

Challenges and Opportunities During the Transformation Process in the Petrochemical Industry

Strengthening European Supply and Value Chains



Executive Summary // Europe's Petrochemical Sector at a Crossroads: Driving Competitiveness Through Focus and Collaboration

EUROPE'S PETROCHEMICAL INDUSTRY IS PIVOTING FROM A GROWTH-CENTRIC PAST TO A FUTURE FOCUSED ON RESILIENCE AND CARBON EFFICIENCY. THE REGION'S PRODUCERS FACE PERSISTENT COST PRESSURES, STRICT CARBON REGULATIONS, AND AGING CRACKER INFRASTRUCTURE.

To remain competitive under these conditions, companies must embrace tighter integration, feedstock flexibility, collaborative partnerships, carbon-smart investments, and value-chain resilience. Success now hinges on strategic focus and coordination across the entire petrochemical value network.

Cracker operators in Europe confront a convergence of challenges. One major issue is feedstock inflexibility – most European crackers rely on naphtha, whereas competitors in North America and the Middle East crack less expensive ethane, making European ethylene

production over three times more expensive than U.S. benchmarks. Additionally, high energy costs (exacerbated by recent crises) and carbon pricing have squeezed margins. Many of Europe's crackers are old and sub-scale, struggling with efficiency; average utilization fell to ~75% during the 2022–23 energy crunch (versus ~90% in healthier times), forcing several shutdowns. These pressures underscore the urgency for structural changes to improve flexibility and reduce costs.

The ethane cracker is a highly efficient producer of ethylene, but its ability to generate additional value through co-cracking is quite limited. In contrast, the naphtha cracker does not represent the most cost-effective pathway for ethylene production, yet it offers significant potential to unlock further value via its co-crack stream." Amid these headwinds, midstream C4 integration has emerged as an important lever for resilience. Evonik Oxeno plays a role as a C4 integrator that

stabilizes the value chain by providing reliable off-take of by-product streams and upgrading them into higher-value products. Operating a C4-Verbund network across Marl (Germany) and Antwerp (Belgium), with Oxeno's technological capabilities Oxeno can handle variable C4 stream qualities, including steam cracker crude C4 and refinery FCC-C4. These capabilities bolster overall supply-chain efficiency and resilience, providing a crucial buffer in a high-cost, volatile market.

Crucially, Oxeno couples this flexibility with decision-centric, scenario-based planning using data-driven supply & operations planning (S&OP) tools.

This cooperative approach prevents bottlenecks and creates win-win synergies: upstream crackers run more smoothly, and downstream consumers receive stable input supply.



CONTENTS

02	EXECUTIVE SUMMARY
04	HISTORICAL CONTEXT AND INDUSTRY TRANSFORMATION DRIVERS
05	CHANGING GLOBAL FEEDSTOCK DYNAMICS
06	OVERCAPACITY AND THE RISE OF ASIA
08	SUSTAINABILITY IMPERATIVES
10	ENERGY PRICES
11	GEOPOLITICAL AND SUPPLY SECURITY ISSUES
14	INTEGRATED C4 PROCESS NETWORKS AND FULL FEEDSTOCK UTILIZATION
16	LEADING ENABLER IN THE C4 VALUE CHAIN
18	CONCLUSION

HISTORICAL CONTEXT AND INDUSTRY TRANSFORMATION DRIVERS

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DURING THE SECOND HALF OF 20TH CENTURY, WESTERN EUROPE ENJOYED A PERIOD OF STEADY GROWTH, BECOMING A WORLD LEADER IN PLASTICS AND CHEMICALS PRODUCTION. HOWEVER, BY THE EARLY 21ST CENTURY THIS ONCE HIGH-GROWTH INDUSTRY HAD ENTERED A MATURE PHASE.
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In fact, EU chemical production peaked around 2007 (at 314 million tons) and never fully recovered after the 2008 – 09 financial crisis. Production briefly rebounded in 2010 and 2017, but by the late 2010s the trend turned downward again¹. Over the decade 2013 – 2023, Europe's chemical production actually shrank slightly (around –0.8% per year) on average². A recent European Chemical Industry Council (Cefic) report notes that European chemical output plunged 6.6% in 2023

(vs 2022)² but then saw only a very modest recovery of 2.5% in 2024³, underscoring the long-term stagnation. The EU27 now accounts for just 13% of global chemical sales (down from 28 % in 2003)². China meanwhile has surged ahead and has become the world's largest chemical producer, its output growing 6.8% in 2024 and contributing an estimated 86% of worldwide chemical production growth that year⁴. In other words, Europe's chemical industry has shifted from an era of expansion to one of structural stagnation and decline. Other emerging economies saw only modest gains – for example, India's output grew just 1.8% in 2024⁴.

At the same time Europe's share of the world chemicals market has also been in steady decline dropping significantly over the past 20 years² as markets became saturated and

showed a shift from growth to maturity. Around the year 2000, the EU accounted for roughly one-third of global chemical sales. Here China has also since surged ahead now holding about 43% of global chemical sales². Historically a net exporter, the EU recently thus saw its first trade deficit in chemicals. In the first half of 2022 – amid an energy price shock – Europe, posted a €5.6 billion trade deficit⁵, reflecting a loss of competitive edge.

CHANGING GLOBAL FEED-STOCK DYNAMICS

In the petrochemical industry, producers can use different feedstocks to produce Olefins. European ethylene producers remain heavily reliant on naphtha feedstock, in contrast to regions like North America and the Middle East that crack ethane from abundant, less expensive ethane-rich natural gas⁶. This has given North American and Middle Eastern crackers a sharp cost advantage. Also, Ethane-fed steam crackers produce primarily ethylene (with smaller amounts of propane/propylene by-products), simplifying logistics and integration. As a result, European ethylene was estimated to cost roughly \$800 per ton in 2024, compared with about \$400/t in the U.S. and \$200/t in the Middle East, due to Europe's higher feedstock and energy costs⁶.

Naphtha cracking on the other hand yields a broad slate of co-products, including C4-rich streams (crude C4 containing butadiene and butylenes) and subsequent fractions like raffinate-1 and raffinate-2. These co-products can be extracted and processed into value-added products (rubber monomers, fuel additives, etc.), adding complexity to European petrochemical operations but also creating a

value pool.

The integrated production model (the Verbund concept) evolved to handle this complexity by maximizing utilization of every fraction. For example, specialized intermediates producers focus on the C4 stream – for example Evonik Oxeno alone takes substantial volume of the region's merchant crude C4, even processing refinery C4 streams (FCC-C4), a sulfur rich C4 cut from oil refineries typically considered challenging to use for chemical processes, that would otherwise end up as gasoline blending components or would be co-cracked.

Still, European steam crackers – often older, smaller units running on oil-derived feed (naphtha) – sit at the high end of the global cost curve. The energy crisis of 2022 – 2023 further eroded competitiveness. Average cracker capacity utilization in the EU sank to 75%, well below the typical 85 – 90% considered healthy⁷ and the historical levels⁶, as demand stagnated and high operating costs forced output cuts. These pressures have already led to several European cracker closures or announced shutdowns in recent years⁸. To adapt, European petro-

chemical players are pursuing feedstock flexibility and selective investments. Many naphtha crackers have upgraded capabilities to switch among liquid feeds or incorporate liquefied petroleum gas (propane/butane) when economical. This flexibility allows firms to respond quickly to volatile supply, demand, or even daily variations in feed composition.

On a larger scale, Europe is also investing in new ethane-based capacity to narrow the cost gap. INEOS's Project ONE in Antwerp exemplifies this shift: a state-of-the-art ethane cracker (1.45 million tons ethylene per year) slated to start up by 2026–27^{8,9}. As the industry's biggest European investment in decades⁹, Project ONE will import US ethane to secure a cheaper feedstock for Europe. Overall, the changing global feedstock dynamics compel Europe to reinvent its model – balancing its unique, integrated co-product value chains with newfound flexibility and feedstock innovation – in order to remain a viable player in the global petrochemical world.

OVERCAPACITY AND THE RISE OF ASIA

THE STAGNATION OF EUROPE'S DOMESTIC PETROCHEMICALS MARKET IN RELATION TO OTHERS COINCIDED WITH A SPECTACULAR RISE OF ASIAN MARKETS. CHINA AND OTHER ASIAN ECONOMIES MASSIVELY EXPANDED THEIR PETROCHEMICAL CAPACITY.

For example, China's ethylene production capacity reached about 55 million tons per year in 2024¹⁰ (up from much lower levels in the 2000s) and is forecast to grow to ~80 million t/y by 2028, accounting for roughly half of new global capacity¹¹. Other countries in Asia – such as India, South Korea, and several in Southeast Asia – have also added large new crackers and aromatics complexes in pursuit of self-sufficiency¹². In the past two decades China in particular pursued petrochemical self-sufficiency with dozens of new world-scale crackers and aromatics complexes. This rapid buildup in Asia, combined with only tepid growth in already mature markets like Europe and North America, has led to a situation of global overcapacity. Supply has overshot demand in many petrochemical chains, putting intense downward

pressure on margins worldwide.

Europe has been especially hard hit. Whereas European producers in the 2000s could often run plants at high utilization to serve in particular export markets, today they face slack capacity. This glut is also evidenced by Europe's cracker margins, which have struggled to recover since the 2020 pandemic and flipped negative during the energy crisis. According to S&P Global Commodity Insights (2024), Northwest European ethylene spot margins in early 2024 were barely one-third of their five-year average level⁷. In effect, Asia's capacity surge and weak demand have created a buyer's market for petrochemicals, eroding the profitability of higher-cost producers in Europe¹³.

The response in Europe has been a wave of capacity rationalization. Cefic observes that the European industry is now facing structural challenges rather than a normal business cycle upturn/downturn. As evidence, numerous plant shutdowns have been announced: in 2023–24 alone, European petrochemical producers slated closure of about 1.0–1.1 million tons per year of olefins capacity (ethylene/

propylene), along with nearly 2.8 million tons of aromatics and 1.8 million tons of polymer⁷. With nearly half of Europe's 40 crackers under 500,000 tons per year capacity¹⁴, many producers are retiring older, inefficient units to focus on larger integrated sites.

In April 2024, ExxonMobil announced it would shut its 425,000 tons per year ethylene cracker in Gravenchon (Port-Jérôme, France) by year-end, citing sustained losses and high operating costs¹⁵. SABIC likewise decided to permanently close one of its two crackers at Geleen, Netherlands (550,000 tons per year ethylene) in 2024 as part of a strategic reorientation¹⁶.

In 2025, additional closures and divestments were announced. Dow opted in early 2025 to idle one of three Terneuzen crackers (600,000 tons per year ethylene) indefinitely rather than overhaul it, given weak European demand¹⁷. In April 2025, TotalEnergies announced plans to shut the older of its two Antwerp crackers by end-2027 to address Europe's ethylene surplus¹⁸, removing about 640,000 t/y of capacity. Meanwhile, LyondellBasell moved to divest instead of close certain facil-

ities: in mid-2025 it agreed to prepare a sale of assets its Berre (France) and Münchsmünster (Germany) cracker sites (465,000 and 400,000 tons per year ethylene, respectively) to investor Aequita¹⁹, avoiding the costs of shutdown and decarbonization. Also BP is looking for a seller for its NRW Scholven-site since this year²⁰.

These permanent capacity reductions underscore that Europe has more petrochemical capacity than it can profitably use under current conditions. Even when demand picks up cyclically, much of the new demand is being captured by Asian producers or Middle Eastern exporters, leaving European plants underutilized. Indeed, Europe's chemical output in early 2024

showed only a meager 0.4% uptick year-on-year (after the steep drops of 2022–23), which was attributed solely to short-term restocking rather than a real recovery in demand. European industry association Cefic warned that this should “not be perceived” as a solid rebound, given the anemic outlook and structural headwinds⁷.



SUSTAINABILITY IMPERATIVES



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ANOTHER EUROPEAN CHALLENGE WHICH UNILATERALLY INFLUENCES AND ADVERSELY AFFECTS THE INDUSTRY ON THE CONTINENT, IS THE EUROPEAN UNION'S GREEN DEAL AND CLIMATE LAW THAT MANDATE A CIRCULAR AND CLIMATE-NEUTRAL (NET-ZERO) ECONOMY BY 2050, WITH AN INTERIM TARGET OF CUTTING GREENHOUSE GAS EMISSIONS TO 55% IN 2030 AND 90% BY 2040²¹.
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This ambitious trajectory has to be met by reducing process-related CO₂ emissions and utilizing non-fossil based feedstocks. In response, Europe's petrochemical industry is pursuing breakthrough decarbonization initiatives. These range from electrifying steam cracker furnaces to deploying carbon capture and storage (CCS) technologies, aimed at significantly reducing CO₂ emissions while maintaining output of key chemicals²². Such measures are central to aligning the sector with the EU Green Deal's objectives. Another option, that is increasingly and repeatedly being discussed in the industry, is the relocation of parts of the production to non-European sites. Or as an even more extreme solution the closure of sites is under consideration or already underway because of the poor economic situation. As a result, the EU chemical sector is advocating policy support to restore competitiveness (e.g. energy cost relief and carbon cost mitigation)^{5,6}.

But there are also other ideas: Oxeno for example has simultaneously developed a roadmap of proj-

ects to reduce process-related CO₂ to almost zero and is able to process any non-fossil C4 based feedstock. This requires significant capital expenditure to enable this transformation. These costs however apply especially to the European producers.

One example of collaboration along the value chain is Oxeno's early adoption of sustainability certifications. Since November 2021, Oxeno's production sites in Marl and Antwerp have been ISCC Plus and ISCC EU certified, providing traceability of sustainable raw materials throughout the supply chain. This directly enables Oxeno's customers to market their end products as ISCC-certified.

ENERGY PRICES

AS ALREADY DESCRIBED, EUROPEAN STEAM CRACKERS FACE SIGNIFICANTLY HIGHER PRODUCTION COSTS THAN THEIR GLOBAL COMPETITORS. TWO FACTORS ARE PRICES FOR NATURAL GAS AND ELECTRICITY IN EUROPE, WHICH HAVE SPIKED IN RECENT YEARS, UNDERMINING CRACKER ECONOMICS FURTHER.

By contrast, U.S. operators enjoy less expensive shale gas and lower electricity prices – a disparity highlighted by INEOS, which noted one major German chemicals site pays €100 million more for gas and €40 million more for electricity annually than an equivalent U.S. plant²³. Such cost gaps severely squeeze European cracker margins.

Some segments even slid into negative margins during the 2022 energy crisis. Industry leaders caution that Europe’s petrochemical sector cannot survive long under such conditions: “The industry is in crisis with such huge disadvantages compared to America... [we are] fighting for survival,” Sir James Arthur Ratcliffe, chairman and chief executive officer (CEO) of the INEOS chemicals group, wrote in an open let-

ter²³. Unless Europe finds relief through cheaper energy or policy support, high production costs will continue to undermine steam cracker viability and deter new investment.

Naphtha cracking is energy-intensive, and many EU crackers are older, smaller units with lower efficiency than modern world-scale plants. Crucially, Europe’s industrial energy prices (natural gas, steam, electricity) are far above those in the US or Middle East. The 2021 – 2023 period saw European gas prices spiking to 4 to 8× US levels²⁴, and while they have eased, structural costs remain.

For instance, electricity for large industrial users in Europe often carries 20 – 30% in taxes and network charges (for electricity transmission, distribution, and renewable funding) and emissions-related levies, Costs largely absent in competitor regions. Analyses indicate that such regulated charges are several-fold higher in Europe than in Asia². These charges add to per-unit costs and reduce flexibility. By contrast, competitors in the Middle East often benefit from subsidized energy, and U.S. producers benefit from lower delivery charges due to abundant local supply infra-

structure. Overall, European olefin producers spend substantially more on energy per ton of output, contributing to a higher baseline cost.

The net effect is that European steam crackers face a “triple penalty”: expensive feedstock, carbon costs, and elevated energy overhead. This is reflected in cost benchmarks – for example, recent industry cost curves show European ethylene production at the high-cost end, in stark contrast to Middle East ethane crackers at the low end.

GEOPOLITICAL AND SUPPLY SECURITY ISSUES

EUROPEAN PETROCHEMICALS’ HEAVY RELIANCE ON IMPORTED OIL, GAS, AND FEEDSTOCKS HAS BECOME A VULNERABILITY AMID RISING GEOPOLITICAL TENSIONS AND INSECURITIES

These became apparent to the greater public for the first time during the Covid-Crises, when a Containership blocked the Suez Canal, disrupting global supply chains. The war in Ukraine slashed Russian pipeline gas to Europe from nearly half of EU supply to under one-fifth by 2023²⁵, forcing a pivot to pricier

seaborne LNG and denying the industry the cheap gas that it previously had thrived on. This also caused concerns about energy security for Europe’s crackers. Even after diversifying suppliers, Europe now faces a volatile global LNG market with competition from Asia, weather-driven demand swings, and shipping bottlenecks.

A recent Middle Eastern conflict underscored this fragility: attacks near the Red Sea led many shippers to avoid Suez²⁶. Other flashpoints loom. The Strait of Hormuz – which carries

about a fifth of the world’s oil²⁷ – remains a constant risk amid Persian Gulf tensions.

Additionally, Europe’s own infrastructure has been targeted: the 2022 Nord Stream pipeline sabotage showed how critical energy routes can be severed.





EUROPEAN PETROCHEMICAL TRANSFORMATION IS BEING DRIVEN BY COST-REDUCTION AND RIGHTSIZING, FOLLOWED BY A REALIGNMENT OF REGIONAL PRODUCTION AND SUPPLY CHAINS. THIS CAN BE ACHIEVED BY **ADVANCED PROCESS INTEGRATION AND SPECIALIZED TECHNOLOGICAL EXPERTISE.**

INTEGRATED C4 PROCESS NETWORKS AND FULL FEED-STOCK UTILIZATION

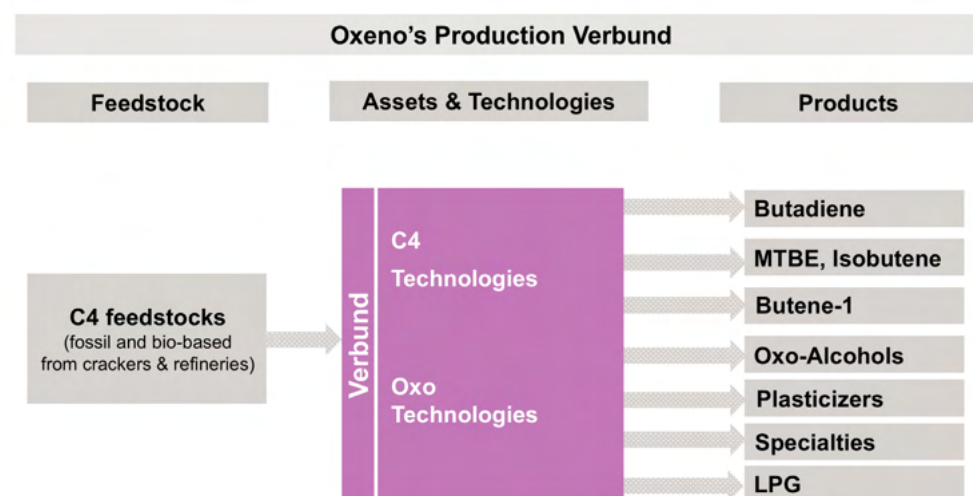
THIS HOLDS TRUE FOR ALL PETROCHEMICAL PLANT FORM CHEMICALS BUT A PRIME EXAMPLE OF INTEGRATION-DRIVEN EXPERTISE IS THE WORLD'S LARGEST INTEGRATED C4-BASED PRODUCTION NETWORK AT MARL (GERMANY) AND ANTWERP (BELGIUM).

This C4-Verbund system is a cluster of processes that cross-utilize each other's outputs: all molecules present in the C4 streams are converted into value-added products, creating a nearly 100% utilization of the raw material.

Such integration requires specialized technologies. For instance, Evonik Oxeno has developed unique purification and catalytic processes that allow it to handle the FCC-C4 stream. By implementing an innovative cleaning and selective hydrogenation procedure, Oxeno became the only company worldwide capable of fully upgrading FCC-C4 into chemical feedstock. This is an alternative to the typical use in refineries to produce fuel ethers and alkylate.

Equally important is the aforementioned feedstock flexibility – the ability to draw value from multiple raw material sources.

The transformation leads to reduced capacities in the cracker landscape causing underutilized C4 units. This offers the opportunity for new symbioses of cracker operators and Evonik Oxeno stabilizing margins across the value chain. In practical terms, Oxeno's integrated process network takes in more C4 raw material than any single downstream unit and through a series of linked processing steps it converts all components of crude C4 into sellable products.



OXENO: LEADING ENABLER IN THE C4 VALUE CHAIN

A CORE STRENGTH OF OXENO LIES IN THE FLEXIBILITY OF ITS INTEGRATED C4 NETWORK. THE COMPANY OFFERS CRACKER OPERATORS A RELIABLE OFFTAKE FOR THEIR C4 BY-PRODUCTS, PREVENTING BOTTLENECKS IN THEIR PROCESSES.

In other words, collaboration with Oxeno creates synergies for everyone – cracker operators can focus on their main products (like e.g., ethylene and propylene) while Oxeno adds value by upgrading the C4 co-products into useful chemicals, ensuring continuous operations and minimizing risk for the suppliers. At the same time, Oxeno's cross-site production network – spanning two fully integrated plants – allows it to balance and redirect streams as needed, maintaining steady output to customers even if feed compositions or availabilities change.

Oxeno's integrated planning systems enable rapid adjustments to supply/demand changes or raw material variations, so that partners along the chain experience stability in their value chains despite a volatile market environment. In essence, Oxeno acts

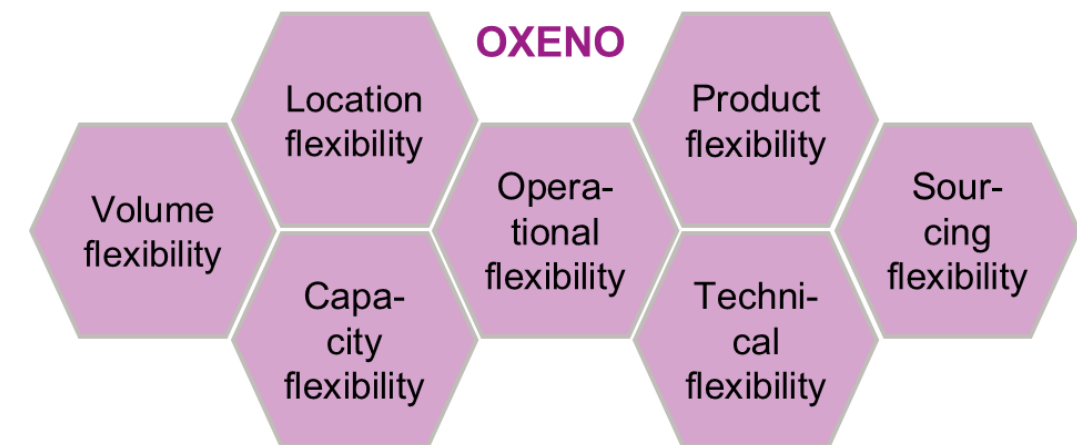
as a central hub in the C4 value chain, converting diverse raw material streams into a broad portfolio of C4-based products, and ensuring that both upstream suppliers and downstream customers benefit from a resilient, well-orchestrated network.

Oxeno's business philosophy is built on long-term partnerships and cooperation. The company actively seeks to expand strategic collaborations across the entire C4 value chain, believing that working closely with partners yields mutual benefits and innovative solutions. Oxeno maintains an open dialogue with industry stakeholders to explore potential opportunities for collaboration across the C4 value chain, in full compliance with applicable competition laws. There are many forms such cooperation could take, from Oxeno guaranteeing full off-take of by-product streams to tolling agreements. By engaging in such dialogues and creative arrangements, Oxeno helps craft win-win outcomes that strengthen the overall value network instead of allowing valuable assets or materials to go underutilized.

This collaborative mindset

extends to day-to-day operations as well: Oxeno works closely with suppliers on digital integration of planning and logistics. The company is implementing a digital network that links organizations, simplifying processes and sharing expertise across company boundaries. In fact, Oxeno already practices collaborative planning of raw material requirements together with selected suppliers, leveraging digital platforms to align supply and demand in real time. Such initiatives underscore Oxeno's role as a reliable, partnership-oriented player that views its customers and suppliers as true partners in a shared value chain.

Highly flexible Verbund



- ✓ Continuously producing multipurpose plant
- ✓ Able to adopt capacity to market development
- ✓ Able to change produced products rapidly
- ✓ 'Verbund' opening options to utilize capabilities of both production sites
- ✓ Ability to decouple sequences of process steps
- ✓ Integration enables drop-in solutions for bio-based and recycled feedstocks
- ✓ Use of reserves and expertise to integrate new capacities and technologies
- ✓ Dynamic plant operation of power consuming components and production steps

Ensuring Europe's Future as a Competitive Petrochemical Hub

EUROPE'S PETROCHEMICAL SECTOR STANDS AT A PIVOTAL JUNCTURE.

To remain a competitive hub amid high costs and carbon constraints, the industry must undergo transformative change. European producers face intense pressure from elevated energy prices and stagnant demand, underscoring the urgency of action. By embracing several strategic priorities – integration, flexibility, collaborative partnerships, carbon-smart investment, innovation of processes and products as well as supply chain resilience – the sector can regain its competitiveness.

Evonik Oxeno, functioning as an operative partner independent of ownership at the interface of cracker outputs and downstream

chemicals, exemplifies how mid-stream integration bolsters this competitiveness. This unit is a leading processor of C4 by-product streams in Europe – by most accounts the single largest offtaker of crude C4 from regional crackers. It handles a significant portion of Europe's C4 fraction, leveraging long-term supply agreements and unique technology (e.g. for FCC-C4) to secure its position. Its integrated C4-Verbund network enables feedstock flexibility and co-product valorization. This ensures upstream operators to have a reliable outlet for by-products and downstream producers to have a steady supply of inputs. Furthermore, Oxeno can absorb almost any C4 quality, amount and even return certain components to crackers as feedstock to balance the system. These capabilities

improve the overall efficiency and resilience of Europe's steam cracker operations.

Looking ahead, Europe can remain a robust petrochemical hub. Integration, flexibility, collaboration, carbon-efficient innovation, and resilient supply networks will define the winners of the future. Companies that move decisively on these fronts will not only secure their own success but also ensure the long-term competitiveness and sustainability of Europe's hydrocarbon industry. Additionally, the European governments have to formulate and apply new industrial policies that rebalance the equivalent ecological and economical needs. Only then, the industry will master the transformation from a fossil petrochemical to a net zero hydrocarbon layout.

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