WHITE PAPER

Opportunities in Global Ethylene Economics

May 2023
By Mirko Rubeis, Marcus Morawietz, Marcin Jedrzejewski, Hubert Schoenberger, Yaroslav Verkh, Rafael Moreno, Graeme McMillan, and Ana Mourao

Introduction

The Ukraine conflict has fundamentally changed the tectonics of global political and economic systems. In all probability, cheap natural gas and oil from Russia as a raw material for the European industries is finally a thing of the past. Skyrocketing energy prices in 2022 have triggered a tendency towards inflation. To counter that, the US has imposed the Inflation Reduction Act (IRA), which is also set to promote sustainability. In fact, it is a gigantic subsidy program for companies investing in the US market and at the same time offers green tax credits for emission reductions. In the current overall situation, IRA is impacting the competitiveness of European producers even more, notwithstanding European Union (EU) programs such as the Green Deal Industrial Plan and Member State Aid, aimed at improving the competitiveness of the local manufacturing industry.

The European basic chemicals and plastics industry is particularly suffering from high feedstock and energy prices, which are squeezing profit margins. The industry is faced with the question to what extent naphtha-based ethylene production will continue to be economically viable. Additionally, climate change and the resulting decarbonization will lead to systemic changes that will further affect the market.

For example, the mobility revolution and electrification of transportation will reduce demand for gasoline. In the medium term, more naphtha will then be available. However, in the long term, falling gasoline demand could also trigger a wave of refinery closures, which will lead to a reduced supply of naphtha.

Furthermore, recycling will become more important as part of the circular economy. For example, the EU passed legislation demanding mandatory shares of recycled plastic in many products. Bio-based polymers such as polylactic acid will replace some ethylene-based polymers such as polyethylene and PET. Declining demand for virgin plastics will impact future capacity increases of polymers. In the following report, we evaluate the impact of the current transformation processes on the chemical industry. We also draw conclusions and provide recommendations.

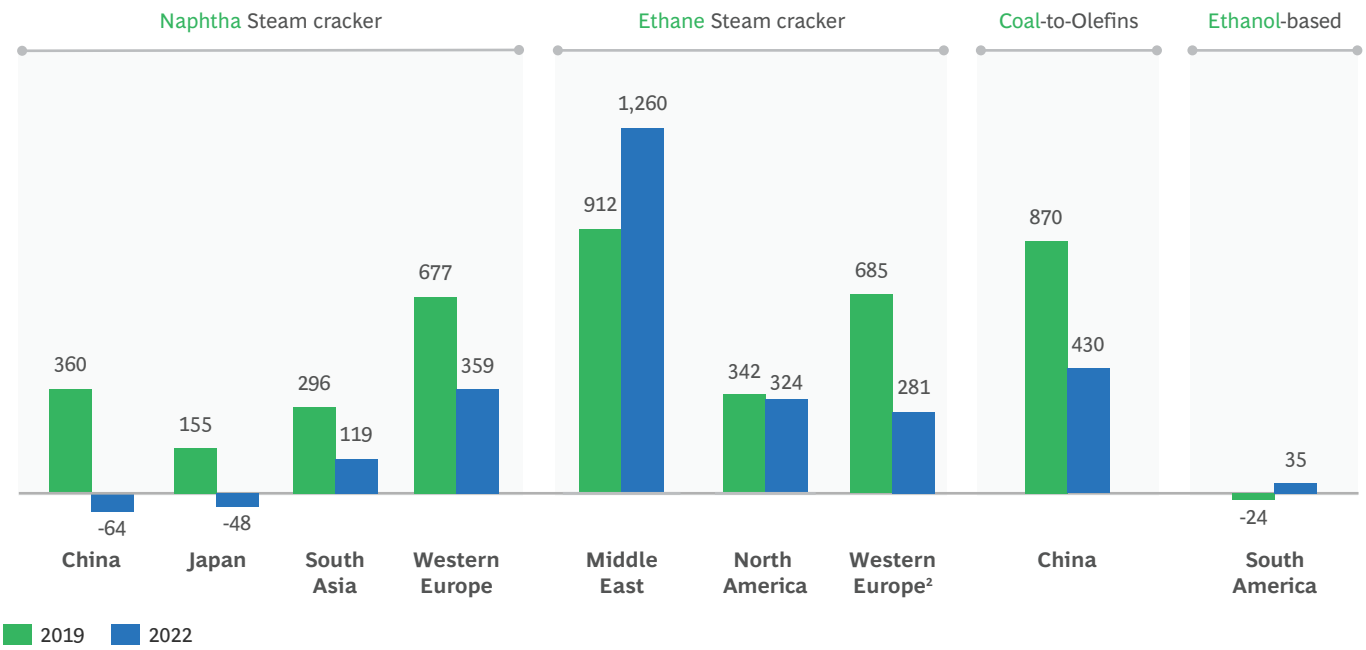
The shale gas revolution has fundamentally changed the structures of global ethylene production

Shale gas production in the US since the end of this century's first decade has changed the global ethylene market. Regional feedstock dynamics, unprecedented on this scale, emerged. They clearly favor gas-based ethylene production over naphtha in the current price environment, as one figure illustrates: since 2021, oil prices have reached record levels that resulted in a price difference between the two ethylene feedstocks, naphtha and ethane, of up to $400 per metric ton.[1] The last time the price difference had been this high was between 2012 and 2014.

C2 margins are generally limited by the ethylene conversion market and demand in the most important market, polyethylene, is slowing down. Producers of naphtha-based ethylene however still benefit from margins generated by the C3 (propylene), C4 (butadiene), and aromatics byproducts of the cracking process. Especially Western Europe profited from a price premium of C3 products in 2021 and 2022.

NAMR & ME Ethane Crackers Resilient in Recent Crises

Avg. Ethylene Margin[1] $/ton



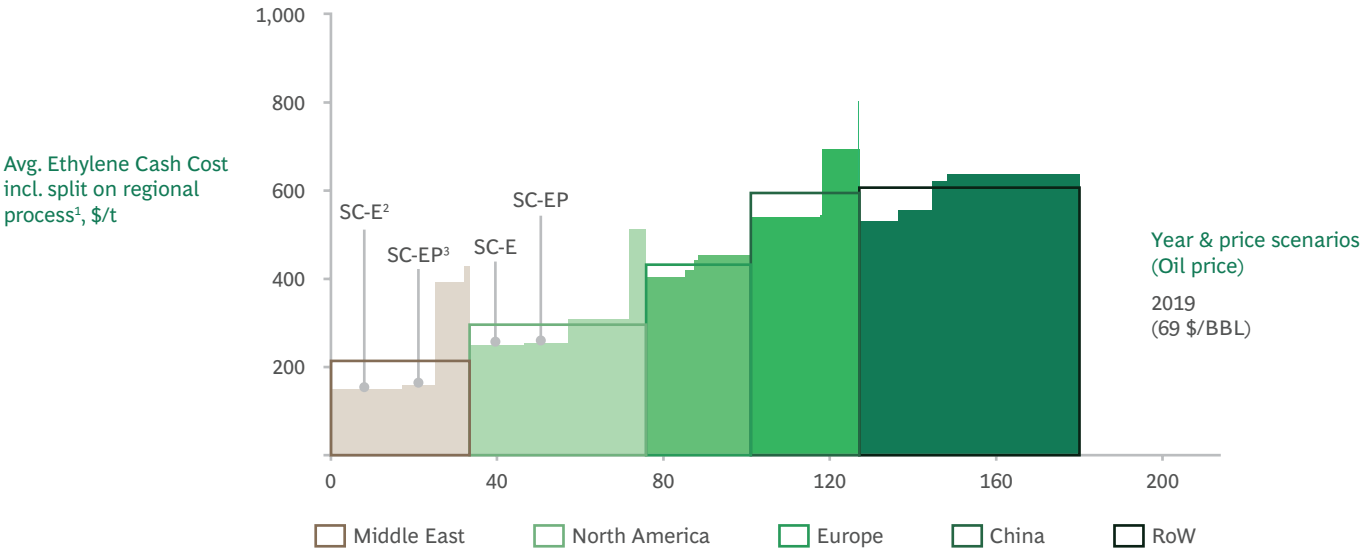
[1] Calculated as [Regional Price] – [Capacity-weighted average regional Cash Cost]
[2] Crackers run with the imported US Gulf Ethane
Source: Nexant; BCG Analysis

1. All measurements contained within this report are given in metric tons, unless specifically indicated otherwise.

Consequently, margins for naphtha-based ethylene are shrinking. Ethane crackers in the US and the Middle East, on the other hand, continue to generate attractive margins. Accordingly, at the start of the 21st century, the US and the Middle East have expanded their plants. Between 2000 and 2010, the latter region alone was responsible for half of the global capacity expansion. This top position has since been lost due to the depletion of ethane sources – despite technical improvements in gas processing and separation, which brought in additional feedstock.

The shale gas boom in the US and China's quest for self-sufficiency were the main capacity expansion drivers in both regions between 2010 and 2020. Over the past five years, global ethylene manufacturing capacity has grown twice as fast as ethylene demand, resulting in a current oversupply, especially in the US, and generating momentum of ethylene exports in addition to ethane exports. This is exemplified by the establishment of a large ethylene export center by the US pipeline operator Enterprise Products.

ME/NAMR Benefit from Gas-based Ethylene Production



[1] Average, plant capacity-weighted Cash Cost is Factory Gate Cash Cost without Depreciation & ROCE; Integration is assumed at Cash Cost; Operating rate assumed is 100%; WE Ethane price adjusted to the US import parity for select crackers in Grangemouth, Mossmorran, Rafnes, Stenungsund, Terneuzen, Wilton, Antwerp
[2] Steam Cracking of Ethane
[3] Steam Cracking of Ethane and Propane

Source: BCG Analysis

Current development of regional markets

US: price advantages and rising export quotas

Currently, the US exports 15 percent of its annual ethane production – equivalent to around 7.7 million metric tons. High oil prices render the exploration of unconventional gas resources very attractive. US deposits rich in natural gas liquids (NGL) will further increase the supply of ethane. Companies such as INEOS and EverGas are capitalizing on this development: they are entering into trading agreements and relying on a fleet of mid-sized, general-purpose gas tankers for transportation. US exports of other C2 value-chain products, such as polyethylene, mono ethylene glycol (MEG), and ethylene dichloride (EDC)/polyvinyl chloride (PVC), will also continue to increase due to the price differential of ethane and naphtha as well as feedstock and energy disadvantages in other regions like Europe. The provisions of the IRA will further increase the imbalance of the basic market conditions in favor of the US.

China: imports and diversification

In China, no further significant increases in ethylene production capacity are expected in the near future. In addition to the high oil price, the overall unfavorable outlook in the refining sector is also a factor here. Instead, the major market players are likely to turn their attention to the direct conversion of Crude-Oil-To-Chemicals (COTC). This is particularly attractive for high-growth regions – such as China, India, and the Middle East – that have traditionally been reliant on integrated refining-petrochemical plants. The direct COTC conversion route will increase petrochemical capacity expansion in a more cost-effective manner: COTC allows for an attractive shift of the production from fuel to petrochemicals while fuel production could become less attractive in the medium term. China has already demonstrated the value of the aromatics variant of COTC with several complexes commissioned recently which support the Chinese PET value chain. The development of the olefin variant of COTC complexes is currently advancing in India and the Middle East.

Middle East: gas discoveries and green hydrogen

Since naphtha is a globally traded and liquid feedstock, Middle East producers do not have a cost advantage when using naphtha crackers. Ethylene production in this region is therefore mostly ethane-based. Whether the regional petrochemical industry remains competitive in the long term depends primarily on the degree of exploitation of the recent gas discoveries, which are rich in NGLs. A challenge for these new ethane sources, however, is to be competitive to US ethane. This is not a given, as some are in unconventional fields that require scale and a multi-year learning curve to bring upstream production costs to competitive levels. Middle-East is also exploring conversion of liquids to chemicals at scale, to direct more locally produced crude to chemicals, and reduce dependency on transportation fuels. Technology and scale are the two bets to make liquid cracking competitive in the global arena.

Another competitiveness factor, especially in the European and North American markets, is the decarbonization of the industry. This is where the IRA plays a role, not least by providing a considerable boost to investment in carbon reduction measures in the US. Given the regional low cost of solar energy, players in the Middle East are very well positioned and have started the decarbonization of the domestic markets with major projects for blue and, above all, green ammonia. The United Arab Emirates (UAE) has already set the goal of serving 25 percent of the global hydrogen market in the future. Similar targets have also been set by Saudi Arabia.

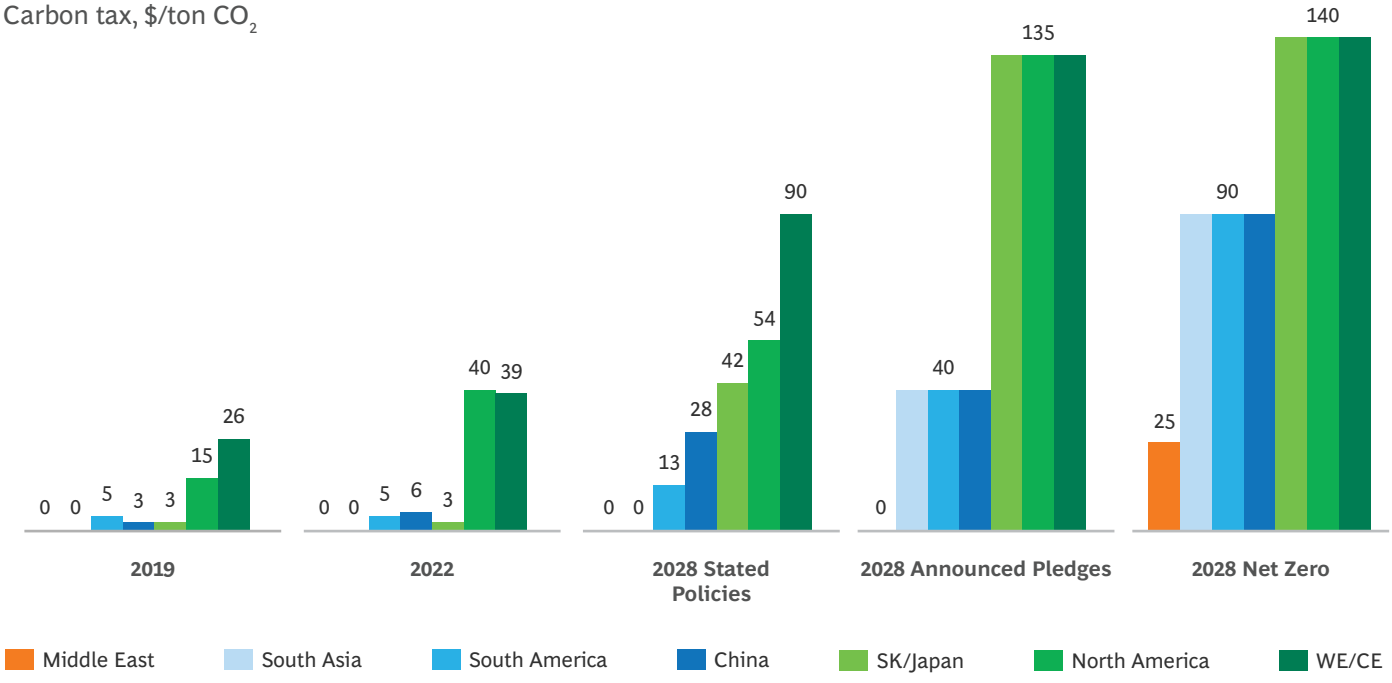
Europe: foreign investment and green products

As the European cracker landscape is mainly based on naphtha, the situation is particularly challenging. To remain competitive, European players are exploring imported ethane as a feedstock and taking advantage of economies of scale of newly built plants – given the current infrastructure in Europe, mainly coastal production sites benefit from potential imports. A good example of this is INEOS investing in a new, large ethane cracker in Antwerp as well as having bought oil and gas assets of Chesapeake Energy in Texas for around $1.4 billion. Naphtha-based C2 margins in Europe are threatened twofold by ethane imports to Europe and by subsidized investments in US infrastructure. European assets will foreseeably switch to green products, and they will try to increase margins with other products beyond C2-based chemicals, for example by refocusing their portfolios on more competitive downstream models. Also, given the continuing structural feedstock and energy disadvantage in Europe, we expect an increased value chain disruption of C1- and C2-based chemicals taking advantage of imports from non-European regions, especially North America and Middle East. Such disintegration of the European value chains will lead to a drop in ethylene demand and a subsequent rationalization of local steam crackers.

Outlook: carbon taxes as an additional challenge

Carbon taxes are expected to add to the cost of ethylene production. According to the International Energy Agency (IEA), based on announcements to date, a carbon tax of $140 per metric ton of CO_2 in developed countries and of $40 per metric ton in developing countries is expected by 2028. The IEA's net-zero scenario for 2028 projects a tax increase for the second group of countries to as high as $90. This scenario assumes that Middle Eastern countries will keep carbon taxes down to a minimum. The European CO_2 border adjustment mechanism (CBAM) will cover basic organic chemical products and polymers in Phase I between 2026 and 2030. This will partially reduce the competitiveness gap with imports.

Industrially Developed Countries Already at the Forefront of Bold Carbon Tax Goals

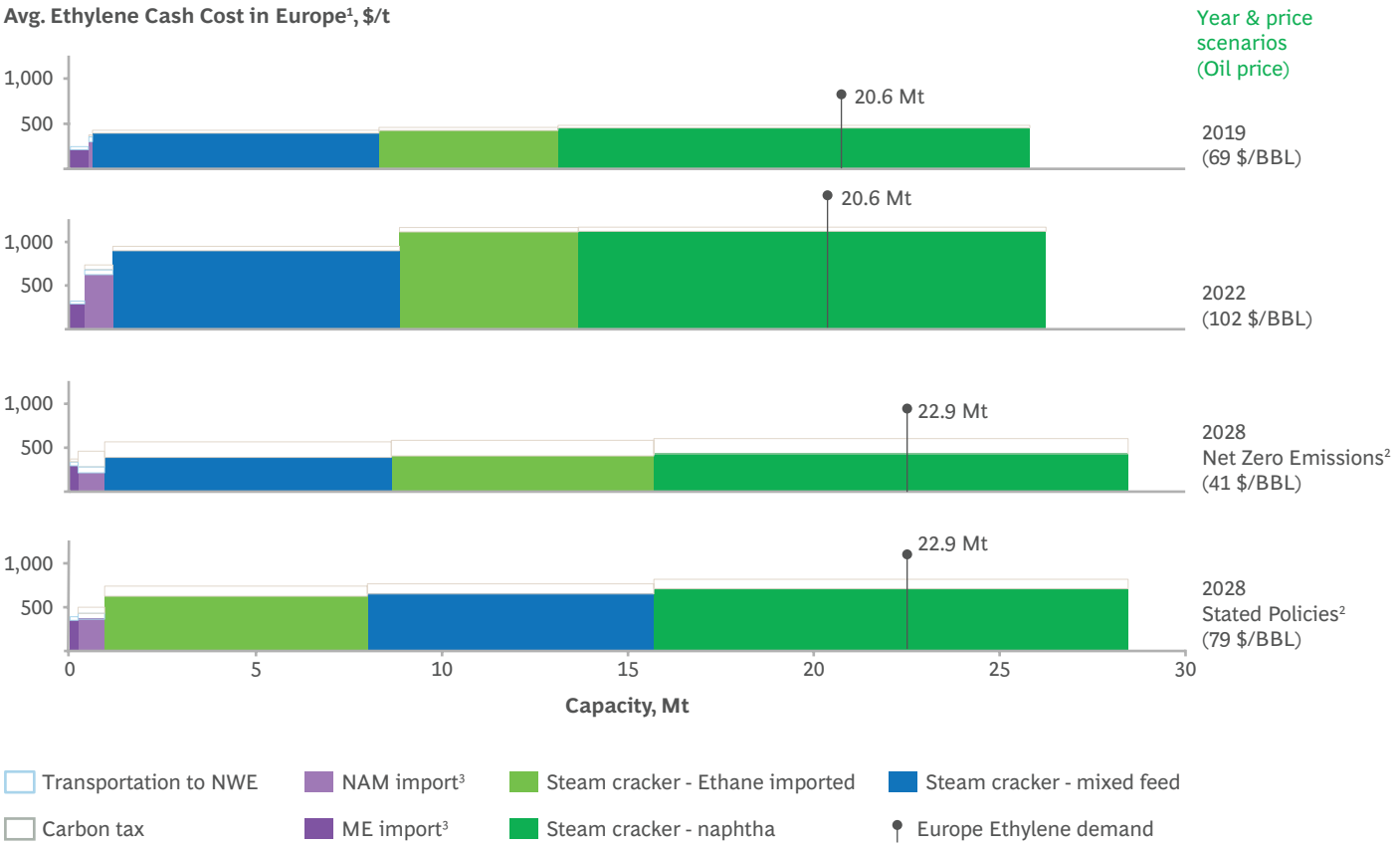


Note: Historic values based on data from C&S KT; 2028 values based on EIA scenario based on EIA's World Energy Outlook scenarios
Source: BCG analysis; IEA

Europe: will imported ethane dominate the market?

Due to the cost advantages of imported ethane and C2-based chemicals, Europe will benefit greatly from ethane as ethylene feedstock, regardless of the carbon tax scenario. According to the stated policies for 2028 at this time, import of ethylene itself is most advantageous. Due to limited merchant ethylene supply however, crackers using imported ethane will be the most viable option.

Europe | Ethylene Supply Curves include Carbon Tax



[1] Cash Cost is Factory Gate Cash Cost without Depreciation & ROCE; Integration is assumed at Cash Cost; Operating rate assumed is 100%; WE Ethane price adjusted to the US import parity for select crackers in Grangemouth, Mossmorran, Rafnes, Stenungsund, Terneuzen, Wilton, Antwerp; Eastern Europe capacity not included; Transportation cost to Rotterdam
[2] Oil, nat. Gas, and feedstock prices based on EIA's World Energy Outlook scenarios
[3] Total net export of the region representing all possible exports to Europe

Source: BCG Analysis

Economic aspects

The starting point of the consideration is the Western European ethylene arbitrage. It maps the relationship between the naphtha price, which is linked to the Brent Crude oil price, and the ethane price. The latter is measured by the Mont-Belvieu price index and incorporates several complex factors like the cost of liquefaction, shipping, regasification, and port handling charges. These variables typically add up to $200 per ton of ethane. At the same time, they correlate only partially with the price of oil. The arbitrage calculation also includes additional revenues and margins from C3, C4, and aromatic byproducts generated during naphtha cracking.

As long as the Brent price index remains in the mid-to-high range for crude oil – above $50/barrel – imported ethane has economic advantages. The various scenarios for carbon taxes do not have a big impact on ethane cracking economics. However, global net-zero efforts could drive oil prices lower, making ethane imports for ethylene production less economically attractive.

Technical and structural aspects

Converting a naphtha cracker into an ethane cracker is feasible, it is, in fact, a simplification of the plant. However, the necessary ethane logistics require long-term capital expenditures (CAPEX) and a corresponding lead time. Also, the downstream value chain needs to be examined. If there are dependencies upon C3, C4, and other by-products, switching to ethane as a feedstock might not be attractive anymore. Consequently, a switch to US ethane as a feedstock is only a viable path for very few producers, namely those with appropriate trading capabilities and supply chain excellence.

INEOS laid the groundwork for ethane imports in Europe. The company has established the corresponding supply chains for its crackers at Rafnes in Norway and Grangemouth in the UK. In addition, INEOS has just completed the financing of the largest European chemical investment of the past 25 years, called Project ONE, valued at $3.5 billion. Among the new facilities at Antwerp in Belgium will be a 1.45 mtpa capacity ethane-cracker. This will be the first new cracker in Europe since MOL's in Tiszaujvaros, Hungary, in 2004.

Global: further markets for US exports

The US has structural advantages in olefin feedstocks, and now also exports ethane and ethylene – both by pipeline to Canada and by ship to Europe and Asia. These C2 exports impact olefin markets that have traditionally relied on naphtha crackers as their main source of ethylene.

Similar to Europe, Asian ethylene producers have now begun to rely on imported US ethane as a feedstock. Corresponding projects are currently underway in India and, above all, China. A look at the projects there provides some interesting insights:

- SP Chemicals operates an ethane- and propane-based cracker in Taixing with a capacity of 650,000 tons per year. Long-term ethane supply contracts have been signed with INEOS for this.
- The Zhejiang Satellite cracker in Lianyungang with its 1.25 mtpa production capacity uses ethane imported from the US. It requires an import volume of 1.6 mtpa. A 160,000 cubic meter ethane tank was specifically built for this project at the port of Lianyungang. It will probably not stop there, since the company is working on doubling the plant's capacity.
- Wanhua has built a 1 mtpa ethylene cracker in Yantai that uses liquid propane as feed-stock. It requires 3.4 mtpa of LPG imports – in this case, sourced from the Middle East.

China's petrochemical industry is thus increasingly relying on American ethane. This increasing share of US-supplied C2 is building pressure on the Middle East, which relies on supplying C2-based chemicals to Asia/China. However, a potential trade conflict between the two superpowers remains a factor of uncertainty.

More ethylene in the future

A potential construction of ethane export facilities on the US West Coast could further increase export capacities. However, the focus of US exports could shift from ethane to ethylene, especially in light of the large-scale plants announced or already under construction in the Gulf of Mexico:

- Shell: ethane cracker in Monaca, 1.5 mtpa
- GCGW: ethane cracker in Portland, 1.8 mtpa
- Bayport Polymers: ethane cracker in Port Arthur, 1 mtpa
- LACC LLC: ethane cracker in Lake Charles, 1 mtpa

Enterprise Products, a leading midstream player, is currently setting the stage for an ethylene export market. For this purpose, pipelines are connecting major crackers in Texas and Louisiana with storage facilities and export terminals capable of handling 1 mtpa of ethylene.

With a capacity increase of 50 percent by the second half of 2023, they are expected to produce more than 2 mtpa by 2025. In addition, the company considers building an ethane cracker with 2 mtpa capacity at a cost of $5 billion on the Gulf Coast.

Overall, however, ethane exports will remain the mainstay for the foreseeable future, with export volumes equivalent to seven or eight major crackers. One to two cracker equivalents will be added in the form of ethylene exports.

C3 supply issues

As a result of the ethane oversupply caused by the shale gas revolution, C3 shortages are to be expected, as ethane crackers, unlike naphtha crackers, only produce it in small quantities. Furthermore, there is an ongoing shift to ethane as ethylene feedstock. At the same time, investments in refineries as the alternative C3 source are slowing down. Nonetheless, due to the versatility of polypropylene and some other attractive derivative groups, such as acrylics, C3 products are among the fastest growing chemicals.

The importance of alternative processes for propylene recovery will therefore grow in the foreseeable future. Propane dehydrogenation (PDH), in particular, will contribute significantly to the global propylene supply. Even in rather stagnant regions such as Europe, there are corresponding projects. For example, a PDH/polypropylene (PP) plant will go into operation in Poland in 2023, and construction work on a plant in Kallo, Belgium, has been resumed with a projected production start in the second half of 2024. INEOS Project One will also include a PDH plant besides the aforementioned cracker. Building PDH plants is a way to meet C3 demand, as declining refinery capacities will decrease the production of Fluid Catalytic Cracking (FCC)-based polypropylenes.

Conclusion: from feedstock to production technology diversification

The US ethane and ethylene exports have far-reaching consequences for all ethylene producers, globally. Especially companies in regions with scarce natural resources, such as Europe and China, will need to reposition themselves in an area of feedstock integration. In addition, producers, distributors, and traders must invest in the necessary infrastructure in good time if they want to benefit from supplies from the US.

Ethylene producers, who have been using naphtha as a feedstock, need to thoroughly evaluate their competitive position. For one thing, production of the feedstock is declining due to reduced demand for refinery products. For another, the revenue mix generated from naphtha crackers will change, making integrated margin optimization a must. The value of byproducts will increase, while that of ethylene itself will stagnate or even decrease. The C3 value chain, which is only poorly covered in ethane cracking, offers particularly significant opportunities.

As in all industries, the issue of sustainable energy use is playing an increasingly important role in ethylene production. Combining low energy and feedstock costs with IRA-related subsidies, the US can set new sustainability standards in petrochemicals. The EU drives the decarbonization of the local industry by establishing subsidies programs, such as the Innovation Fund or Invest EU.

Increasing alternative processes

To reduce dependence on ethane, new production technologies will play a major role: other examples beside COTC are Methanol-To-Olefins (MTO) and Oxidative Coupling of Methane to Ethylene (OCM), which is still under development. Carbon Capture, Usage, and Storage (CCUS) based processes will contribute to further diversification in the future.

In Asia and the Middle East, large crude oil chemical complexes are expected to go into operation. For oil-producing countries, COTC also opens up a sales market for hydrocarbons beyond transportation fuels. The challenge with COTC is economics: there is an economy of scale, but no economy of feedstock.

An accelerating focus on the C2 value chain in an environment of growing mandatory recycling rates will increase the vulnerability of disadvantaged assets and also create a challenge for new assets which rely on polymers with increasing recycling rates.

Five recommendations on how petrochemical companies can remain future-proof

Future vulnerabilities must be tackled now! This may involve the supply chain or production sites. Nothing should be off-limits in the process.

- Focus on improving margins. Evaluate the entire value chain for optimization potential to lower costs; operational excellence and opportunities beyond C2 open up new opportunities.
- Location is a key factor for successful transformation. Rigorously rethink your investment strategy; identify advantageous production networks as well as partnerships to create new perspectives. Assess opportunities by leveraging global production networks and incorporating imports of feedstock, ethylene, or basic chemicals from advantaged regions to restructure the existing European production networks.
- Sustainability is the topic of the next decades. No long-term growth will be possible without environment-friendly innovations, and first movers will have strategic advantages. They will need environment-friendly solutions and technologies (energy and feedstock), prepare their market launch strategically, and adapt them to (expected) regulations.
- Abide by the golden rules for the profitability of new investments. The decisive factors are: feedstock advantage, innovative and marketable technologies that generate economies of scale, market access, and stable supply chains.
- Take multiple bets in large-scale developments – analogous to the old stock market rule. It is a high risk to focus on one raw material such as imported ethane or a single technology, as this creates a high dependency. Multiple positions in very large-scale assets leave more room for maneuvering.

Authors

Mirko Rubeis is a Managing Director and Senior Partner, Dubai.

Marcus Morawietz is a Managing Director and Senior Partner, Frankfurt.

Marcin Jedrzejewski is a Partner and Associate Director, Dubai.

Hubert Schoenberger is a Knowledge Senior Director, Munich.

Yaroslav Verkh is a Lead Knowledge Analyst, Dusseldorf.

Rafael Moreno Lahore is a Partner and Associate Director, Madrid.

Graeme McMillan is an Associate Director, London.

Ana Mourao is a Knowledge Expert, Madrid.

Boston Consulting Group partners with leaders in business and society to tackle their most important challenges and capture their greatest opportunities. BCG was the pioneer in business strategy when it was founded in 1963. Today, we work closely with clients to embrace a transformational approach aimed at benefiting all stakeholders—empowering organizations to grow, build sustainable competitive advantage, and drive positive societal impact.

Our diverse, global teams bring deep industry and functional expertise and a range of perspectives that question the status quo and spark change. BCG delivers solutions through leading-edge management consulting, technology and design, and corporate and digital ventures. We work in a uniquely collaborative model across the firm and throughout all levels of the client organization, fueled by the goal of helping our clients thrive and enabling them to make the world a better place.


bcg.com