corporate overheads such as general marketing, company administration, and R&D nor does it include working capital. Cash cost does not include shipping costs or tariffs associated with delivering product from the plant gate to global customers. As such, it is purely a measure of production cost at the plant location, wherever the plant may be located. This provides a fair basis from which production cost competitiveness can be measured for plants located in different regions of the world.

Cash cost curves developed for this study plot cash cost of producers against cumulative capacity, the curve is a key analytical tool that can be used to:

- **Understand pricing and profitability in an industry:** In a competitive industry, the market price is expected to equilibrate at the cost of the marginal producer.
- **Assess the competitiveness of a region:** A region positioned at the bottom of the cost curve is very competitive and has a number of strategic options, while a region positioned at the top of the cost curve must differentiate to survive.
- **Understand the structural attractiveness of an industry:** A structurally attractive industry has a steep cost curve, typically implying the presence of few competitors, a range of technologies and costs, entry barriers, and value-in-use pricing. On the other hand, a structurally unattractive industry has a flat cost curve, usually implying the presence of many competitors, mature technology, similar costs, exit barriers, and cost-based pricing.
- **Evaluate the impact of changes in an industry:** The impact of additional capacity on pricing can be assessed, while the impact of new technology can also be projected using cost curves.

9.2.2 Delivered Cost Competitiveness Basis

An analysis of the cash cost of production, is a useful indicator of competitive positioning, but to emphasise the impact of factory gate costs on a given market, freight, handling and tariff charges, where appropriate, need to be considered. Freight and any applicable tariffs and duties are added to the cash cost to arrive at a delivered cash cost of production figure.

As the Project will be a new build, it is important to understand the impact of depreciation, and the return on investment expected against selling the product in the marketplace. Cost competitiveness analysis provides a useful insight into the relative merits of the Project.

The economics of the Project will need to be competitive with products imported from other global regions, local producers and local market price. By considering the leading producers in selected regions, NexantECA has conducted the delivered cash cost analysis for the Project and key competitors for 2027. The capacities of the plants used to carry out the analysis are noted in the tables in each product section. All plants have been selected as the leader plant in each of the regions and as such, they represent the most competitive regional suppliers.

9.3 COST COMPETITIVENESS ASSUMPTIONS

9.3.1 Selected Regional Plant Leaders

LyondellBasell's SPHERIPOL technology was selected as the process for all the polypropylene leader plants analysed as this was the leading process technology globally, with over 27 million tons of installed capacity in 2023. The PP plant modelled is assumed to be 500 000 tons per year in each location. For upstream integrated PDH plants, UOP Oleflex technology was analysed as this was the leading process used in 2023 globally. The PDH plant modelled at each location is assumed to be 600 000 tons per year in size. Selected leaders are summarised in the table below.

Table 9.1 Selected Regional Leaders and PP Plant Configurations

Region	PDH/PP integrated	PP non-integrated
Middle East	✓	
Western Europe		✓
USGC	✓	✓
SEA	✓	✓
NEA		✓

For all non-integrated PP plant, the propylene is assumed to be purchased at the market price.

9.3.2 Capital Costs

Capital cost elements typically included in the capital investments include inside battery limits investments (ISBL), outside battery limits investments (OSBL) and other project costs. The ISBL and OSBL for each plant were derived from NexantECA's database of plants using similar technology to each plant. Other Project Costs (OPC) are very site/project specific and were not included in the capital cost assessment. They typically range from 20 to 40 percent of installed ISBL and OSBL costs.

9.3.3 Variable Cost

As indicated in the figure above, the variable cost of production includes the costs of raw materials – feedstocks plus catalysts and chemicals – and utilities at cash cost or purchase cost, with a credit for co-products (by-products- or secondary products made in conjunction with the primary product).

9.3.3.1 Raw Material and By-Product Costs

Raw material costs play a vital role in a Project's cost competitiveness position. Producer with low feedstock costs will have a significant advantage over those that are based on higher feedstock costs.

The following approach has been taken for the competitiveness analysis:

- Cash Cost of production is developed by establishing net raw material costs (accounting for co-product credits), utilities and fixed costs.
- For the integrated PDH/PP leader, propane was used as a feedstock material. Produced propylene from the PDH plant was transferred to the PP plant at the cost of production (or transfer price)
- For non-integrated PP leader, propylene was used as a feedstock material, purchased at the market price.
- Since the Project is an integrated PDH/PP plant, propylene cost is transferred to the PP plant at a production cost.

9.3.3.2 Utility Costs

Utility costs are based on NexantECA's wide ranging experience of the selected regions. NexantECA's utility assumptions for this analysis are summarised in the following table:

Table 9.2 Utility Cost Assumption (2027)
(Current US$, based on US$80 per barrel crude oil scenario)

	Units	Saudi Arabia (Project)	Middle East Leader	Western Europe Leader	USGC Leader	South-East Asia Leader	North-East Asia Leader
Power	*MWh*	32	32	98	62	94	100
Boiler Feedwater	*Ton*	1.0	1.0	-	0.73	1.3	-
Fuel Gas	*MMBtu*	-	1.25	-	3.5	10	-
Cooling Water	*Kton*	-	40	53	35	63	69
Process water	*Ton*	-	-	0.47	-	-	0.56
LP Steam	*Ton*	-	-	39	-	-	24
Nitrogen (Inert Gas)	*Ton*	35	-	109	-	-	111

9.3.4 Fixed Cost

9.3.4.1 Direct Fixed Costs

The direct fixed costs shown in the table below include:

- Salaries of operating staff plus associated on-costs such as social insurance and fringe benefits.
- Maintenance costs including materials and labour, with periodic maintenance costs such as two or three–year shutdowns averaged over the period; maintenance costs are usually calculated as a percentage of process plant capital cost.

The table below shows the labour cost assumptions used by NexantECA in the analysis. Labour costs are regional in which producers in developed regions paying higher rates than those in remote locations.

Table 9.3 Labour Cost Assumptions, 2027
(Thousand US$ per worker per annum)

	Operator	Foreman	Supervisor
Saudi Arabia (Project)	35	44	132
Middle East Leader	35	44	132
Western Europe Leader	79	92	157
USGC Leader	87	99	119
South-East Asia Leader	30	36	41
North-East Asia Leader	15	22	29

In this analysis, NexantECA has assumed a direct plant overhead to be a percentage of fixed labour, ranging from 40 to 100 percent depending on the location and product. For maintenance costs, it is typically calculated as a percentage of process plant capital cost which reflects the severity and complexity of the process conditions, the age of the plant, etc. NexantECA typically uses a value of two to four percent per annum of the Inside Battery Site Limits (ISBL) capital cost.

9.3.4.2 Indirect Fixed Costs

The indirect fixed costs are the site charges, which are necessary for production, but which are not directly associated with the operation of the specified process plant. They include packing and warehousing, storage and workshops, site laboratories, safety and environment, security, site management, and on-site amenities for the workers. Insurance of the fixed assets is also counted under indirect fixed costs.

NexantECA has assumed a general plant overhead to be a percentage of the direct fixed costs element, ranging from 50 to 70 percent. For tax and insurance, a value of one to two percent per annum of the total capital cost are used for the plants modelled.

9.3.5 Location Factors

As indicated above, the capital costs of the plants to be compared are of significance since costs such as maintenance and some general plant overheads tend to be related to capital costs. Capital costs vary around the world depending upon factors such as where major process items are to be sourced from, and the local cost of labour. The table below shows the location factors used in this study expressed relative to a United States level of 1.0. These values reflect NexantECA's knowledge of petrochemical and refining projects around the world:

Table 9.4 Regional Location Factors, 2027

	Location Factors
Saudi Arabia (Project)	1.00
Middle East Leader	1.00
Western Europe Leader	1.01
USGC Leader	1.00
South-East Asia Leader	0.87
North-East Asia Leader	0.65

9.3.6 Delivered Markets

The total delivered cash costs are estimated for producers supplying products to markets in North-East Asia (using Shanghai as a reference) and Western Europe (using Rotterdam as a reference). The competitor costs shown in this analysis are generic and do not represent a specific plant but are representative of leader plants in the regions specified.

Delivered cash cost estimates for polypropylene producers are presented for representative leader plants in the key exporting/producing regions of the Middle East, United States, Western Europe, South-East Asia and North-East Asia.

9.3.7 Freight and Logistics

The freight costs include all elements involved in transporting the material from the works to the importing ports. All locations considered are at or near the coast such that the major element of freight cost is shipping. Overall, marine bunker fuel oil (bunker oil) price is a major cost component of shipping costs. Bunker oil price historically tracks closely with crude oil price which is highly volatile.

Aside from the costs incurred in actually owning and operating a ship, the canal charges and port charges also make a significant contribution. The shipping costs forecasted by NexantECA's are checked against market rates for the cargoes in consideration and should be seen as typical or representative costs of what a volatile cost is, which fluctuates with demand for shipping. However, should costs rise or fall, this will apply to all export-orientated producers using the spot or short-term contract shipping market.

The delivered cost analysis considers applicable port/handling costs and freight to a target market in addition to the cost of production. NexantECA has used the following ports for each country/region in the cost competitive analysis:

Table 9.5 Port Destinations in Selected Regions

Country/Region	Port
Middle East	Jubail, Saudi Arabia
Western Europe	Rotterdam, Netherlands
United States	Port Houston, Texas
North-East Asia	Shanghai, China
South-East Asia	Singapore

Port costs and freight cost assumptions used are outlined in Section 6.1.3.

9.3.8 Other Considerations

It is important to note that this analysis does not include any financing costs, such as depreciation for the final product plant, investment return expectations and interest payments as these will vary by company accounting practices. Clearly should depreciation costs be included, the advantage of any particular plant would be reduced, especially if the comparisons are made with existing, fully depreciated plants. This analysis only indicates how competitive key players, and the Project are in comparison to each other when supplying into the key target markets.

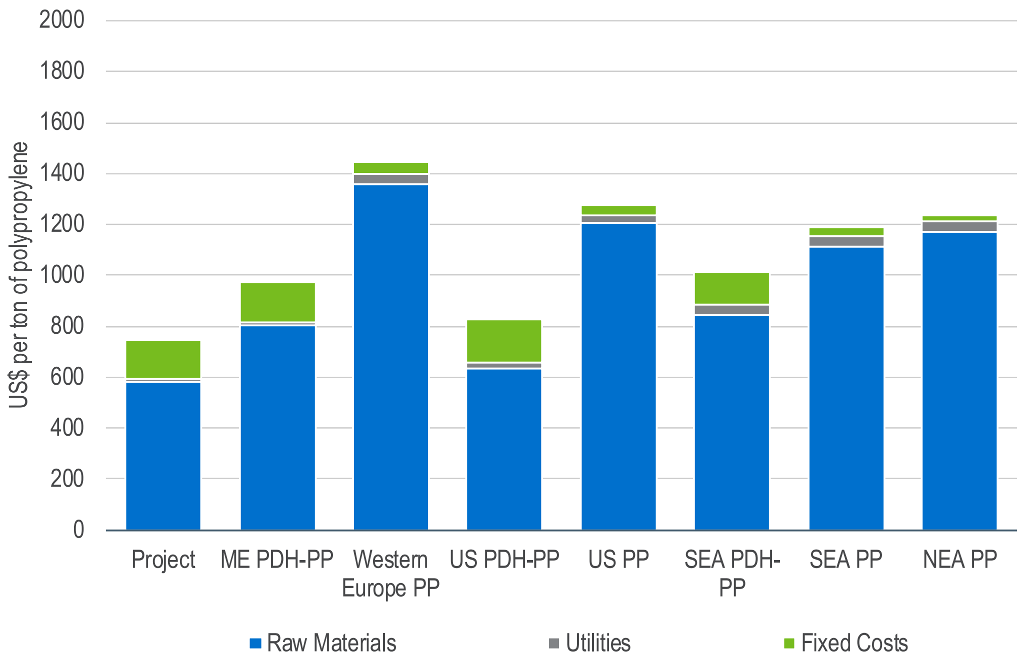
9.4 EX-WORKS CASH COST RESULTS

9.4.1 Ex-works Cash Cost Competitiveness

The results of the ex-works cost competitiveness analysis cover only those regional leaders described in section 9.3.1.

Ex-works cash cost of production analysis is based on an estimation of the production cost at the factory gates. For the Project, the client provided information on the material and utility balances, whereas for the selected regional leading plants, the data was sourced from NexantECA's internal database. The analysis was carried out for three agreed-upon NexantECA crude oil price scenarios and summarised in the figures below.

Figure 9.2 Ex-Works Cash Cost PP – Medium Oil Scenario
(2027, $80 per barrel)



The Project is expected to have the lowest cost of polypropylene production among all reviewed regional leaders. The Project's raw material costs are lower than that of the Middle East integrated producer because Saudi Arabia's propane price is calculated as a discount of the Japanese propane price, excluding the freight. In contrast, the Middle Eastern price is calculated by adjusting the Asian propane price to reflect freight costs to that market. Thus, the Project's cost advantage widens under the high crude oil price scenario, but narrows under the low crude oil price scenario (see figures below). Furthermore, the Project configuration benefits from the by-product credits, such as off-gas, hydrogen, and C4 hydrocarbons, which have not been assumed for the other regional leaders.

The Project is closely followed by the U.S. competitor with the integrated PDH-PP configuration, which also has advantaged low feedstock costs but has a slight disadvantage of higher utility costs. On the other hand, a non-integrated Western European leader is heavily penalised by the high raw material costs out of all analysed competing archetypes, leading to the highest cash cost out of all competitors. Non-integrated polypropylene plants in the US, SEA, and NEA have comparable second-highest costs of production.

Regions where an integrated and non-integrated polypropylene plant were analysed show that the integrated plant with upstream PDH would be more competitive. This is due to low propylene prices, which are transferred at cost from the PDH plant compared to higher prices for purchasing propylene at the prevailing market prices.

Figure 9.3 Ex-Works Cash Cost PP – Low Oil Scenario
(2027, $50 per barrel)

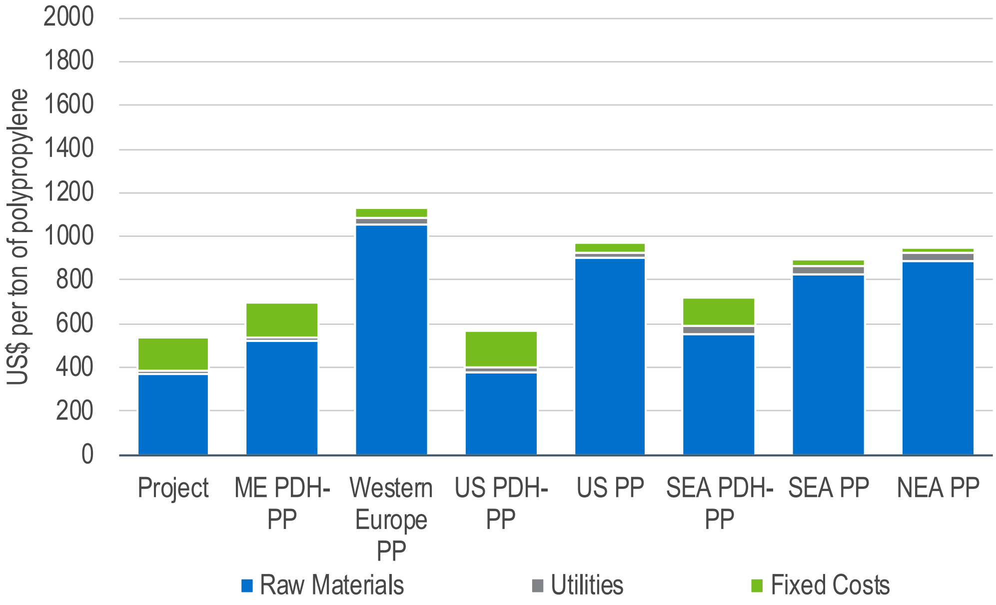
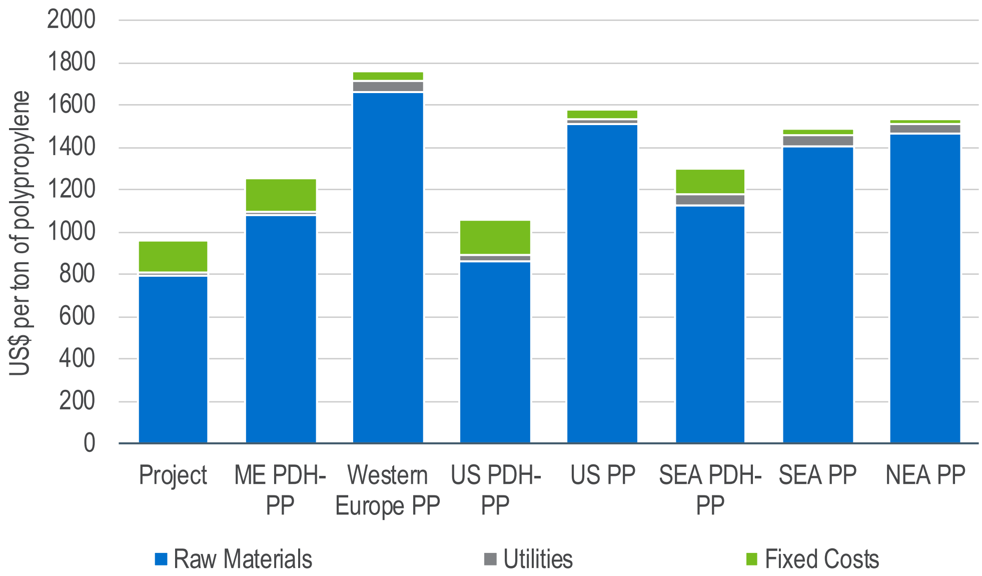


Figure 9.4 Ex-Works Cash Cost PP – High Oil Scenario
(2027, $110 per barrel)



9.5 DELIVERED CASH COST RESULTS

The results of the delivered cost competitiveness analysis cover only those regional leaders described in section 9.3.1.

9.5.1 Delivered to North-East Asia

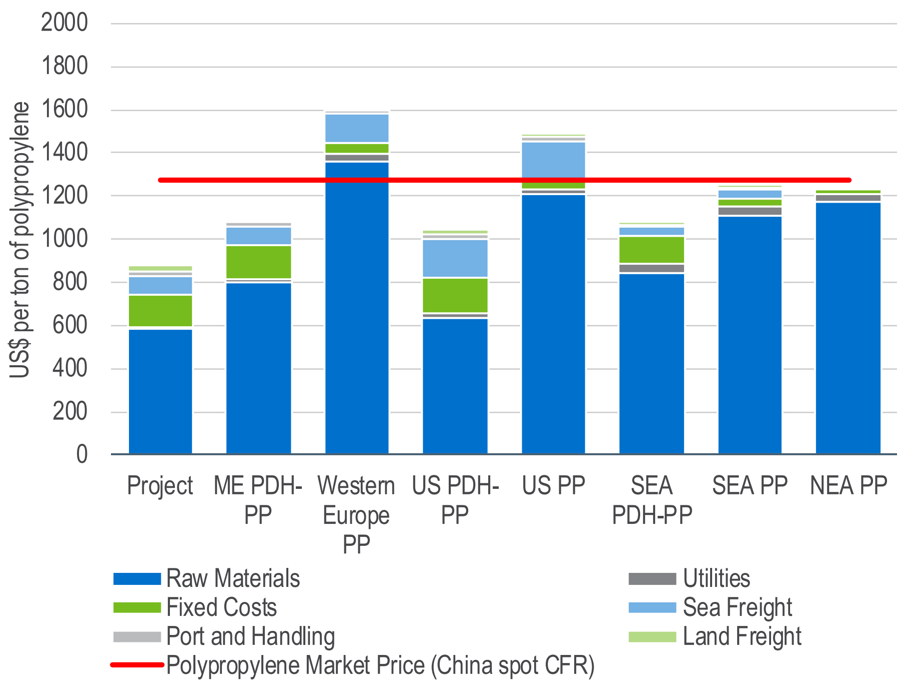
Most of the analysed regional leaders could profitably deliver PP to the North-East Asia market (Shanghai reference) based on the destination market prices. The only two exceptions are the non-integrated PP producers in the Westen Europe and the US. These producers are disadvantaged with high raw material costs and high logistic costs due to the distance to the target market. Regions where an integrated and non-integrated PP plant were analysed show that the integrated plant with upstream PDH would be more competitive due to low propylene prices which are transferred at cost from the PDH plant compared to higher prices for purchasing propylene at the prevailing market prices.

The Project's PP cost of production is estimated to be the most competitive due to the lowest raw materials cost even compared to the Middle East integrated producer. This is because Saudi Arabia's propane price is calculated as a discount of the Japanese propane price, excluding the freight. In contrast, the Middle Eastern price is calculated by adjusting the Asian propane price to reflect freight costs to that market. In addition, the Project's raw materials cost includes by-product credits, such as off-gas, hydrogen and C_4 hydrocarbons. NexantECA has assumed that the other regional leaders do not have similar byproduct credits for these streams.

The integrated-US configuration also had a competitive cash cost position but was offset by high freight costs compared to the Project case, on a delivered cost basis.

Figure 9.5 Delivered Cash Cost PP to Shanghai, China, CFR Basis – Medium Oil Scenario

(2027, $80 per barrel)



NexantECA also carried out analysis for delivered cash cost to North-East Asia under the low and high oil scenario. The projections shown below deliver a similar result for cost competitiveness to the medium oil scenario explained above, where the Project remains the most competitive on a delivered cash cost basis to the delivered market.

Due to the described propane pricing mechanisms established in KSA and in the Middle East, the Project's cost advantage widens under the high crude oil price scenario, but narrows under the low crude oil price scenario.

Figure 9.6 Delivered Cash Cost PP to Shanghai, China, CFR Basis – Low Oil Scenario
(2027, $50 per barrel)

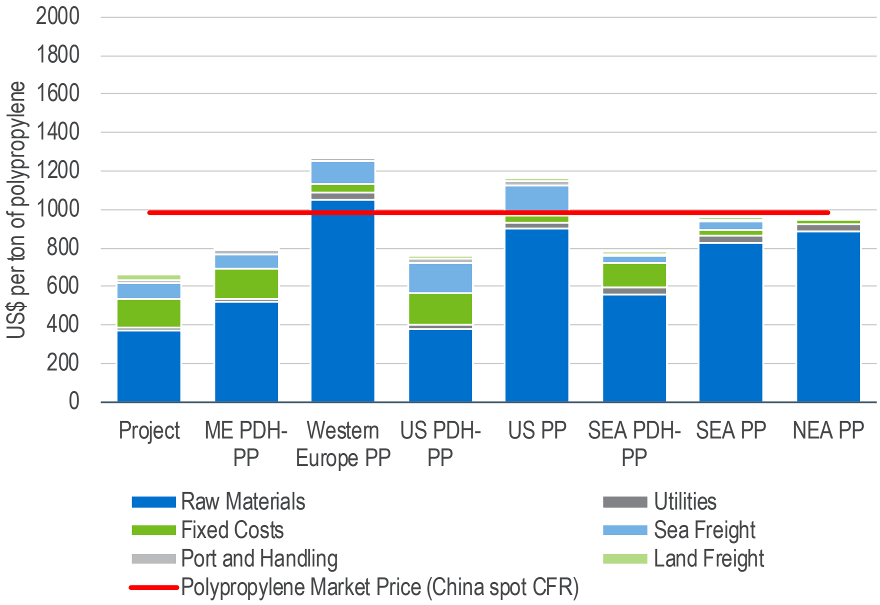
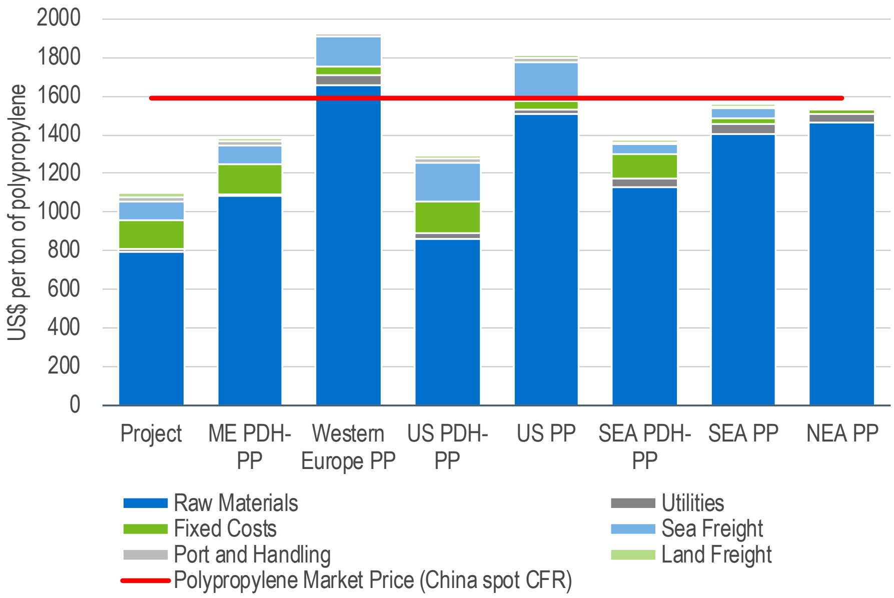


Figure 9.7 Delivered Cash Cost PP to Shanghai, China, CFR Basis – High Oil Scenario
(2027, $110 per barrel)



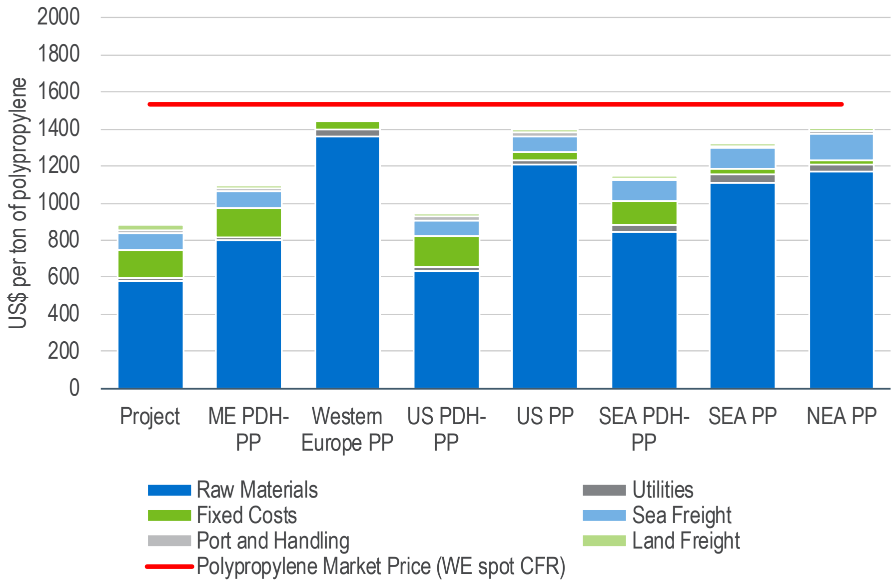
9.5.2 Delivered to Western Europe

All analysed regional leader configurations could profitably deliver PP to Western Europe (Rotterdam as reference) based on the destination market price. The Project's PP cost of production is estimated to be the most competitive due to the lowest raw materials cost even compared to the Middle East integrated producer. This is because Saudi Arabia's propane price is calculated as a discount of the Japanese propane price, excluding the freight. In contrast, the Middle Eastern price is calculated by adjusting the Asian propane price to reflect freight costs to that market. In addition, the Project's raw materials cost includes by-product credits, such as off-gas, hydrogen and C_4 hydrocarbons. NexantECA has assumed that the other regional leaders do not have similar byproduct credits for these streams.

The Project is followed closely by the U.S. regional leader with the integrated configuration who also have advantaged feedstock costs in comparison to the WE leader. Non-integrated players are the most uncompetitive due to high raw material costs, with Asian players at an extra disadvantage due to higher freight costs.

Figure 9.8 Delivered Cash Cost PP to Rotterdam, Western Europe, CFR Basis – Medium Oil Scenario

(2027, $80 per barrel)



Analysis under the low and high oil scenarios yielded a similar pattern for cost competitiveness for delivered cash cost to Western Europe as shown below. The main difference was that under the low oil scenario, the integrated U.S. leader was projected to become the most competitive as it had the lowest raw material costs. In all three oil scenarios analysed, the propane price in the U.S. was lower than for the Project case. However, by-product credits for the Project, which included off-gas, hydrogen and C_4 hydrocarbons, were able to offset the price gap under the high and medium scenarios leading to a lower delivered cash cost for the Project.

Figure 9.9 **Delivered Cash Cost PP to Rotterdam, Western Europe, CFR Basis – Low Oil Scenario**
(2027, $50 per barrel)

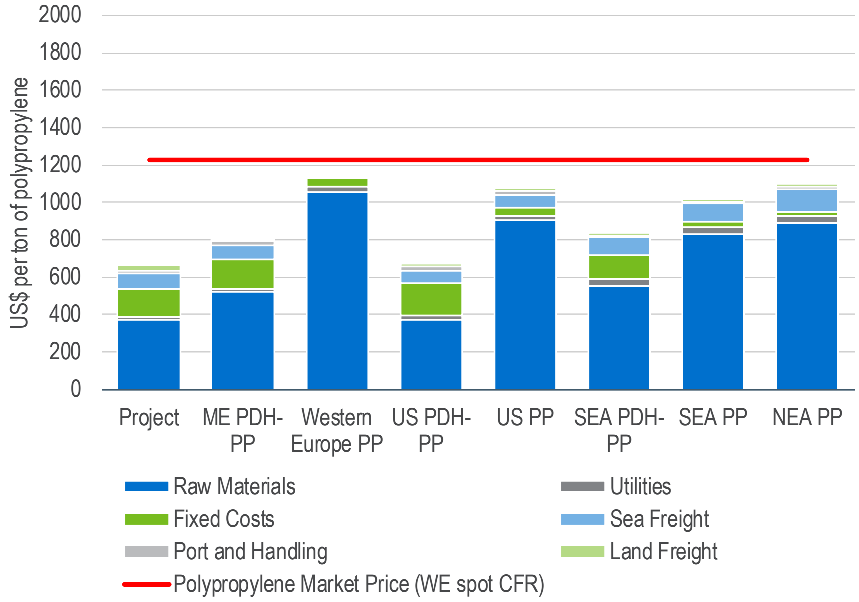
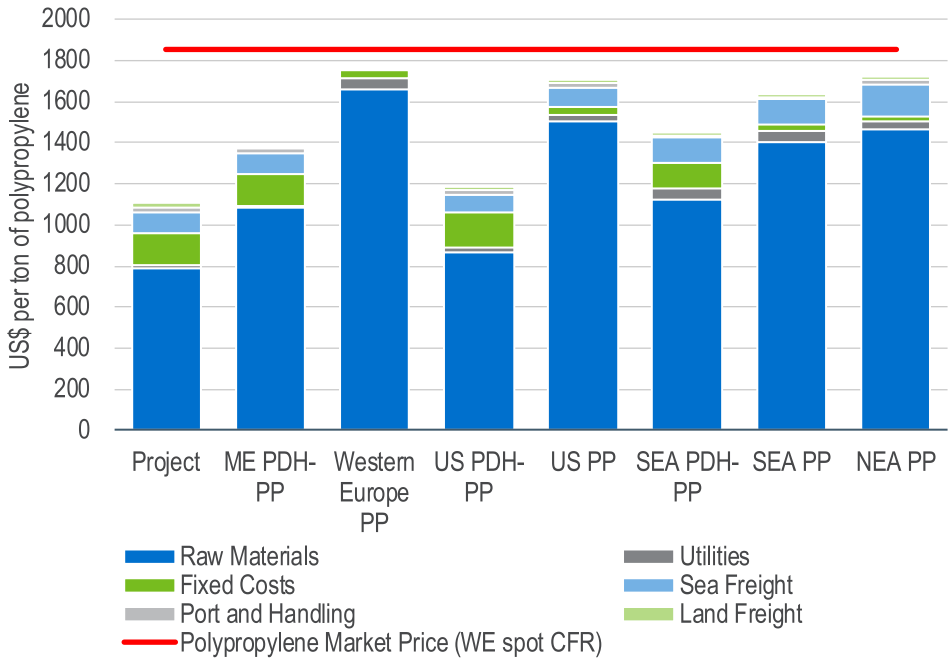


Figure 9.10 **Delivered Cash Cost PP to Rotterdam, Western Europe, CFR Basis – High Oil Scenario**
(2027, $110 per barrel)



Section 10
Direct Fixed Costs

10.1 INTRODUCTION

NexantECA has developed a financial model to analyse the economic feasibility of construction and operation by Alujain of a new PDH-PP plant in Yanbu, Saudi Arabia. This section presents the inputs and results of the financial modelling, with the model projecting annual costs and revenues associated with the construction and operation of a PDH plant with a capacity of 600 000 tons per year and a PP plant with a capacity of 550 000 tons per year.

The financial analyses have been undertaken for three oil price scenarios: a ‘Low’ oil (Brent crude price) case, a ‘Medium’ oil case, and a ‘High’ oil case.

10.2 MODEL SETUP AND ASSUMPTIONS (BASE CASE)

10.2.1 Basis Model Elements

The Project model includes the following basic assumptions, which can be adjusted as desired.

Table 10.1 Financial Model Assumptions

Model Element	Assumption
EPC Start Year	2024
Duration of EPC Phase	3
Operations Start Year	2027
Duration of Operational Phase	20
Operations Final Year	2046
CAPEX Spend Profile – Yr 1	25 percent
CAPEX Spend Profile – Yr 2	50 percent
CAPEX Spend Profile – Yr 3	25 percent
Plant Terminal Value	4.5 multiple of final year EDITDA

10.2.2 Capital Expenditure

The capital expenditure (CAPEX) in this study have been provided by Alujain. NexantECA did not independently verify these figures but has provided for sensitivity analysis in the FM evaluation. Plant capital costs include three main aspects: ISBL, OSBL and Other Project Costs.

10.2.2.1 Inside Battery Limits (ISBL)

The inside battery limits (ISBL) portion of a plant can be thought of as a boundary over which are imported raw materials, catalysts and chemicals, and utility supply streams. In a like manner, main products, by-products, and spent utility return streams are exported over this boundary. ISBL includes the main processing blocks of the chemical plant necessary to manufacture products.

The major items included in the ISBL are the unit process equipment (reactors, vessels, pumps etc.), spare equipment, process and utility pipes and racks, instruments (including control systems), foundations and structures. The installed cost also includes construction overhead costs, such as benefits, equipment rentals, site support services, temporary construction facilities, etc.

10.2.2.2 Outside Battery Limits (OSBL)

Outside battery limits (OSBL) investment includes the plant investment items that are required in addition to the main processing units within the battery limits. These auxiliary items are necessary to the functioning of the production unit but perform in a supporting role rather than being directly involved in production. These are primarily ringfenced outside of the process area.

Major items included in the OSBL investment are storage capacity, auxiliary buildings, roads and walkways, electrical main substation, and sanitary and storm sewers. A distinguishing characteristic of OSBL is the potential for sharing offsite facilities among several production units in a large plant or complex, in which case investment cost would be allocated or prorated.

10.2.2.3 Other Project Costs (OPC)

These costs are very site/project specific and for this project, consist of working capital and financing costs.

10.2.3 CAPEX Summary

In the process of developing a PDH-PP complex, Alujain supplied estimated capital expenditure (CAPEX), based on the Class 3 estimate (-20 to +30 percent of accuracy), which is summarized in the table below.

Table 10.2 Alujain CAPEX Breakdown
(US$ million)

Budget Items	Value
Building/Infrastructure	111
PDH	780
PP	560
Tie-ins	103
UTOS	575
Initial Working Capital	45
Finance Cost	50
Total	**2 223**

Within the FM, initial working capital (IWC) and Finance Cost were removed from the total project costs as the cash flow model generates this value. The table below shows how the values provided by Alujain was used in the model, with the split between ISBL and OSBL.

Table 10.3 Project CAPEX Allocation
(US$ million)

	Propylene	Polypropylene	Complex
Capacity, thousand tons per year	600	550	
ISBL	780	560	1 340
OSBL	459	329	788
OPC	55	40	95
Total	**1 294**	**929**	**2 223**

10.2.4 Operational Parameters

NexantECA has made assumptions on key operational parameters for the proposed production facility, based upon NexantECA's in-house knowledge as well as information provided by Alujain.

10.2.4.1 Consumption Factors

The factors used in the model for consumption of raw materials and utilities and for formation of by-products are shown in the table below for each unit/product and were provided by Alujain.

Table 10.4 Consumption Factors for PDH-PP Complex

		PDH	Polypropylene
Raw Material	**Unit**		
Propane	ton/ton	1.133	-
Propylene	ton/ton	-	1.000
Catalyst & Chemicals	$/ton	1.000	1.000
Extruder Addititives	$/ton	-	1.000
By Products			
Off-gas	ton/ton	(0.093)	-
C4HC	ton/ton	(0.054)	-
Hydrogen	ton/ton	(0.043)	-
Utilities			
Power	Mwh/ton	1.2773	0.3480
Steam (Low Pressure)	ton/ton	-	0.0981
Nitrogen (Inert gas)	ton/ton	0.0206	0.0167
Boiler Feedwater	ton/ton	1.0760	-
Steam (High Pressure)	ton/ton	(0.5173)	-
Fuel Gas	Gcal/ton	1.6786	-

In the base case, Alujain have confirmed that the by-product consumption will be set to zero.

10.2.4.2 Labour Assumptions

Labour requirements for the PDH-PP complex have been assumed from in-house NexantECA information for comparable plants. These assumptions are shown in the table below.

Table 10.5 Labour Assumptions - 2027

Cost		**Propylene**	**Polypropylene**
Labour	US$/person	38 000	38 000
Foreman	US$/person	48 000	48 000
Supervision	US$/person	143 000	143 000
Factors			
Labour	# person	29	29
Foreman	# person	8	8
Supervision	# person	1	1

10.2.4.3 Operational Assumptions

NexantECA has assumed the following ramp-up in operating rates of the Project units following completion of the EPC phase, as is commonly observed on newly implemented projects:

- Year 1 – 80 percent
- Year 2 – 90 percent
- Year 3 onwards – 100 percent

The operation in the initial year following start-up assumes that in the first two years the plant does not meet its full production capacity as the plant operations and commercial arrangements are optimised. NexantECA considers this to be a conservative assumption. From the third year of operation onwards, the plant is assumed to operate at 100 percent of the design rate over 8 000 hours (given that a year has 8 760 total hours). These assumptions are the same as all the global the licensors when they rate their process designs.

10.2.5 Other General Assumptions

Other assumptions included in the financial model are defined in the 'Assumptions' tab in the model, and are described as follows:

- Direct Overheads are defined as 45 percent of Labour Costs
- General Plant Overheads are defined as 55 percent of Direct Fixed Costs
- Maintenance costs are defined as 2 percent of ISBL
- Insurance costs are defined as 0.4 percent of ISBL + OSBL
- Environmental costs are defined as 0.5 percent of ISBL + OSBL

10.2.6 Financing and Financial Indicators Assumptions

Assumptions on the financing of the Project have been discussed and agreed with Alujain as follows. These are adjustable on the 'Assumptions' tab as required.

- Debt-to-equity ratio of 70 / 30, split into
  - Equity – 30.0 percent
  - SIDF Loan – 34.4 percent
  - Commercial Debt – 35.6 percent
- SIDF Loan Assumptions
  - Facility Interest Rate – 2 percent
  - Term – 10 years
  - Upfront Fee – 8 percent
- Commercial Debt Loan Assumptions
  - Facility Interest Rate – 7.3 percent
  - Term – 11 years
  - Upfront fee – 1.5 percent
  - Commitment fee – 0.4 percent
- In assessing the NPV of the Project, a discount rate of eight percent has been applied, a NexantECA standard assumption.
- The Project IRR has been assessed both with and without inclusion of a terminal value for the facility. In assessing the terminal value, a value of 4.5 times the final year EBITDA is considered reasonable.
- 65 percent of the EBT will be subject to a 2.5 percent Zakat tax, and 35 percent of the EBT will be subject to a 20 percent Corporate Income Tax.
- Depreciation is included, over 20 years.
- SG&A expenses and Marketing Fee are defined as 1.5 percent and 0.5 percent of net revenue respectively.

- Polypropylene production is split 85:15 homopolymer PP to Impact PP.
- The sales distribution of excess propylene (circa 50 000 tons per year) and the polypropylene is defined in the model into both domestic and foreign markets.

10.2.7 Working Capital

The assumptions on working capital requirements have been discussed with Alujain and are included as follows (can be changed on the ‘Assumptions’ tab):

- Inventory of raw material of 5 and 10 days for the PDH and PP respectively.
- Inventory of catalyst & chemicals of 180 days for the individual process units.
- Inventory of products of 10 days for the individual units.
- Accounts payable of 25 and 30 days of variable production and fixed costs for the PDH and PP respectively (total 55 days).
- Accounts receivable of 15 and 25 days of net revenue for PDH and PP respectively (total 40 days).
- Cash in hand of 30 days of fixed costs for the individual units (total 60 days).

10.2.8 Marketing Plan

The marketing plan in the Financial Model is aligned with the marketing plan as discussed in Section 5 in the study. The assumptions on marketing plan have been discussed with Alujain and are shown in the table below. These assumptions constitute the base case scenario of the Project; these are editable inputs in the model and can be changed to suit the user.

Table 10.6 Marketing Plan

	Propylene	Homo PP	Impact PP
Western Europe	40%	10%	10%
North America	30%	0%	0%
Middle East	20%	0%	0%
North East Asia	10%	10%	10%
South East Asia	-	20%	20%
North Africa	-	10%	10%
Saudi Arabia	-	10%	10%
Turkey	-	25%	25%
Central Europe	-	15%	15%
South America	-	0%	0%

10.3 FINANCIAL MODEL OUTPUTS

The economic return projected for the Project will ultimately determine its feasibility and “bankability”. The return acceptable for a project will depend on the perception and judgement of the Lender and/or the Sponsor. The internal rate of return (IRR) is normally the basis for evaluation, with companies expecting returns above their cost of capital and at a suitable premium to risk-free returns. Additionally, clients and lenders monitor the net present value (NPV) of the project for additional comfort. Project satisfaction is made on a number of these factors at this stage of the Project execution. The level of IRR or NPV acceptable to lenders and project sponsors varies widely depending on the project types. Sponsors could use the financial model at the feasibility stage to support further discussion on their project fundamentals.

10.3.1 Base Case Analysis

10.3.1.1 Medium Oil Case

The IRR for the complex is presented in the table below. The returns are presented for both project IRR and equity IRR, to distinguish project returns with and without financing.

Table 10.7 Base Case Complex Financial Results

(Price inputs – NexantECA's US$80 per barrel Medium Oil Scenario)

		Complex
Investment (incl. initial WC)	*MM$*	2 174
Net Present Value (8% discount rate)	*MM$*	611
Project IRR		11%
Equity IRR		15%
**IRRs with Terminal Value*		

Note: the investment value excludes US$50 million allocated for the finance cost in the Project CAPEX.

Based on the information provided by the client (i.e. CAPEX) and assumptions modelled in the FM the Project IRR stands at 11 percent and the Equity IRR at 15 percent. The Project funding is split at 30 percent equity 70 percent debt.

By far the main cost determinant for the PDH-PP complex is the propane price. The project CAPEX cost and PP netbacks are the other leading variables that have an impact on the Project returns. The propane price assumptions were based on the Saudi propane price, which has been explained in Section 6.2. As can be seen in the sensitivity analysis, product price of polypropylene is an important determinant of the profitability of the Project, as it directly influences the revenue. The same can be observed about the CAPEX cost.

It is important to note that in the base case by-products are assumed to be zero; if these were taken to account, the financials of the Project would improve.

Lenders will undertake their own risk profiling for lending prospects for the Project under current economic and oil market conditions and perceived future conditions.

10.3.1.2 Low Oil Case

The IRRs for the complex under the Low oil case is presented in the table below. The key assumptions are the same as above, except for the oil price, which alters the feedstock, and product prices.

Table 10.8 Complex Financial Results

(Price inputs – NexantECA's US$50 per barrel Low Oil Scenario)

		Complex
Investment (incl. initial WC)	*MM$*	2 166
Net Present Value (8% discount rate)	*MM$*	291
Project IRR		9%
Equity IRR		13%
**IRRs with Terminal Value*		

Note: the investment value excludes US$50 million allocated for the finance cost in the Project CAPEX. The value of the overall investment under the low crude oil scenario is slightly lower than that of the medium crude oil scenario due to lower prices used to calculate the initial working capital.

The returns are slightly lower than under the medium oil scenario, which is consistent with NexantECA expectations.

10.3.1.3 High Oil Case

The IRRs for the complex under the High oil case is presented in the table below. The key assumptions are the same as above, except for the oil price, which alters the feedstock, and product prices.

Table 10.9 Complex Financial Results

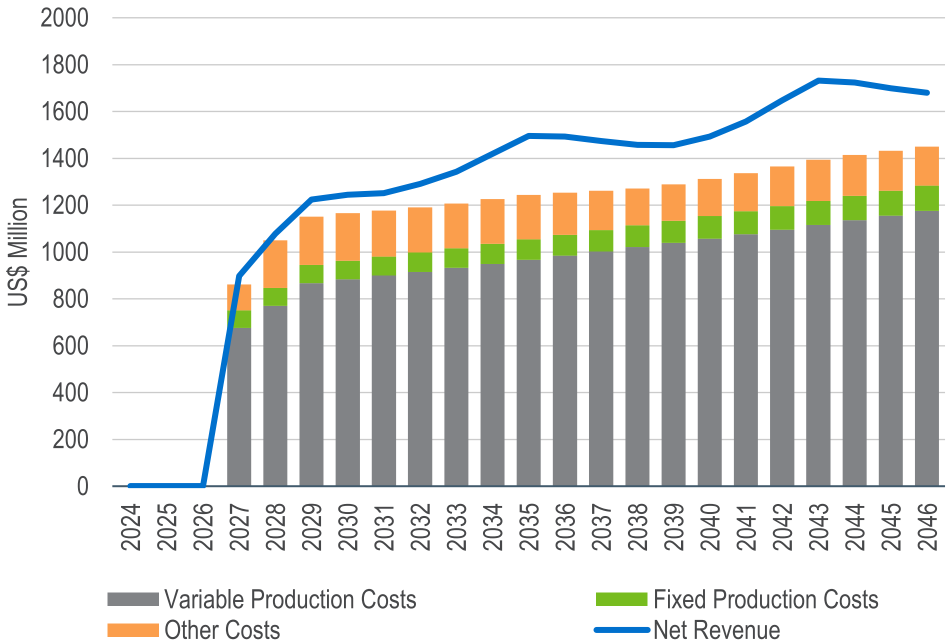
(Price inputs – NexantECA's US$110 per barrel High Oil Scenario)

		Complex
Investment (incl. initial WC)	*MM$*	2 182
Net Present Value (8% discount rate)	*MM$*	955
Project IRR		12%
Equity IRR		17%
**IRRs with Terminal Value*		

Note: the investment value excludes US$50 million allocated for the finance cost in the Project CAPEX. The value of the overall investment under the high crude oil scenario is slightly higher than that of the medium crude oil scenario due to higher prices used to calculate the initial working capital.

The returns are slightly better than under the medium oil scenario, which is consistent with NexantECA expectations.

Figure 10.1 Revenue and Cost



Note: Other Costs refer to SG&A Expenses, Marketing Fees, Depreciation, Increase in Product Inventory, Debt Interest Payments and Tax Payments.

Figure 10.2 Complex Economics

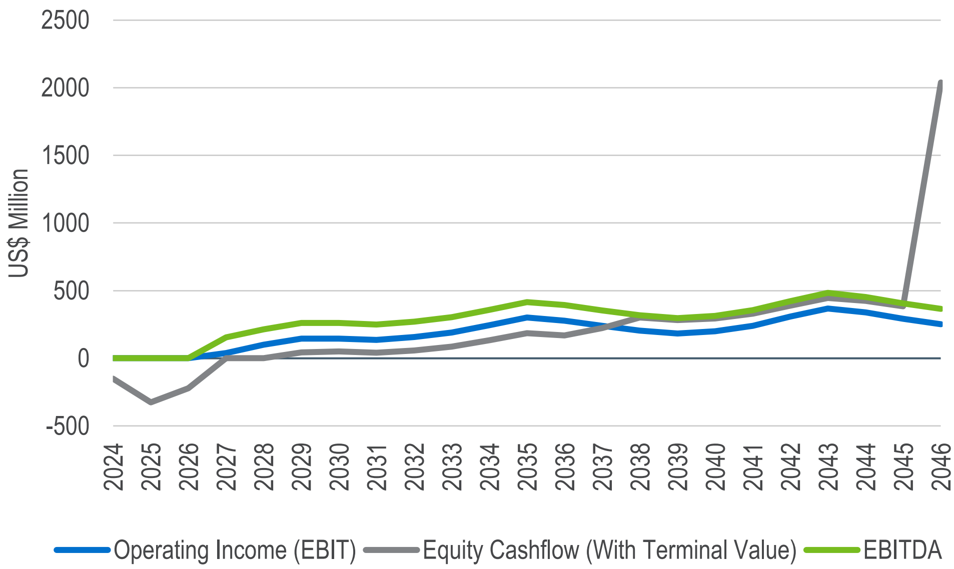
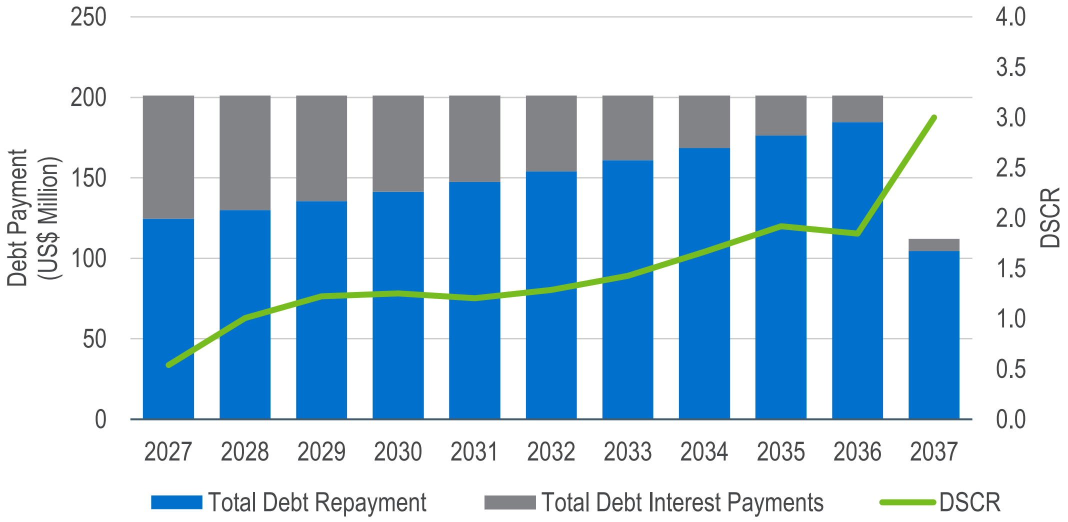


Figure 10.3 Debt Economics



10.3.2 Sensitivity Analysis

10.3.2.1 Production Costs, Revenue and CAPEX

The model has been designed to be highly flexibly which enables the user to easily change the assumptions and perform several sensitivity analyses to the base case assumptions. NexantECA has performed a range of sensitivities on the base case configuration, which spans the spectrum of possible deviations to the base case assumptions. The sensitivities test some of the key assumptions used in modelling the economic performance of the Project and illustrate the impact on IRRs and the NPV of varying these key assumptions. The financial results of the sensitivity cases for the Base Case (Medium crude oil price scenario) are summarised in the following figures. The FM has the functionality to run all the different sensitivity analysis under low and high oil price scenarios.

Figure 10.4 Sensitivity Analysis on Project IRR (Base Case)

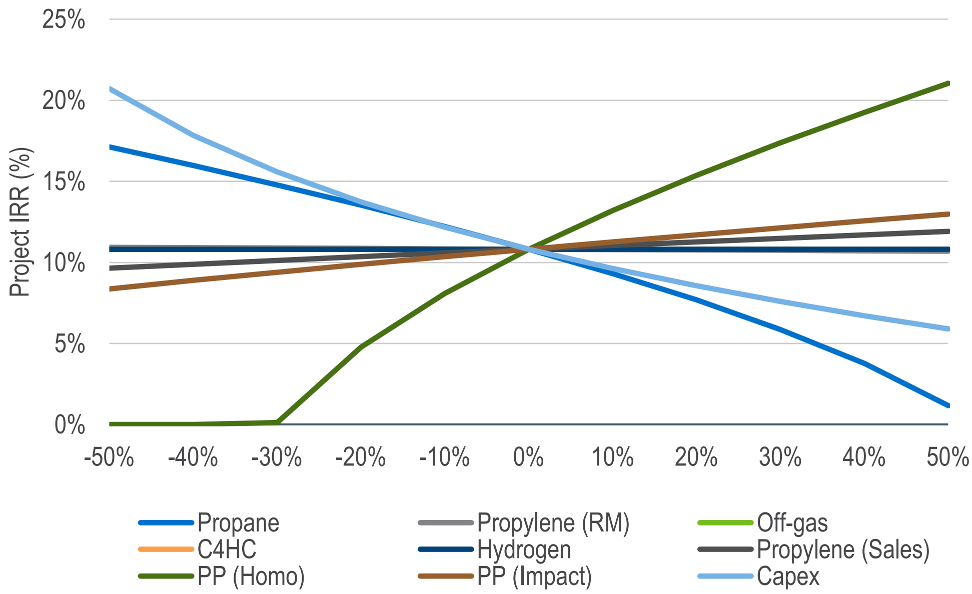


Table 10.10 Sensitivity Analysis on Project IRR (Base Case)

	Project IRR Sensitivity										
	-50%	-40%	-30%	-20%	-10%	0%	10%	20%	30%	40%	50%
Propane	17%	16%	15%	14%	12%	11%	9%	8%	6%	4%	1%
Propylene (RM)	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%
Off-gas	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%
C4HC	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%
Hydrogen	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%
Propylene (Sales)	10%	10%	10%	10%	11%	11%	11%	11%	11%	12%	12%
PP (Homo)	No Return	No Return	0%	5%	8%	11%	13%	15%	17%	19%	21%
PP (Impact)	8%	9%	9%	10%	10%	11%	11%	12%	12%	13%	13%
Capex	21%	18%	16%	14%	12%	11%	10%	9%	8%	7%	6%

Figure 10.5 Sensitivity Analysis on Equity IRR of Complex (Base Case)

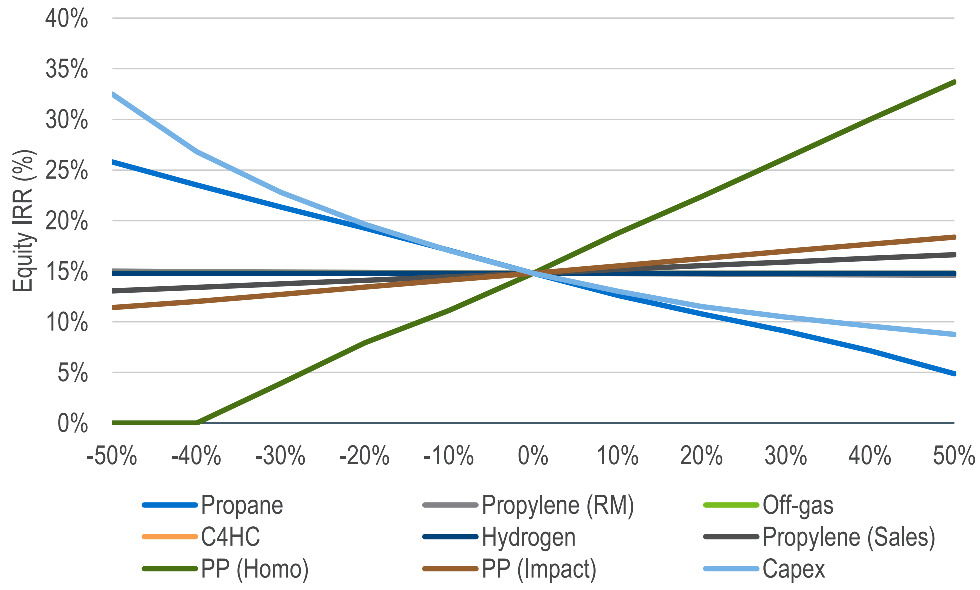


Table 10.11 Sensitivity Analysis on Equity IRR of Complex (Base Case)

	Equity IRR Sensitivity										
	-50%	-40%	-30%	-20%	-10%	0%	10%	20%	30%	40%	50%
Propane	26%	24%	21%	19%	17%	15%	13%	11%	9%	7%	5%
Propylene (RM)	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
Off-gas	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
C4HC	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
Hydrogen	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
Propylene (Sales)	13%	13%	14%	14%	14%	15%	15%	16%	16%	16%	17%
PP (Homo)	No Return	No Return	4%	8%	11%	15%	19%	22%	26%	30%	34%
PP (Impact)	11%	12%	13%	13%	14%	15%	16%	16%	17%	18%	18%
Capex	32%	27%	23%	20%	17%	15%	13%	12%	10%	10%	9%

Figure 10.6 Sensitivity Analysis on NPV of Complex (Base Case)

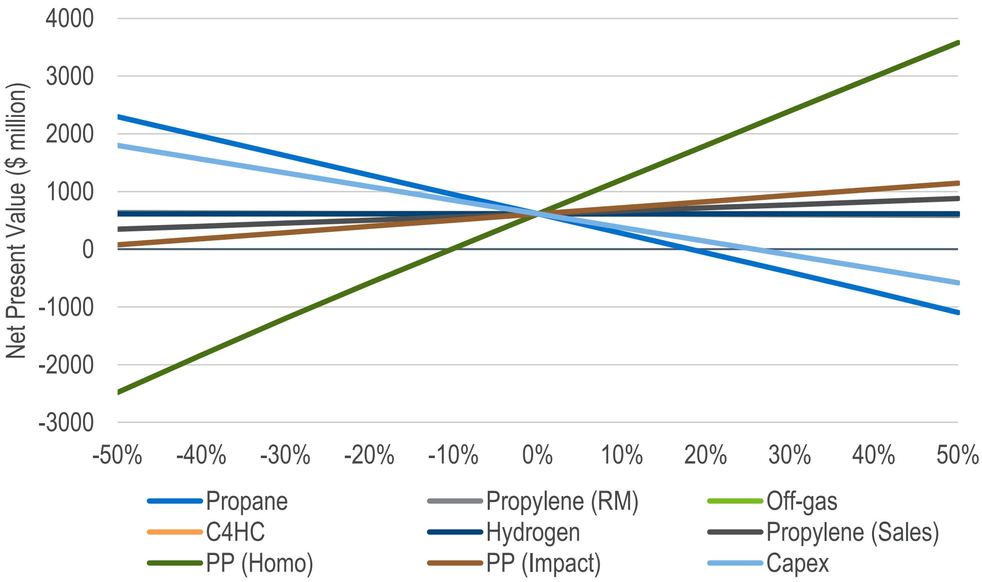


Table 10.12 Sensitivity Analysis on NPV of Complex (Base Case)

	NPV Sensitivity										
	-50%	-40%	-30%	-20%	-10%	0%	10%	20%	30%	40%	50%
Propane	2 295.0	1 958.3	1 621.5	1 284.8	948.1	611.3	274.6	(62.7)	(401.3)	(742.6)	(1 093.8)
Propylene (RM)	638.4	633.0	627.5	622.1	616.7	611.3	605.9	600.5	595.1	589.7	584.3
Off-gas	611.3	611.3	611.3	611.3	611.3	611.3	611.3	611.3	611.3	611.3	611.3
C4HC	611.3	611.3	611.3	611.3	611.3	611.3	611.3	611.3	611.3	611.3	611.3
Hydrogen	611.3	611.3	611.3	611.3	611.3	611.3	611.3	611.3	611.3	611.3	611.3
Propylene (Sales)	345.8	398.9	452.0	505.1	558.2	611.3	664.4	717.5	770.6	823.7	876.8
PP (Homo)	(2 479.1)	(1 834.6)	(1 196.9)	(581.2)	16.8	611.3	1 205.7	1 800.1	2 394.5	2 988.9	3 583.3
PP (Impact)	75.0	182.3	289.5	396.8	504.0	611.3	718.6	825.8	933.1	1 040.4	1 147.6
Capex	1 799.8	1 562.1	1 324.4	1 086.7	849.0	611.3	373.6	135.9	(102.1)	(340.8)	(579.6)

The financial attractiveness of the Project is mainly influenced by variations in:

- Propane price
- Homo polypropylene netbacks
- Capex

The propane price is the single most important determinant of the cost of PP production. A high propane price not only lowers the general financial attractiveness of the Project. At the Base Case, the Project and Equity IRR are 11 and 15 percent, respectively. At a 20 percent increase in the price of propane the NPV of the Project becomes negative and the Project and Equity IRR drop to eight and 11 percent, respectively.

Homo PP prices have a strong influence on the Project's economics, resulting in no return for both project and equity IRR when prices have reduced by 40 percent. Polypropylene is a global commodity, and any typical single producer has limited bearing on international prices given the size of the market and limited market concentration. Typically, producers aim to optimise their marketing and sales plans to maximize their netbacks, where possible.

The CAPEX to build the facilities is another very important factor to determine the financial attractiveness of the Project. Unlike product prices, CAPEX can be optimised by choosing EPC contractors with good track records delivering similar projects on time and budget. Since the modelled CAPEX is based on pre-FEED level study, the sensitivity analysis can indicate the expected level of returns should the CAPEX change after finishing the FEED study.

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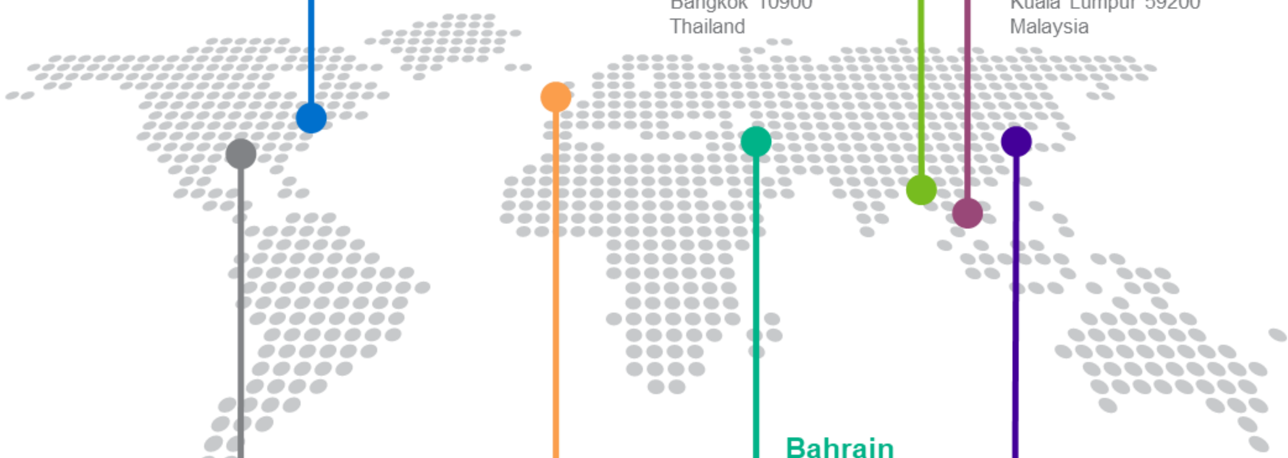

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