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NATURAL-GAS-LIQUID DERIVATIVES

THE ENERGY TSUNAMI'S NEXT WAVE

By Clint Follette and Yanyu He

The tsunami that yielded abundant unconventional-natural-gas supplies has also generated a glut in the byproducts of those gases: natural-gas liquids (NGLs) including ethane, propane, and butane. As we described in a previous article, the unique interplay between the primary and secondary products has set off a self-reinforcing downward spiral in NGL prices as NGL supply quickly outpaced new demand creation. (See "Natural-Gas Liquids: The Implications of the Next Energy Tsunami," BCG article, October 2012.)

Equally important has been a ripple effect down the value chain to NGL derivatives. We have highlighted ethylene, propylene, and butadiene, which are three NGL derivatives that have seen significant market changes with far-reaching implications for many players in the chemical and end-use industries.

At the root of the ripple effect is the feed mix to steam crackers. Traditionally, naphtha (a heavy feedstock from oil refining) and NGLs (primarily ethane) have been the chief inputs. The surge in shale gas production has seen the supply of its byproduct ethane increase; indeed, ethane supply has grown beyond the ability of steam crackers to consume it. The excess supply of ethane has flowed to its next best use, which is as a fuel, and thus the price of ethane has declined to natural-gas parity on a British thermal unit (BTU) basis, in line with this lower-valued application.

In response, petrochemical companies have proactively invested in their facilities to increase flexibility and accommodate ethane cracking. As a result, the U.S. cracker-feed mix has shifted from about 40 percent naphtha in 2005 to about 10 percent currently. Naphtha's share is likely to continue to decline as ethane supply grows.

With ethane feed, there is increased selectivity to ethylene over propylene, mixed butenes, butadiene, toluene, and benzene and also less production of low-value products such as methane and fuel oil. Even with high market prices for byproducts such as propylene and butadi-

ene, ethane's low relative price provides a strong incentive to shift away from naphtha feed.

At recent prices for naphtha and cracking products, the indifference point, the point at which steam-cracking margins are equivalent for naphtha and ethane feed and yields, would be reached when the price for ethane neared $900 per ton. However, actual ethane prices have recently been closer to $200 per ton.

Ethylene: Rebirth with a U.S. Production-Cost Advantage

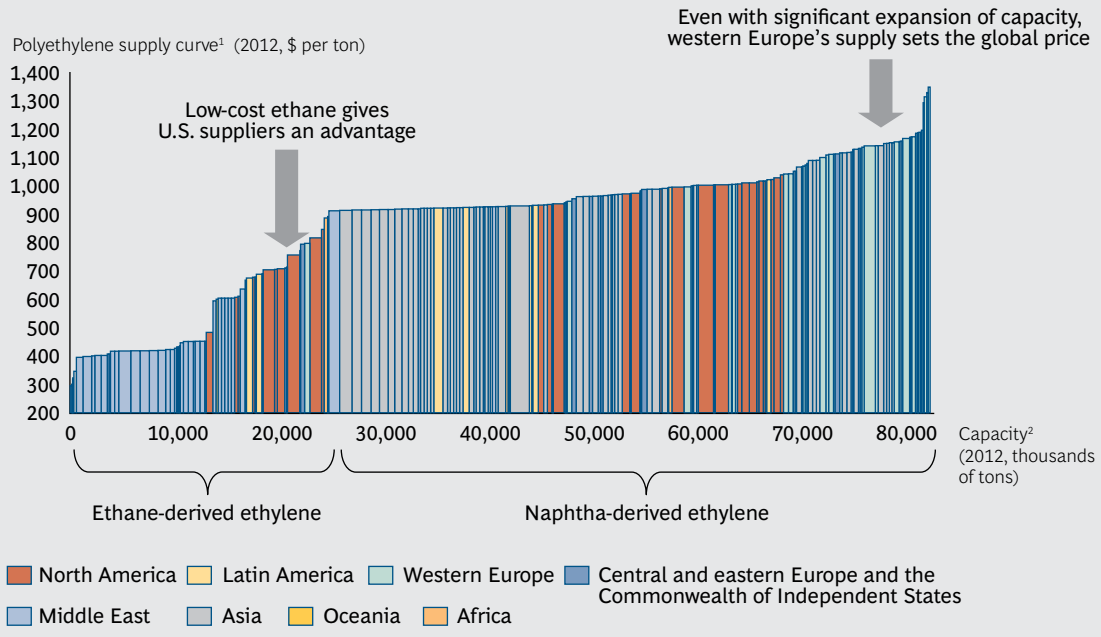
With ethane feed, the yield to ethylene is about 75 to 80 percent compared with naphtha feed's ethylene yield of approximately 20 to 30 percent. U.S. ethylene production, which had been in a decline instigated by recession-induced capacity requirements, will, as a result of the feedstock shift alone, turn around.

Because of ethylene's physical properties, transporting it is not practical. Hence, producers make polyethylene products close to the ethylene supply and then ship them to export markets rather than exporting the ethylene and producing polyethylene overseas. This means that along with the expansion of U.S. ethylene capacity, U.S. polyethylene capacity has increased to consume the additional ethylene. Thus, as a result of new production, U.S. polyethylene exports have grown and have displaced existing suppliers.

The global polyethylene supply curve illustrates that U.S. ethane-based supply has a cost advantage over supplies from most regions in the world. (See Exhibit 1.) Favorable price dynamics and increased yield are driving investment in new U.S. ethane-cracking capacity. If global capacity outstrips demand growth, the price of polyethylene could decline by as much as $200 per ton. However, even if this decline occurs, U.S. ethane crackers and polyethylene plants would maintain robust cash margins ($300 to $400 per ton).

Looking forward, as the polyethylene supply from the U.S. and other regions (including the Middle East and Asia)

Exhibit 1 | U.S. Suppliers Can Capture Large Margins in Global Polyethylene Supply



Sources: Icis; *Oil & Gas Journal;* Platts; BCG ChemCom database; BCG supply-curve toolbox.
[1]High-density-polyethylene supply cost.
[2]Both high-density and low-density polyethylene capacities were included.

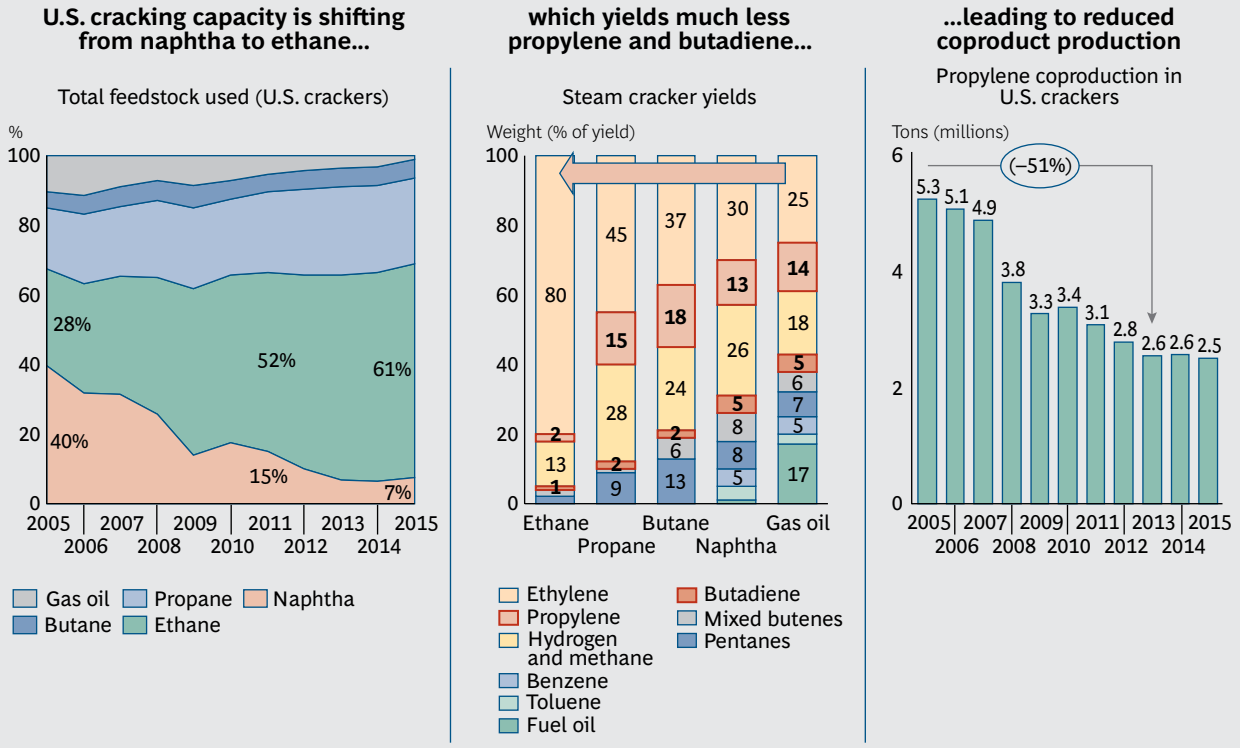
increases, European naphtha-cracking capacity and associated polyolefin production are expected to face significant cost pressure. The 6 million tons of pure naphtha-cracking capacity and 17 million tons of mixed feed capacity in Europe will be challenged to operate economically. Thus far, European capacity has been resilient; players have cut costs and improved efficiency to cope with low margins. Over time, though, once opportunities to remove costs are no longer available, the market will see capacity rationalized.

The shift toward ethylene brings with it a shift away from valuable coproducts of the cracking process including propylene and butadiene. The yield to propylene and butadiene with pure naphtha feed is 13 percent and 4 to 5 percent, respectively. With pure ethane feedstock, the yield to propylene is 1 to 2 percent and the yield to butadiene is about 1 percent—a five- to sevenfold decline in both. The feedstock shift from naphtha to ethane has led to a reduction in annual steam-cracking propylene production by 2.7 million tons, or about 50 percent, since 2005. (See Exhibit 2.) Annual butadiene production has declined by 300,000 to 400,000 tons, or about 20 percent, causing both of these markets to experience shortages.

Propylene: On-Purpose Production to Address Tight Market Conditions

At present, propylene demand exceeds supply, as evidenced by the run-up to a 2011 average price of more than $1,600 per ton compared with an annual average price of approximately $1,000 per ton during the previous five years. U.S. propylene prices have been lower than ethylene prices for the past 20 years, but the propylene shortage led to an increase in the ratio of propylene to ethylene prices, from 0.95 in 2005 to 1.5 in 2011. The combination of

EXHIBIT 2 | U.S. Steam Crackers Are Shifting to Ethane Feedstock, Which Yields Less Propylene and Butadiene



Sources: IHS Chemical; Deutsche Bank; Wells Fargo; Nexant; BCG analysis.

low-cost propane from shale gas production and high-priced propylene created a significant advantage for on-purpose production of propylene through the propane dehydrogenation (PDH) process.

The Boston Consulting Group (BCG) recently analyzed near-term production costs and compared them with those of competing technologies. We found that PDH is in the middle of the supply curve relative to other technologies. With current prices, naphtha cracking and the on-purpose metathesis process, which cannot benefit from the propane-to-propylene price spread, rank as the most expensive technologies. The current spread and the competitive cost position of PDH on the supply curve have induced Dow Chemical, Formosa Plastics, Enterprise Products, Williams Companies, and Ascend Performance Materials to announce new PDH plants in North America.

Looking forward, the price spread between propylene and ethylene is unlikely to be sustained. BCG's analysis shows that the new PDH additions will eliminate the shortage and that the price on the Gulf Coast will once again be set by the variable cost of the metathesis process, at about $1,200 per ton.

Many of the PDH investors have locked in production contracts with fixed fees, protecting the investors from price fluctuations. However, those that benefit from exposure to high propylene prices will likely experience a negative impact. Conversely, players that benefit from low propylene prices, such as acrylonitrile and propylene-oxide suppliers, would gain from exposure to the market price.

The dynamics of the U.S. polypropylene market differ from those driving the polyethylene market. The U.S. polypropylene supply base exceeds domestic demand and is currently at about 80 percent utilization, but it is not sufficiently competitive to support exports (recently, exports have made up less than 5 percent of total sales). In this highly competitive, self-contained market, domestic utilization fluctuates to meet domestic demand and producers earn little to no profit because low input costs are passed on in the form of low polypropylene prices. With a more diversified feedstock base, price volatility may decline and allow some growth in polypropylene use. This dynamic differs from that of more-global derivatives such as propylene oxide, where a supplier can benefit from reduced input costs yet still sustain higher product prices in export markets.

Butadiene: Shortage and High Prices to Persist

Much as with propylene, the reduction in butadiene production has exacerbated an already tight market in the U.S.

Dating back to World War II, butadiene was produced on purpose through dehydrogenation. However, with the growth in the global chemical industry, byproduct "crude C4" streams containing butylenes and butadiene increased. From these streams, butadiene could be extracted to supply the U.S. market. Currently, all U.S. butadiene producers are operating extraction units to remove butadiene from crude C4 feedstock. With the market short of domestic C4s, prices have spiked to more than $4,000 per ton, a level that has encouraged imports of finished butadiene and crude C4s. Even with high prices, on-purpose production has not been economical in recent history.

The shift in steam cracker feedstock has further reduced the availability of crude C4s, leaving U.S. extraction units without feed and, thus, idle. The lack of butadiene supply has had a significant impact on the downstream chain. Sixty percent of the butadiene market is for synthetic rubber compounds including styrene butadiene rubber (SBR) and polybutadiene rubber (PBR); 75 percent of the volume of these two materials is used in the production of tires. Capacity utilization in the U.S. SBR and PBR industry has been limited to the 60 to 70 percent range since 2008 given the lack of available butadiene supply at competitive prices.

U.S. tire manufacturers are meeting their production needs by importing SBR and PBR. At the same time, they are seeing competition from imported tires. A cheaper, domestic source of butadiene supply could find a market by displacing butadiene extracted from imported C4s, supplanting SBR and PBR imports, and enabling domestic tires to better compete with imports.

In the case of butadiene, the solution to the shortage is less clear than it is with propylene. There is no off-the-shelf technology for on-purpose butadiene production. Historically, there have been a few commercial processes for on-purpose butadiene production, including the Houdry catadiene process, the Phillips oxidative dehydrogenation process, and TPC Group's Oxo-D process. All have yields of less than 75 percent, and an improved yield is needed to make investment more economical. Toward that goal, TPC recently restarted a dehydrogenation unit used to make isobutylene and announced an engineering study to investigate reopening an idled dehydrogenation unit to produce butadiene in 2015 or 2016.

TPC will likely be the first mover, but other global players have expressed interest in on-purpose butadiene technologies. For example, Enterprise Products recently pointed to on-purpose butadiene as one of the potential business opportunities that it is considering.

If TPC or another player is able to successfully commission an on-purpose unit to produce butadiene from butane and achieve acceptable yields, it will have a significant technology advantage in an attractive market. The growth potential for butadiene in the U.S. creates room for approximately two new world-scale plants (with production for each at approximately 270,000 tons per year) while still maintaining a relatively high market price for butadiene. However, until new capacity is available in the market, we expect volatility and prices that exceed $2,000 per ton to continue for a significant period of time.

Implications of Changing Market Dynamics

Even as the U.S. shale-gas boom is depressing the prices of gas and NGLs, oil prices and associated naphtha prices have remained high. These market dynamics have shifted the cracking feed mix from naphtha to ethane and are reducing propylene and butadiene output and increasing their prices.

With NGL market fundamentals in flux, what will future prices look like? BCG's analysis indicates the following characteristics:

- Sustained high oil prices and relatively low gas prices
- Ethane prices that will remain at BTU value until demand catches up with supply
- Propane and butane prices that will remain low, stabilized by exports
- Propylene prices that will decline as PDH capacity comes online to fill the market shortage
- Butadiene prices that will remain high and volatile until a viable on-purpose technology can be developed and deployed

These dynamics will have significant implications for players throughout the petrochemical, polyolefin, and rubber industries and for end consumers.

U.S. Ethylene Crackers. These facilities are likely to be advantaged through 2017 or 2018 until expansion and new building cause capacity to exceed supply.

U.S. Ethylene and Propylene Derivatives. There will be opportunities for profitable new investments down the ethylene and propylene value chains. Increased ethylene will enable profitable growth in ethylene derivatives including polyethylene and ethylene oxide. Propylene's increased availability and more stable price are likely to create growth opportunities in propylene derivatives as well.

European Crackers. Not all industry players will be winners. European players that rely on naphtha as a significant portion of their feed will remain disadvantaged. To improve their competitiveness, European players must improve feed flexibility and may also begin pursuing imports of excess NGLs from North America.

U.S. Polyolefin End Consumers. U.S. consumers of polypropylene will benefit from lower and more-stable propylene prices that make their way through the value chain, but polyethylene consumers may find that prices continue to be buoyed by global demand.

U.S. Synthetic Rubber and Tire Players. With volatile butadiene prices and uncertainty about on-purpose technologies, U.S. synthetic rubber and tire players will remain in a bind. Some may move to control their own destiny and partner to develop and deploy on-purpose butadiene capacity.

Preparing for a Volatile Future

The biggest wild cards in the NGL derivatives market outlook are shale gas development outside North America, the amount of shale gas that is wet (NGL-rich) gas, and the proportion of ethane, propane, butane, and heavier hydrocarbons in the NGLs. A number of countries are in the exploration stage; Argentina, Poland, Ukraine, China, Australia, and South Africa are in the lead. With production not expected before 2015 at the earliest, however, it is unlikely that this new development will be a significant factor for the prices of NGLs and derivatives in the next several years.

There remains tremendous uncertainty regarding how the NGL derivatives market will evolve. Consequently, players must fully understand the supply-and-demand dynamics for oil, naphtha, natural gas, and NGLs. Certainly, the shale gas boom will cause markets to continue to shift and prices to remain volatile—thus having an impact on crackers, polyolefin and rubber producers, and end users. Players that can position themselves flexibly to adapt to industry shifts will reap a competitive advantage—both in the near term and the longer term.

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