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A nighttime photograph of a city street with light trails from cars in shades of red, orange, and yellow. In the background, city buildings are lit up with blue and white lights.

# *Future of chemicals VIII*

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**Rebalancing  
global feedstock  
disruptions with  
“on-purpose”  
technologies**

The PwC logo, consisting of a stylized grid of squares above the lowercase letters 'pwc'.

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## Contacts

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### Berlin

**Matthias Bäuml**  
*Partner*  
+49-30-88705-852  
matthias.baeuml  
@strategyand.pwc.com

### Chicago

**Eduardo Alvarez**  
*Senior Partner*  
+1-312-578-4774  
eduardo.alvarez  
@strategyand.pwc.com

### Dallas

**John Corrigan**  
*Partner*  
+1-214-746-6558  
john.corrigan  
@strategyand.pwc.com

### DC

**Peter Bertone**  
*Senior Partner*  
+1-703-682-5719  
peter.bertone  
@strategyand.pwc.com

### Dubai

**Andrew Horncastle**  
*Partner*  
+971-4-390-0260  
andrew.horncastle  
@strategyand.pwc.com

**David Branson**  
*Executive Advisor*  
+971-4-390-0260  
david.branson  
@strategyand.pwc.com

### Düsseldorf

**Joachim Rotering**  
*Senior Partner*  
+49-211-3890-250  
joachim.rotering  
@strategyand.pwc.com

**Sven Vallerien**  
*Partner*  
+49-211-3890-260  
sven.vallerien  
@strategyand.pwc.com

### Frankfurt

**Marcus Morawietz**  
*Partner*  
+49-69-97167-467  
marcus.morawietz  
@strategyand.pwc.com

### Hong Kong

**Krishnan Narayanan**  
*Senior Executive Advisor*  
+852-3182-7192  
krishnan.narayanan  
@strategyand.pwc.com

### Houston

**Jayant Gotpagar**  
*Partner*  
+1-713-650-4107  
jayant.gotpagar  
@strategyand.pwc.com

**Juan Trebino**  
*Partner*  
+1-713-650-4151  
juan.trebino  
@strategyand.pwc.com

### London

**Andrew Clark**  
*Partner*  
+44-20-7393-3418  
andrew.clark  
@strategyand.pwc.com

### New York

**Richard Kauffeld**  
*Partner*  
+1-212-551-6582  
richard.kauffeld  
@strategyand.pwc.com

### São Paulo

**Arthur Ramos**  
*Partner*  
+55-11-5501-6229  
arthur.ramos  
@strategyand.pwc.com

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# ***About the authors***

**John Corrigan** is a partner with Booz & Company in Dallas. He specializes in the gas value chain, including unconventional gas, and topics related to strategy development, operating model, and organization design.

**Andrew Horncastle** is a partner with Booz & Company in Dubai. He specializes in mergers and acquisitions, strategy, organization and integration, and cost reduction for chemicals companies.

**Dr. Jayant Gotpagar** is a partner with Booz & Company based in Houston who co-leads the firm's North American chemicals practice. He focuses on business unit growth strategies, operating model design, innovation management, and operational improvement programs in the chemicals and downstream oil and gas sector.

**Asheesh Sastry** was formerly a principal with Booz & Company.

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# Executive summary



**The global petrochemicals industry** has recently experienced significant disruptions in the supply and pricing of key chemical building blocks — ethylene, propylene, butadiene, and benzene — due to the changing mix of feedstocks used in petrochemicals production. Supplies of ethylene have surged as U.S. shale gas production has boomed. Meanwhile, propylene, butadiene, and benzene supplies have declined. As a result, ethylene prices have decoupled from those for propylene, benzene, and especially butadiene, all of which have become more expensive relative to ethylene. Going forward, gas developments in Iraq and China could further distort supply and prices.

“On-purpose” production technologies exist, or are in development, to create propylene, butadiene, and benzene. Until recently these technologies were considered economically marginal, but they are becoming attractive. Indeed, on-purpose technologies for propylene and benzene should correct current supply imbalances, and could reduce prices over the short to medium term. This does not apply to butadiene, whose on-purpose production remains marginal and expensive, likely perpetuating pricing distortions for the foreseeable future.

These developments have implications for all players in the chemicals value chain: global producers, Gulf Cooperation Council (GCC)<sup>1</sup> producers, and consumers. Global producers have significant new growth opportunities in regions where feedstock is available for on-purpose production. These producers have mostly invested in process technology, but now must consider product technology, their research and development strategy, and the ways to play in this market. GCC companies will need to recognize that on-purpose production in the region would be less attractive or marginal without the availability of advantageously priced feedstock. GCC companies will need to augment their existing capabilities and seek new geographies where feedstock is available for on-purpose production. Finally, customers will need to make backward integration a top priority to ensure security of supply and price stability.

# *New feedstock sources are emerging*

The global petrochemicals industry relies on a few key building blocks to create its end products. Crackers produce these building blocks — ethylene, propylene, butadiene, and benzene — as a by-product of certain raw materials (feedstock), such as “light” natural gas and “heavy” liquid naphtha.

Over the last few years the emergence of potential new sources of light feedstock is significantly changing the availability of these four chemical building blocks, as light feedstock is replacing the heavier ones. This is because light feedstocks mostly produce ethylene, whereas heavy feedstocks mostly produce the other three. These changing supplies are a result of developments in North America, the Middle East, and China. The result is supply–demand imbalances and pricing distortions among the key petrochemical building blocks the likes of which are unprecedented.

## *Shale gas developments in North America*

Shale gas in North America is already having a substantial impact on the global petrochemicals industry. Once in decline, the U.S. chemicals industry is now booming thanks to a shale gas bonanza that has created abundant and cheap natural gas and ethane supplies. This is reshaping the global petrochemicals playing field by giving U.S.-based players a significant cost advantage compared to European and Asian players. For example, once shale gas basins proved to be rich in natural gas liquids (NGLs), many producers shifted their investments toward oil- and liquid-rich plays instead of pure methane. As a result, NGLs flooded the market after 2008 and the price of ethane disconnected from crude oil.

Abundant, cheap shale gas-derived NGLs have displaced naphtha at many existing steam crackers. Most of the cracker capacity in North America is already mixed feed, and several naphtha crackers have been upgraded to take mixed feed so as to take advantage of cheap ethane. The result is that the share of naphtha in steam cracking declined by 8 percent from 2005 to 2008, and then dropped by another 8 percent from

*The U.S. chemicals industry is now booming thanks to a shale gas bonanza.*

2008 to 2009. The level of naphtha in steam cracking in 2012 is around 15 percent. By 2015, we estimate that the share of naphtha in North American steam cracking will fall further to about 12 percent — close to the theoretical limit for the level of naphtha necessary to operate mixed feed crackers.

Although plans for about a dozen new crackers have been announced, we estimate that only 3 to 5 million metric tons<sup>2</sup> per annum (mmtpa) of new steam cracking capacity will actually come online in North America by 2020 compared to the nearly 10 mmtpa capacity being planned and under development. Producers are hesitant to add new capacity because they do not know how long the shale gas basins will be productive. They therefore worry about the future supply and price stability of feedstock because there are many competing demands from many different users of gas (such as power and industry).

### *Gas developments in the Middle East*

Whereas North America is awash with natural gas, the GCC finds itself in precisely the opposite position. Gas production (currently mostly associated with oil) is increasing modestly in line with oil extraction. However, most of the anticipated supply is already committed to existing and new projects. National oil companies in the Middle East are responding to the shortage of natural gas by exploring for non-associated gas, unconventional gas, and shale gas.

Middle East petrochemicals companies have adapted to the shortage of natural gas by shifting to cracking more liquid feedstocks. Outside the GCC, Iraq has an abundant gas supply in the form of associated gas, which is rich in NGL content. Iraq has set an oil production target of 13 million barrels per day by 2017, and there are a wide range of forecasts and estimates on its future production potential. Nonetheless, the growth in oil production will also result in an increase in gas production. The Iraqi government has stated clearly that increased capture and utilization of associated gas for petrochemicals production is a priority, although it seems unlikely that associated gas as feedstock will be available before 2020.

### ***Shale gas developments in China***

In the medium to long term, China could have a significant impact on global feedstock supply. China has the largest shale gas reserves in the world, with 1,275 trillion cubic feet (36.1 trillion cubic meters) compared to reserves of 862 trillion cubic feet (24.4 trillion cubic meters) in the U.S. There is currently no shale gas production in China but it may soon ramp up. Although the government's five-year plan calls for 6.5 billion cubic meters of domestic production by 2015, independent estimates conclude that about 3 billion cubic meters is achievable in this time frame. It is still impossible to know the NGL content of Chinese shale as there has been no exploration, which makes assessing China's potential impact on the petrochemicals industry uncertain.



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# *The supply of critical chemicals is changing*

The North American shale gas boom is already changing the petrochemicals landscape. With the Middle East stepping up exploration and China about to tap huge reserves, more supply and changes are on the way. Put otherwise, the global petrochemicals industry is headed toward a glut of ethylene supply and the world will become increasingly long, that is will have overcapacity, in ethylene production. Crackers that can tap into these light feedstock sources will have a notable competitive advantage as they will have the capability to produce more ethylene at a significantly lower cost than many existing mixed feed crackers. As new capacity comes on stream to produce ethylene, margin will compress and prices will decline further, putting even more pressure on marginal producers (*see Exhibit 1, next page*).

The downward trend in prices could mean that by 2025, 10 to 20 percent of existing cracker capacity may come under threat. Some of these crackers may be forced to close. Those most at risk are smaller crackers with capacity under 700 kilotons per year and geographically stranded crackers in Europe and Asia, such as those in China that process mixtures of naphtha and gas oil. However, large-scale naphtha crackers in these regions will continue to thrive.

The industry's transition to light feedstock and the closure of some naphtha cracker facilities could seriously disrupt the production of other critical petrochemical building blocks. Ethane, liquefied petroleum gas (LPG), and propane — light feedstocks — primarily produce ethylene with negligible quantities of other co-products. Propylene, butadiene, and benzene are produced only when naphtha or heavy liquids undergo steam cracking.

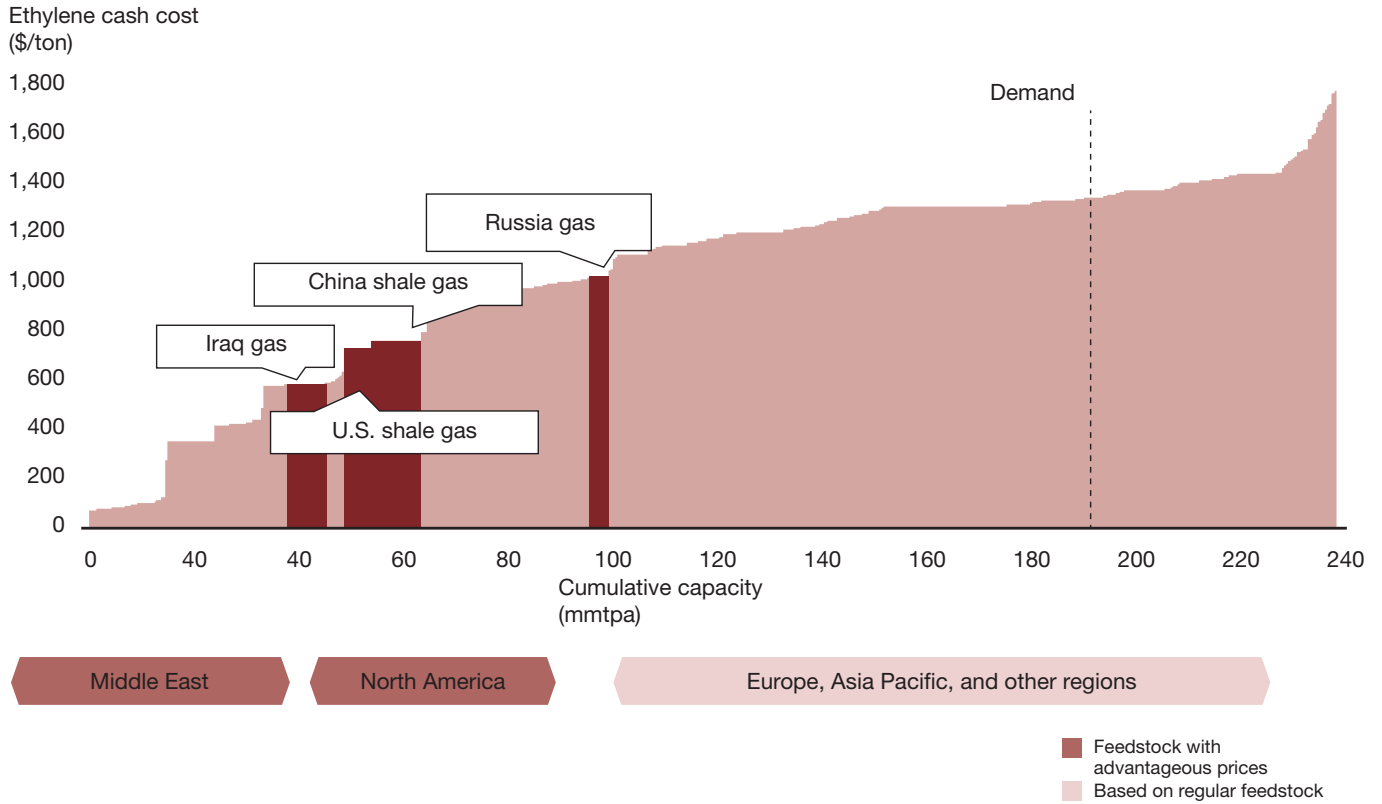
Thus, as light feedstocks replace heavy feedstocks, the supply of critical co-products is tightening. This position is likely to become more acute in coming years. To date, mixed feed cracker facilities have substituted heavy feedstock with light feedstock, but after 2015 most new facilities will not be mixed feed — they will not be capable of processing the heavy feedstocks that yield propylene, butadiene, and benzene.



Exhibit 1

Ethylene will be oversupplied in 2025 with European and Asian crackers under cost pressure

Global ethylene industry cost curve  
oil price at \$90/barrel in 2025



Note: Gas prices were assumed to be \$3/mmBtu (\$21 per cubic meter) in Iraq and Russia, and \$6/mmBtu (\$42 per cubic meter) in the U.S. and China. All oil projections in real 2012 prices.

Source: Nexant; Strategy& analysis

## ***Propylene***

The supply of propylene is dwindling, especially in North America where the natural gas boom is pronounced with clear impact on prices (*see Exhibit 2, next page*). By 2015, the global shortage could reach approximately 3 mmtpa, half driven by U.S. feedstock substitution and half by cracker shutdowns in Europe and Asia. Beyond 2015, U.S. feedstock substitution will reach its technical limits. By 2025, if new crackers are built in China, Iraq, and Russia that produce plenty of ethylene, but no by-products, the global propylene shortage could reach about 14 mmtpa, or around 10 percent of forecast global demand.

There are three ways to address the propylene shortage. First, high-density polyethylene, polystyrene, and polyethylene terephthalate could substitute for polypropylene in some applications. We estimate these substitutions could reduce polypropylene demand by 2 to 6 mmtpa over the next three to five years. Second, as this report demonstrates, on-purpose production technologies such as propane dehydrogenation may become economically feasible. Finally, if substitution and on-purpose technologies cannot close the supply gap, propylene prices will have to rise, perhaps substantially, to compensate existing naphtha crackers for the by-products that they produce.

## ***Butadiene***

The butadiene market is about one-tenth the size of the propylene market, which means even small disruptions in naphtha cracking can move butadiene prices significantly upward. Prices have already jumped to two to three times that of ethylene over the last five years, which before 2005 was the most expensive output from a steam cracker. The butadiene shortage could reach approximately 10 percent of demand by 2015, and 25 percent of demand by 2025. By 2015 shortages would be primarily felt in North America, with Asia and Europe experiencing shortages soon thereafter.

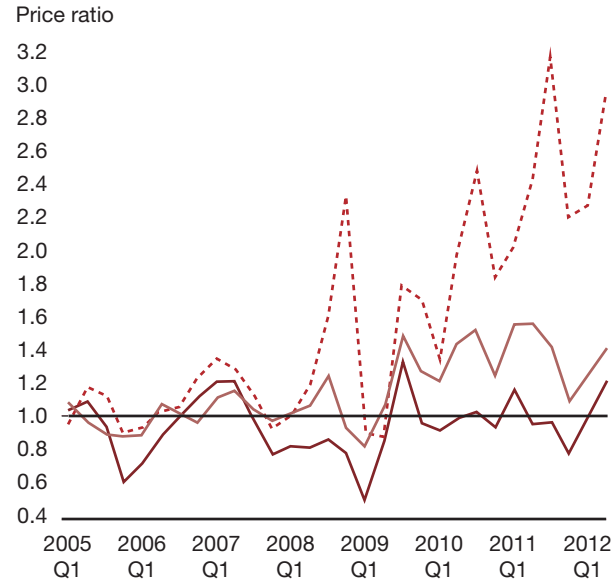
## ***Benzene***

Benzene prices have also risen. The increase has been less than in butadiene's case because steam crackers supply only one-third of the global benzene market. The remainder is supplied by refineries and extraction from coal tar. At worst, the global benzene shortage could reach about 8 percent of forecast global demand by 2025.

Exhibit 2

Shortages in propylene and butadiene have affected prices across the value chain

U.S. base chemicals/ethylene



- Butadiene-to-ethylene
- Propylene-to-ethylene
- Benzene-to-ethylene
- Ethylene (reference)

U.S. derivative products/high-density polyethylene (HDPE)



- Styrene Butadiene Rubber-to-HDPE
- Polypropylene-to-HDPE
- HDPE (reference)

Note: Between 2005 and 2009, synthetic rubber prices were assumed to be equal to natural rubber prices.

Source: Nexant; "Rubber Statistical Bulletin," International Rubber Study Group; Economist Intelligence Unit; Strategy& analysis

# ***On-purpose technologies will rebalance the market***

Supply shortages and price distortions for propylene, butadiene, and benzene are creating opportunities for on-purpose production technologies that were once marginal or uneconomical.

## ***Propylene — on-purpose is here to stay***

Three on-purpose technologies currently supply the propylene market — propane dehydrogenation (PDH), methanol to propylene (MTP), and olefin metathesis. While PDH and MTP have become significantly more attractive from a cost perspective, olefin metathesis economics have suffered (*see Exhibit 3, next page*). There is a fourth on-purpose propylene technology, biomass to propylene, which is potentially economical but is as yet unproven on a commercial scale.

Improved PDH economics are driven by the propylene–propane price differential. Whereas propylene prices have risen significantly in recent years, propane has remained linked to crude oil and so has not risen as fast. Similarly, MTP feasibility depends on low-cost methanol, which in turn requires low-priced coal or methane. This dependency limits MTP's success to certain regions. Cheap coal encourages coal to propylene (CTP) in China, and methane-based MTP is successful in Trinidad and Tobago and Mozambique.

Metathesis, however, is a different story. Unlike the PDH and MTP on-demand technologies that have benefitted from the cost of raw materials, the price of 2-butene, the primary raw material for metathesis, is rising — which keeps metathesis on the margins.

Based on these economics, significant PDH and MTP capacity is planned to come online between 2015 and 2016. Global PDH capacities are expected to grow by up to threefold by 2016, reaching 12 mmtpa. Meanwhile, global MTP capacity may quadruple to almost 6 mmtpa. Furthermore, average plant size should increase as producers seek to maximize yield and minimize fixed cost per ton of output. New PDH plant capacities will increase, from about 350 kilotons annually to 600 to 750

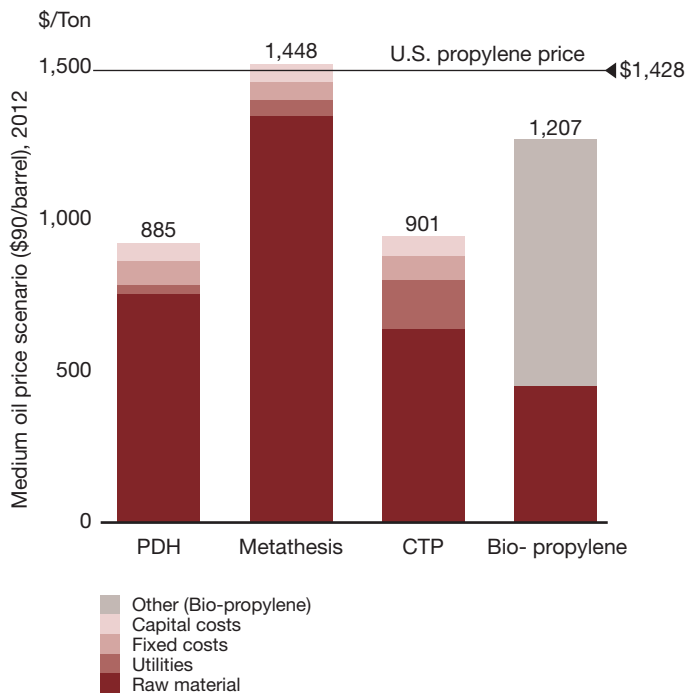
kilotons in 2015. For example, the Dow Chemical Company and the Enterprise Chemical Corporation are both planning plants in Texas with annual capacity of 750 kilotons each.

We estimate that by 2015 propylene supply from existing and planned crackers and PDH and MTP plants will satisfy projected annual global demand of about 95 million tons. Eventually, propylene prices may drop

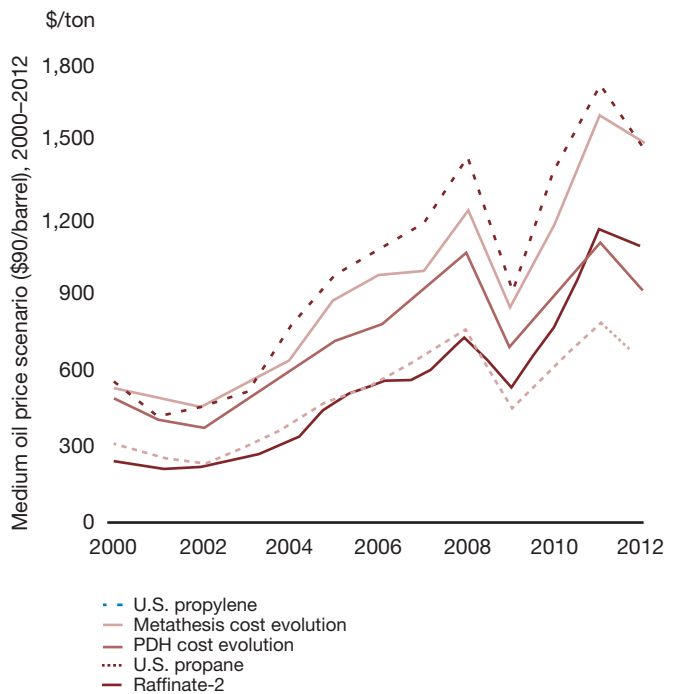
*Exhibit 3*

**Most propylene on-purpose production is profitable**

**Propylene cost by technology**  
medium oil price scenario (\$90/barrel), 2012



**Propylene price/cost**  
medium oil price scenario (\$90/barrel), 2000–2012



Note: Coal to propylene costs should be compared against South East Asia propylene price (\$1,247 per ton). Cost evolution curves assume 2-butene follows mixed C4 price evolution and 2% inflation on other costs.

Source: ChemSystems; Strategy& analysis

from their current high, but we expect PDH and MTP to continue with their significant supply contribution; indeed, as the marginal suppliers they may effectively set prices. As a result, however, metathesis will probably remain a marginal technology (see Exhibit 4, next page).

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## **Propylene on-purpose production technologies**

**1. Propane dehydrogenation (PDH)** uses propane as both feedstock and fuel with yields of 80 to 90 percent. In the process, propane is fed into fixed bed reactors, where it undergoes hydrogen elimination at temperatures of around 500°C, followed by distillation to separate propylene.

PDH is a relatively mature process with three commercially proven technologies:

- Oleflex (from Honeywell's UOP LLC)
- CATOFIN (from CB&I Lummus Technology)
- STAR (from ThyssenKrupp Uhde)

Scalability is also high (350 to 750 kilotons per year) and the economics are attractive under current conditions with cash margins up to around US\$550 per ton in the U.S. and Middle East. Global PDH capacity is around 4.5 mmtpa (2012 figure), set to increase to around 12.5 mmtpa (2016 forecast).

**2. Methanol/coal to propylene (MTP/CTP)** uses methanol to produce propylene. The methanol itself is produced from either coal (through gasification) or methane (through reforming). A relatively significant amount of methanol is consumed in the process (3.2 tons per one ton of propylene). Cheap sources of coal or methane are essential to make MTP economically viable.

There are three relatively new but commercialized technologies:

- CTP/MTP (from Lurgi)
- CTO/MTO (from CB&I Lummus)
- DTP (from Mitsubishi Chemical and JGC)

Cash margins are healthy when coal/methane prices are cheap (\$250 to \$350 per ton at Chinese coal prices or Middle East methane prices).

Capital expenditure is substantial and could be a barrier — \$1.6 billion for a 520 kilotons per year CTP facility in China; around \$850 million for a 450 kilotons per year MTP plant in the Middle East.

Current global capacity is 1.3 mmtpa (2012 figure), forecast to rise to around 6 mmtpa by 2016.

**3. Metathesis** involves reacting ethylene and 2-butene in a double bond rearrangement reaction followed by distillation to separate propylene. Ethylene and 2-butene are mixed in a ratio of 0.3:0.9 tons per ton of propylene.

Olefin Conversion Technology (OCT) from CB&I Lummus is the only commercial metathesis technology.

Most metathesis units are small to medium size, 150 to 350 kilotons per year, and are built on the back end of refineries to use the limited raffinate-2 stream.

Capital expenditure requirements are relatively low, around \$300 million for a 300 kilotons per year plant in the Middle East. However, the economics are marginal.

Global capacity is scheduled to rise from around 3.5 mmtpa in 2012 to a forecast 5.2 mmtpa in 2016.

This forecast may be missed because of the marginal nature of the economics at present.

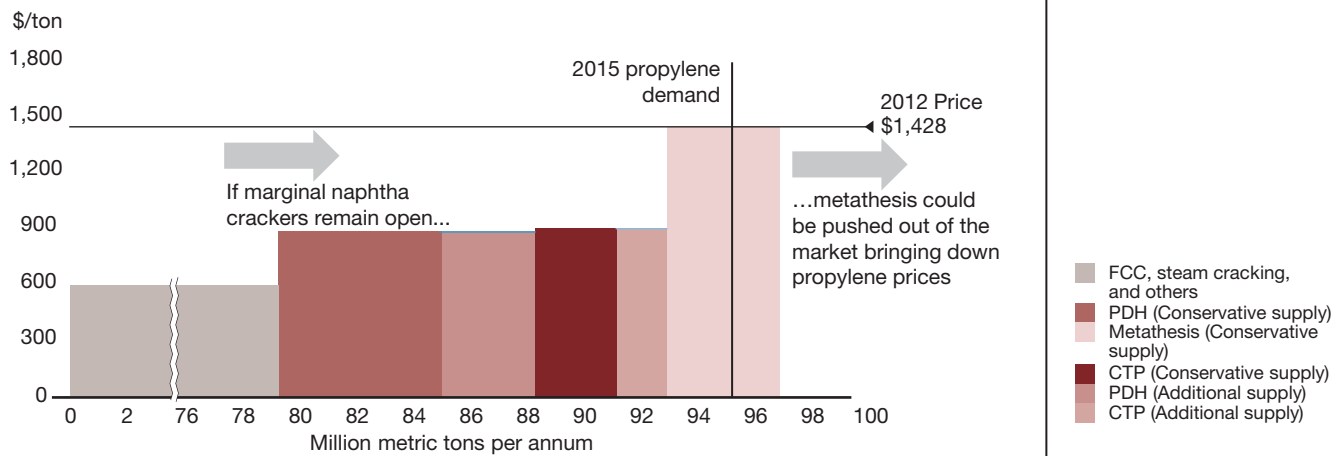
4. Biomass to propylene can follow two routes:

- Biochemical: Fermentation of sugarcane/corn to ethanol followed by dehydration to ethylene, followed by dimerization (to produce 2-butene) and subsequent metathesis.
- Thermochemical: Gasification of biomass to methanol followed by MTP.

Process maturity of both routes is quite low with no commercial scale plants. Economics can be attractive with cash margins of around \$100 to \$150 per ton if ethanol is available at cost. This, however, requires backward integration into fermentation plants.

**Exhibit 4**  
**Metathesis could still be profitable depending on the fate of european crackers**

**Projected global propylene cost curve, 2015**



Note: Analysis assumes steam cracking and FCC units are the most economical sources of propylene, and assumes an oil price of \$90 per barrel. Conservative PDH and MTP supply is based on a 60% utilization of existing capacity and new additions. Additional supply is based on realization of all announced plants and 80% utilization.

Source: ChemSystems; Nexant; ICIS; Strategy& analysis



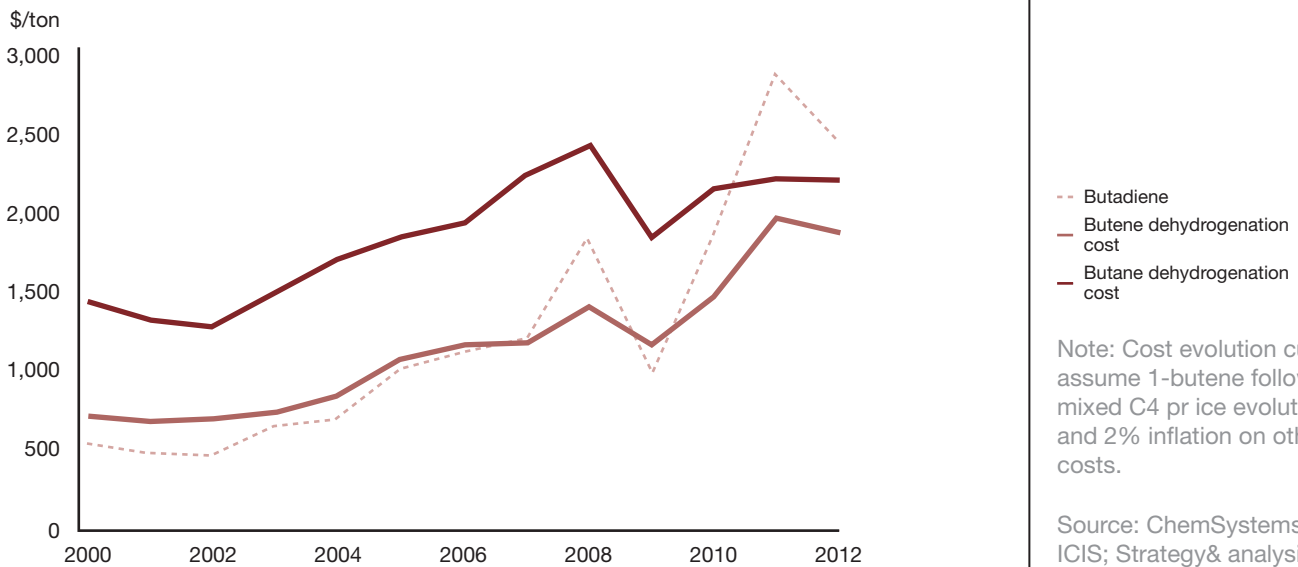
## Butadiene — A Constrained Supply

Most butadiene is produced through extractive distillation of mixed C4 (methane, ethane, propane, and butane) hydrocarbons at the end of steam crackers. The only commercially proven on-purpose alternative is butane/butene dehydrogenation (BDH), but extremely low process yields have kept it uneconomical. This seems to be changing. Given butadiene's current high prices, BDH is looking more attractive (*see Exhibit 5*). However, given its marginal nature, even a slight correction will make it uneconomical again and it is, therefore, a risky proposition.

### Exhibit 5

#### Butane and butene dehydrogenation are currently profitable

##### Butadiene price versus cost (BDH)



## ***Butadiene on-purpose technologies***

**1. Butane/butene dehydrogenation** involves hydrogen elimination from butane or 1-butene using either a catalytic or oxidative process. Although yields are much higher for 1-butene (around 80 percent) compared to butane (40 percent), availability of 1-butene is limited.

The process is mature, but scalability is low at 100 to 250 kilotons per year.

Economics under the current scenario seem attractive with cash margins of around \$500 per ton at 2012 butadiene prices. Historically, the economics have been in the red. As a result, global capacity is very small, less than 500 kilotons per year, and mostly idle.

**2. Bio-butadiene** is currently in nascent stages of development with multiple routes being considered:

- Biomass/carbon monoxide fermentation to butanediol followed by dehydration to butadiene (Versalis, Novamont, and Genomatica partnership/LanzaTech and Orochem partnership).
- LanzaTech is also separately exploring direct carbon monoxide fermentation to butadiene.
- Global Bioenergies and Synthos are working on the artificial metabolic conversion of biomass to butadiene.

Commercialization of these technologies will take at least four years or more, making their commercial implications speculative at best.

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The high cost of butadiene is enticing some producers to develop other on-purpose alternatives to BDH. Most of these experiments are based on butanediol production (from biomass/carbon monoxide) followed by dehydration (by the Versalis, Novamont, and Genomatica partnership and the LanzaTech and Orochem partnership). Other, more novel processes are also being explored, such as the artificial metabolic conversion of biomass to butadiene (by Global Bioenergies and Synthos, for example). However, these technologies will need at least another four years before commercialization, which means that butadiene prices are likely to remain high for the foreseeable future.

## ***Benzene/aromatics — The by-product story***

Supplies of benzene are not as constrained as propylene or butadiene, which is why prices have not risen as fast. This is partly because only about 30 percent of global benzene supply comes from naphtha crackers through the pyrolysis gasoline reforming process. A significant amount of the world's supply comes from catalytic reforming of naphtha at the back end of refineries, which could compensate for any supply shortages from naphtha cracker shutdowns.

Aromatics can also be produced from LPG using the Cyclar process. However, the economics of the Cyclar process depend on LPG demand and on the price of LPG versus the price of the aromatic hydrocarbons in BTX (BTX refers to mixtures of benzene, toluene, and xylenes, all of which are

aromatic hydrocarbons). A much more prevalent on-purpose process is the conversion of excess toluene from BTX into benzene through either toluene hydrodealkylation or toluene disproportionation.

Finally, there are coal-based technologies for benzene. The coke oven light oil to BTX process has gained prominence in recent years, despite being a by-product route. This process is particularly important in China where approximately 30 percent of the country's benzene supply comes from coke production associated with the metals industry. Any impact on global metals demand, therefore, is likely to affect the benzene supply. Given that both these commodities (metals and benzene) are closely correlated to real GDP growth, benzene shortages from this route are less likely the faster the economy grows.

Overall, on-purpose and alternative technologies seem most promising for propylene and adequate for benzene. Over the short to medium term these on-purpose technologies should correct imbalances and bring prices back to historical parity. However, the outlook for butadiene is less certain. On-purpose production is still on the margin and not profitable, which means pricing distortions will continue (*see Exhibit 6, next page*).

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### ***Benzene: alternative aromatics technologies***

**1. Catalytic reforming of naphtha** entails conversion of naphthenes and paraffins to aromatics through dehydrogenation, hydrocracking, or isomerization. Key technologies are continuous catalyst regeneration platforming (referred to as CCR platforming) and Aromax.

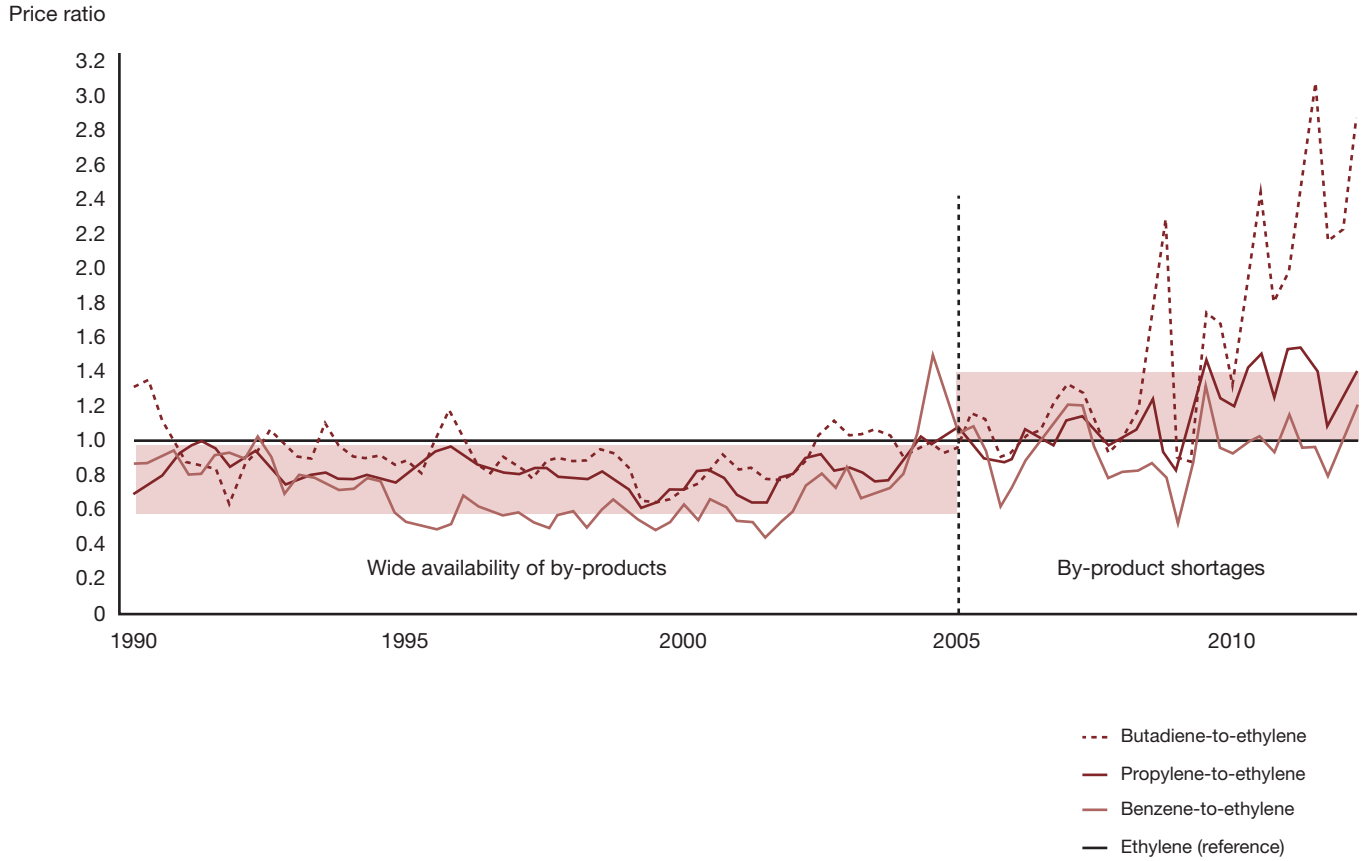
**2. LPG to aromatics** involves dehydrogenation of light paraffins to olefins followed by oligomerization and cyclization to naphthenes and subsequent dehydrogenation to aromatics. The key technology is Cyclar.

**3. Toluene hydrodealkylation** is the process by which the alkyl group is removed from toluene to increase benzene yields from BTX.

**4. With the coal tar (coke oven light oil) route**, lighter fractions of coal tar (a by-product of coke production) that are rich in aromatics are first separated by distillation followed by solvent-based separation to yield BTX.

*Exhibit 6*  
**Shortages have led to price imbalances**

**By-product prices relative to ethylene**



Note: Propylene price premium versus ethylene price. Fuel (around 50%) and other petrochemicals (around 15%) account for the remainder (in 2010).

Source: ChemSystems; Strategy& analysis

# ***Middle East/GCC players have on-purpose potential***

Middle East petrochemical companies have built significant capabilities over the last few decades based on the “cracker + 1” model of producing the key petrochemical building blocks and then converting them into basic polyolefins. As a result, current feedstocks are sufficient to meet the capacity of Middle East producers.

Going forward, however, looming gas supply shortages could challenge growth and will encourage Middle East producers to further adopt on-purpose technologies. Given the changing feedstock environment, Middle East companies need to augment their existing on-purpose capabilities. They will also need to seek new geographies where feedstock is available for on-purpose production. Increasing on-purpose production will however require that these companies develop or acquire more technology-centric capabilities.

Existing on-purpose production of propylene via PDH in the Middle East will remain competitive due to advantageous feedstock prices. However, declining availability of propane could constrain the growth of PDH technology. Regardless of these factors, the production economics for Middle East-based PDH plants will be less attractive than for PDH facilities in the U.S. or for CTP plants in China (*see Exhibit 7, next page*).

Similarly, if ethylene and 2-butene are available at advantageous prices, the metathesis technology for propylene production will be competitive. However, if it is based on market prices, metathesis will remain a marginal technology.

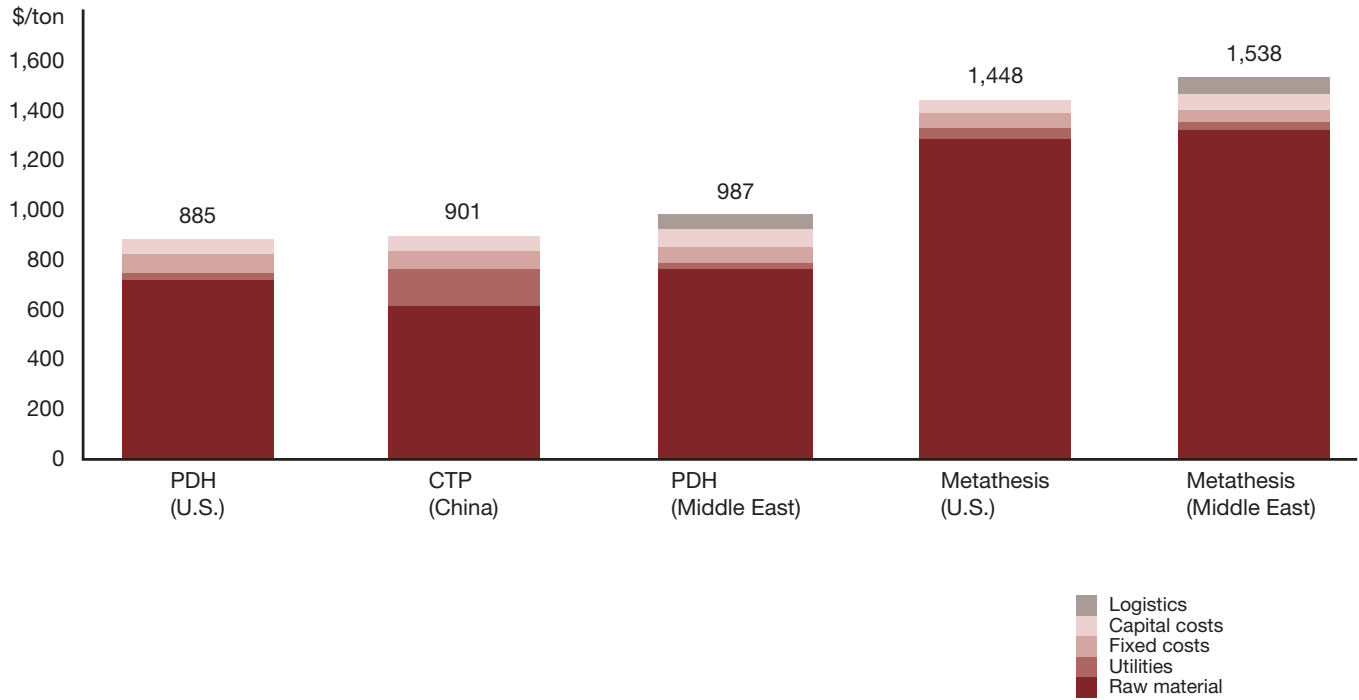
On the aromatics side, Middle East producers should consider the coal to BTX route given the positive outlook for construction in the Middle East and in certain Asian countries such as India and South Korea. The necessary steel production to fuel construction will raise the availability and lower the cost of the coal tar needed for the coal to BTX route.

Finally, the economics of methanol to olefins (MTP) in the Middle East (based on locally produced methanol on a natural gas price of \$2/million tons BTU, or \$14 per cubic meter) might at first seem more attractive than CTP in China. However, the MTP economics are marginal at best.

Exhibit 7

Middle east on-purpose propylene production has challenging economics

Propylene cost across technologies and regions  
medium oil scenario (\$90/Barrel), 2012



Note: Metathesis costs based on U.S. raw material prices for lack of Middle East-specific data.

Source: ChemSystems; Strategy& analysis

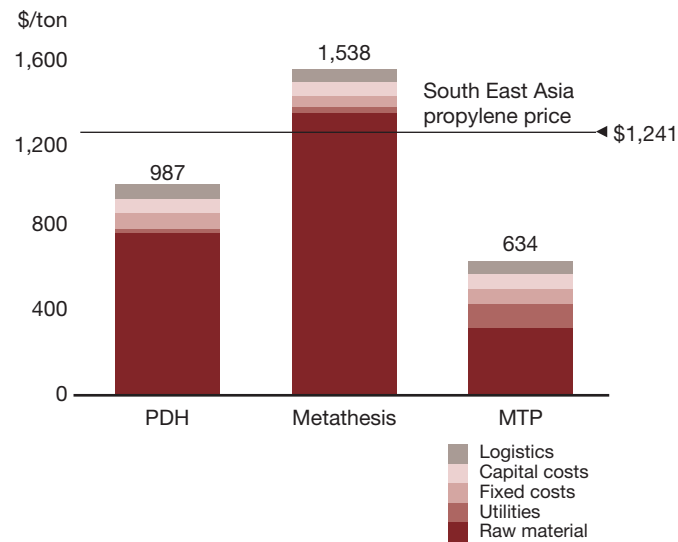
Propylene margins are about \$800 per ton, but do not adequately compensate for the methanol used in production because methanol itself can be sold on the market for about \$300 per ton.

Middle East/GCC players considering investments in on-purpose technologies also need to consider additional aspects such as higher capital costs, logistics costs, and destination markets. Capital costs and logistics costs in the Middle East tend to be higher than in North America, which increases the total cost of production. The margins are further reduced because Middle East products are primarily sold in South East Asia (see Exhibit 8).

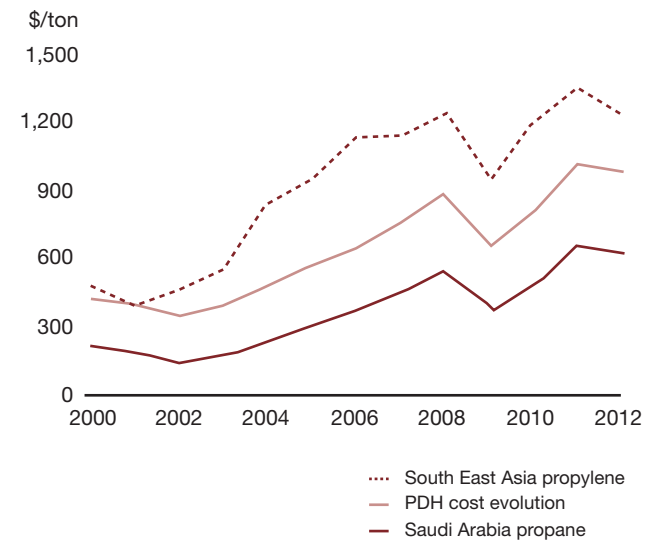
*Exhibit 8*

**Ethylene will be oversupplied in 2025 with European and Asian crackers under cost pressure**

**Middle east propylene cost by technology medium oil price scenario (\$90/barrel), 2012**



**Middle East PDH cost/South East Asia propylene price medium oil price scenario (\$90/barrel), 2000–2012**



Note: Gas prices were assumed to be \$3/mmBtu (\$21 per cubic meter) in Iraq and Russia, and \$6/mmBtu (\$42 per cubic meter) in the U.S. and China. All oil projections in real 2012 prices.

Source: Nexant; Strategy& analysis



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# ***Conclusion***

Feedstock developments have significant implications for all players in the chemicals value chain. The growth opportunities are particularly important for global producers of propylene, butadiene, and benzene in those parts of the world where feedstock is available for on-purpose production. To date, many have invested in process technologies to bring down costs. However, going forward global producers must rethink their research and development strategies. They must focus on the most promising product technologies to create on-purpose production. At the same time, customers for propylene, butadiene, and benzene need to ensure security of supply and price stability through backward integration.

Wherever they are based, all players across the value chain must recognize that recent feedstock developments in North America represent fundamental changes in the industry. It behooves all of them to consider their competitive responsiveness to assure production and access to a steady supply of critical chemical building blocks at reasonable prices. For most players, investing in some aspect of on-demand production will be crucial to their long-term success.

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