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## Linear alpha olefins – **A question of balance**

Mark Morgan P3



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## Vision & contents

# The outlook has not seen such a high degree of uncertainty...

Mark Eramo, Vice President, IHS Chemical, Houston, TX



➤ **During March 2016, over 1000** attendees will gather for the 31st Annual IHS World Petrochemical Conference. This gathering is unique, as it brings together delegates from every region, representing all dimensions of the chemical industry. While it is known for the deep content it provides, many delegates come to hear the views regarding the future of the industry. The outlook for major factors which impact chemical industry profitability and the resulting boardroom decisions, have not seen such a high degree of uncertainty for many years. This uncertainty appears to have caused a “collective pause” within boardrooms regarding future investments, which by 2020 could result in supply limitations not seen since the late 1980’s.

The chemical industry is an enabler of modern living. It has the ability to take a barrel of crude oil and produce consumer end-use products

that provide for society’s basic needs, while at the same time producing advanced materials used to meet the most sophisticated needs of many emerging industries. Chemical investment decisions are driven by assumptions regarding energy and global economic growth. From 2009 to 2014, there appeared to be a predictable pattern for both. Energy markets were defined by high crude oil prices (controlled by OPEC) and low natural gas prices in North America (resulting from shale developments). The economy was defined by growth in the developing world led by the BRIC’s (Brazil, Russia, India, China). Today, those paradigms are shattered. Crude oil markets are looking to North America to cut production and while India grows, Russia and Brazil struggle with recessions and China’s economic engine endures change. Add in the chaos caused by evolving geopolitics, increasing regulations and sustainability requirements; strategic planners have never been more challenged to deliver sound investment cases.

In order to deal with today’s uncertainties, industry boardrooms need scenario planning flexibility combined with analytical capabilities that can pull together integrated value-chain forecasts, based on current and relevant market data. Combine that with decades of industry experience and strategic insight, and this is what we call IHS Chemical.

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# Linear alpha olefins – A question of balance

By Dr. Mark Morgan



**➤ In the light of recent investment announcements it is important to remember that this industry serves a very wide variety of customers in very different end-use industries, each with their own challenges and opportunities.**

## A very complex industry

Today the linear alpha olefins (“LAOs”) is a 5.0 million metric ton industry, growing well ahead of average GDP. The complexity of the industry comes, in part, from the established technologies that make them. So-called “Full Range” LAO technologies convert ethylene into a distribution of products with even carbon numbers from butene-1 (C4) all the way to C20+ (eicosene-1). The complexity of the business comes from LAOs serving multiple industries from large volume commodity polymer producers to small volume specialty chemicals producers across a very broad customer base, each with their own specific needs in respect of logistics, volumes consumed, etc. LAOs come in the form of gases (butene-1, usually transported as a pressurized liquid like butadiene), liquids, through to waxes (C22+), which are shipped in

flake or even molten form.

In more recent years the apparent divergence in growth rates between lower LAOs (C4, C6, C8), serving mainly commodity and specialty polymer applications and higher LAO (C10+), has encouraged companies to explore and develop a range of on-purpose technologies to target specific LAO fractions. Capturing and developing a detailed and deep view of the global industry is a challenge, but IHS Chemical has now achieved this with the capability to cover market dynamics for twelve inter-related LAOs, serving 25 different applications across all regions.

The range of applications served can be mapped to different carbon numbers (*see Chart 1*). Specific fractions target commodity polymers and polyolefin elastomers, synthetic lubricants, plasticizers intermediates, surfactants, oilfield chemicals, waxes and several niche specialty chemicals from alkylamines through to aluminium alkyls. The supply base not only includes ethylene, but also coal-derived synfuel streams (Sasol) and refinery/petrochemical C4 streams.

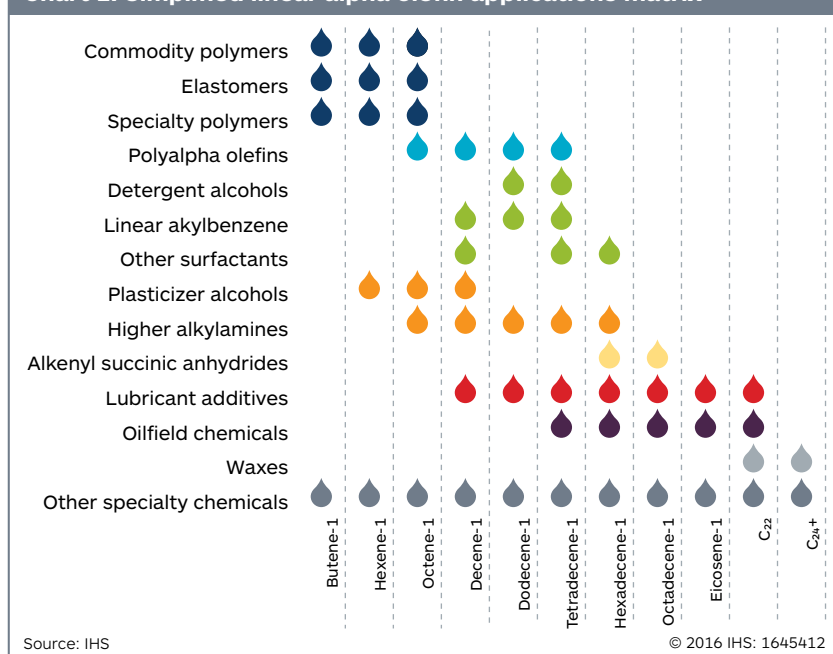
## Demand drivers vary considerably by application

Polyethylene comonomers dominate overall demand and offer strong growth potential well ahead of average GDP. The complexity in this part of the business arises from inter-competition between different polyethylenes on a price versus performance basis. This is particularly true of C4-LLDPE and C6-LLDPE inter-competition. A number of polymer producers are trying to push C6-LLDPE grades into the Chinese market with different levels of success.

Specialty polymers too, like polyolefin elastomers or “Plastomers”, offer a strong growth opportunity, particularly for octene-1. These polymers are finding widespread use in flexible packaging, through to durables in, for example, automotive, where their “soft touch” properties are useful. Indeed, these materials are substituting well-established polymers like EPDM, EVA, etc.

After commodity polymers, polyalpha olefins (“PAOs”) consume most LAOs, notably in the mid-range (*See Chart 2*). PAOs are so-called Group IV synthetic lubricants. Decene-1 is the major PAO building block, although higher fractions are used, either because decene-1 supply is restricted or there are particular applications where tailored PAOs

Chart 1: Simplified linear alpha olefin applications matrix



Source: IHS

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## Feature

perform better in-service. PAOs are used mainly in mass transit applications for light vehicle crack-case lubricants, automatic gearbox transmission fluids, etc. Industrial applications include gear oils for wind turbines, machinery, etc. PAOs have an excellent balance of properties in respect of viscosity, pour point, oxidative stability, etc., that make them an ideal choice for many applications, but they are relatively expensive. In the last decade PAOs have faced major challenges from competing lubricants, especially hydrocracked base stocks. Today however, more aggressive legislation is driving emissions reduction in the automotive industry. This, in turn, impacts engine designs to run hotter and under these conditions PAOs become the synthetic lubricant of choice, driving new demand. Even in China PAOs are expected to see major growth, starting from a low base as automotive OEMs move production to the Asia Pacific region. New PAO products based on octene-1 and metallocene-based catalysis, have been introduced, focused on industrial applications but with some blending into conventional PAOs serving mass transit applications.

**A resurgent alpha olefins industry is encouraging new investment in full range as well as on-purpose capacity as polymers, plastomers, synthetic lubricants, etc., drive demand growth**

In the surfactants industry, Shell operates a unique adaptation of full range LAO technology. Shell can take higher and lower LAO fractions and process them using metathesis to manufacture a range of linear internal olefins (“LIOs”) that supply its integrated synthetic detergent alcohols business. These, in turn, serve ethoxylation and sulphonation units to supply a

wide range of surfactants. These compete against natural oil-derived products. The dynamics of crude oil, gas and lauric pricing impact competitiveness. However, within the surfactants product family, there are materials like alpha olefin sulphonates (“AOS”) that use exclusively mid-range LAOs with India a major producer.

As the LAO demand segments become more specialised then the market tends to become more fragmented. Although crude oil prices are currently relatively weak, the oilfield chemicals sector is a major destination for higher range LAOs. In the off-shore sector, HSE legislation; particularly biodegradability, impacts LAO use in drilling muds and fluids. In the on-shore sector the situation is far more complex. Horizontal drilling, for example, takes place in geologies of great variety requiring almost drilling-well-tailored drilling muds/fluid formulations, with a need for a wide range of functionalised LAOs and LIOs.

Industries like alkylamines, waxes, mercaptans, heavy alkylbenzenes, alkyl-naphthalene, chlorinated organics, etc. all have their drivers and challenges.

### Western markets dominate but China becoming more important

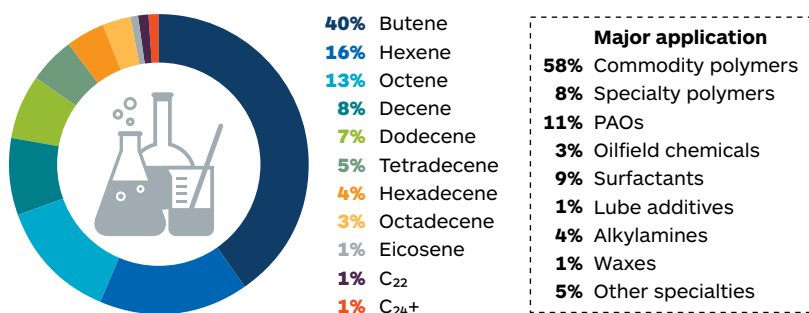
North America remains the largest alpha olefins market (*see Chart 3*) where many of the major players, ChevronPhillips, Ineos and Shell are captive in many downstream industries. Asia is a large market for comonomers, mainly butene-1 as is the Middle East. Although relatively small today, the C10+ sector in China has considerable growth potential in segments such as PAOs, oilfield chemicals, specialties, etc. This is on top of an already large commodity polymers industry, consuming mainly butene-1 today, but with opportunities to widen its comonomer portfolio. Over the longer term, IHS Chemical believes there may be an increased need for local full range LAO supply which would require an investment in China itself, or somewhere close by to serve this growth opportunity.

### Technology access is a challenge

Today, on-purpose LAO production capacity slightly outweighs full range production capacity (*See Chart 4*). This is a very view from maybe a little as ten years ago. The development of refinery and petrochemical complexes in China has made more C4 streams available for butene-1 separation. There has been only limited investment in full range processes, the last being the ChevronPhillips-Qatar Petroleum joint venture in Qatar. Technology access is limited.

Theoretically, full range LAO technology is available for third party license, namely  $\alpha$ -SABLIN® (Sabic/Linde) – which is commercial, as well as offerings from Axens (Alphaselect®) and UOP (Linear-1®) – these are not commercial. In the past some of the major players

**Chart 2: Linear alpha olefin demand breakdown**



Source: IHS

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have licensed their full-range processes on a tactical basis, either to third parties or to joint ventures. Could they do so again?

Butene-1 (Raffinate-based and Axens - Alphabutol®) and, to a lesser extent, hexene-1 (e.g., Axens - Alphahexol®) technologies, appear more straightforward to access. In addition, there are other possibilities, e.g., CBI Lummus C4s to hexene-1, or possibly even a bio-based processes for decene-1 from natural oils such as that claimed by Elevance.

#### The industry faces a number of challenges and questions

In looking forward there are a number of challenges facing the industry, for existing producers, consumers as well as companies seeking to enter. The choice of technology – full range versus on-purpose is very important. Each technology has advantages or disadvantages. A long LAO distribution, C4-C30+, for example, provides a wide range of products but only makes sense if there is demand growth across the whole spectrum with a wider variety of customers to serve. LAO producers have to achieve margins across the distribution to support viable investment returns. Shorter distributions, favouring comonomers and C10, still make some C14+ and the quality of these products varies considerably, with some fractions heavily branched reducing their utility.

Even in the case of on-purpose supply, now with Sasol's tetramerization process installed in the United States, there are questions as to whether this will achieve its design capacity and its impact if it is fully successful or not.

In looking forward there are some key questions that IHS Chemical is very well paced to answer. These include:

- What is the impact of higher penetration of C6-LLDPE in China?
- What is the impact of higher or lower penetration of Plastomers?
- What is the impact of new PAO developments in the synthetic lubricants market?
- What issues will impact synthetic and natural alcohol inter-competition in future?
- Who will or can invest and where and with what technology platform?
- Who are the winners and losers?
- Where will or can new technology make a difference as this too, is key to growth?

IHS Chemical Consulting now has a new offering in LAOS that brings together knowledge, expertise and insight from IHS Energy (lubricants, oilfield developments, etc.), IHS Automotive (engine design, legislation impact and lubricants), IHS Chemical Insight (surfactants, specialties, etc.) as well as its in-house experts to model market dynamics for all fractions

Chart 3: Linear alpha olefins – regional demand

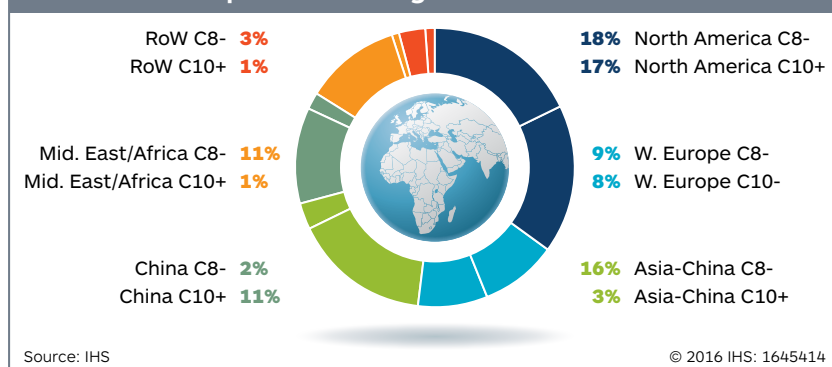
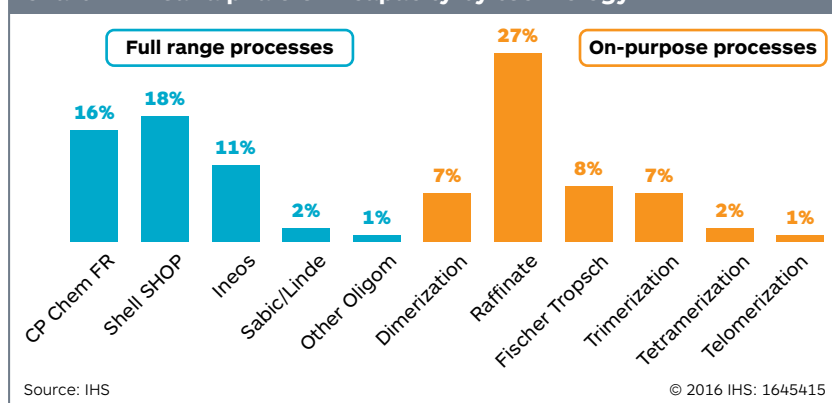


Chart 4: Linear alpha olefin capacity by technology



and downstream, pricing, advice on business strategy, etc., even within a framework relating to IHS' views on global megatrends.

In summary, LAOs form a complex industry, currently in growth mode with ongoing investments, growing across multiple frontiers, namely regions, applications and technology. Understanding and navigating this business is also complex and IHS Chemical is well placed to support its customers along the LAO journey, whether a supplier, a consumer, an investor, or would-be supplier. ■

Dr. Mark Morgan is a UK managing director within the chemical consulting business of IHS. Mark's background is broad from chemical technology, specialty chemicals, through to advanced materials.

# Assessing the impact of rising Saudi Arabia feedstock prices

By Steve Lewandowski



➤ **Low oil prices have been a boon for some** ethylene producers. By swapping reduced-priced ethane for high-priced naphtha in their ethylene production, many companies have realized savings of more than 50%. But ethylene producers shouldn't expect bargain petrochemical feedstock prices to continue indefinitely for either ethane-fed steam crackers or naphtha-fed crackers.

Recent feedstock price increases announced by the Kingdom of Saudi Arabia (KSA) will create ripple effects throughout the chemicals value chain. Yet the impact of these changes may surprise even veteran industry professionals. How should companies deal with the rising cost of feedstocks?

## Dramatic price increases

Saudi Arabia has long offered the cheapest gas prices in the Middle East, among the lowest in the world. This pricing created a significant cost advantage in the olefins industry, thanks to ethane pricing designed to incent foreign and domestic investment. Yet the direction of feedstock pricing in Saudi Arabia has been marked by uncertainty over the last four years, thanks to the lack of a new pricing policy, after the 2002-2011 program expired.

That ambiguity ended with Saudi Arabia's recent announcement of price increases for ethane and methane. Facing higher defense spending and a dramatic drop in oil prices, KSA decided to reduce subsidies and raise government revenues. As of January 1, the price of ethane rose 133%, from \$0.75 per million BTU to \$1.75 per million BTU. Methane costs jumped 67%, up from \$0.75 per million BTU to \$1.25 per million BTU.

## Minimal long term worries

Although these price increases seem significant, their actual effects may be surprisingly inconsequential – especially in the ways that concern industry watchers most. One reason for calm: despite the price increases, the cost of Saudi feedstocks remains among the lowest in the world. (See Chart 1)

Furthermore, the long-term impact of this increase is small. A comparison of cash costs between the old and new pricing models reveals a relatively insignificant change over the long term. (See Chart 2)

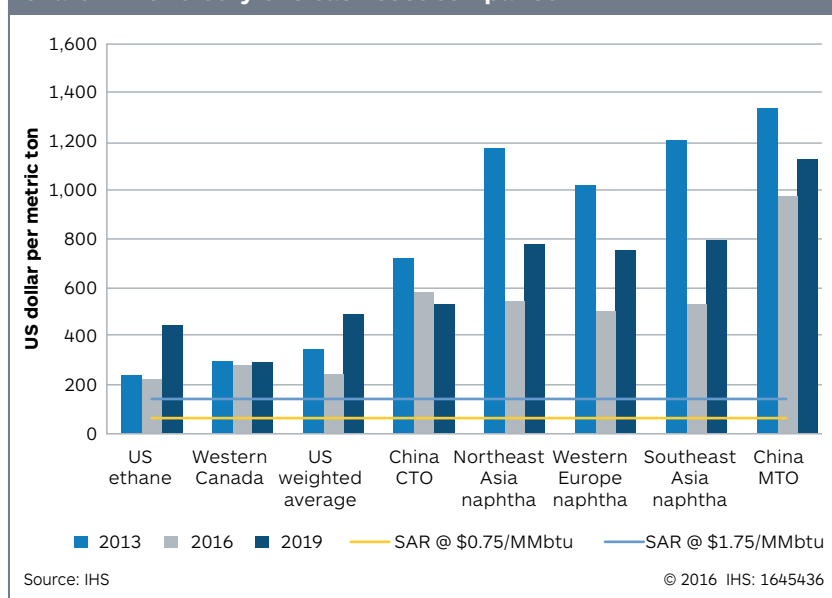
It is true that value chain partners who are driven by the cost of monomers will experience some limited impact of price increases. Ultimately, chemicals companies will be exposed, as costs are pushed through the chain. Over the long term, EBITDA actually drops for some of these firms. Even so, the impact of the price increase over the full term – especially in the later years of the period surveyed – is fairly inconsequential. (See chart 3)

## Real concerns for the near future

Although long-term impact of KSA price increases is minimal, the chemicals industry will experience certain short- and medium-term effects. As designed by Saudi Arabia, the most immediate change will be a shift in profitability, with benefits realized by upstream oil and gas producers such as Saudi Aramco. Cash cost changes for Saudi cracker operations will be largely balanced, with rising ethane prices offset by falling prices for liquefied petroleum gas (LPG). Lower LPG prices will also benefit propane dehydrogenation plants in Saudi Arabia by reducing feedcost.

Although chemicals companies may experience modest reductions in earnings, their historically high profitability will help these organizations absorb the net cash cost effect. By no means will feedstock price increases eliminate the competitive

Chart 1: World ethylene cash cost comparison



The Saudi Arabia feedstock price increases seem significant. However, their actual effects may be surprisingly inconsequential – especially in the ways that concern industry watchers most

advantage of these businesses.

Looking further ahead, the most significant midterm impact of price increases could be a higher incentive for KSA to resume investing in upstream and midstream natural gas and natural gas liquids production. Higher sales prices increase the potential return on investment. Therefore, new wells, new recovery equipment, and additional gas and natural gas liquids help feed the appetite for global petrochemical growth.

Until recently, market growth has been limited by a lack of raw materials, not low ROI for petrochemical players. For this reason, it is possible we may see another round of investment in petrochemicals rather than the currently forecasted growth. Alternately, new investment could increase the volumes of recovered gas, displacing local oil needed for energy. In this case, oil markets could remain soft, lowering the cost of monomer production on naphtha-based crackers.

#### Essential questions and expert insight

Chemicals companies must prepare for the changes likely to result from feedstock price increases. The following questions can help industry leaders derive benefit and mitigate risk from these changes:

- KSA wanting to move to more value-added chemicals, is there an investment opportunity for those with unique technology, once the basic chemicals of methanol, ethylene, and propylene become available?
- What is the risk of a second, third, or fourth bump in pricing? Alternately, what is the risk that KSA will remove pricing controls and allow the free market to decide prices, as that government has done with crude oil?
- Will longer-term depressed crude oil prices create cash flow constraints that raise KSA's interest in developing more joint venture partners? Is there an opportunity to become a joint venture partner of choice? Or will KSA instead decide to go it alone?
- Will local companies realize long-term benefits from investments, or will benefits go to international companies who partner with KSA?

Understanding the consequences of rising feedstock

Chart 2: Saudi Arabia steam cracker cash costs

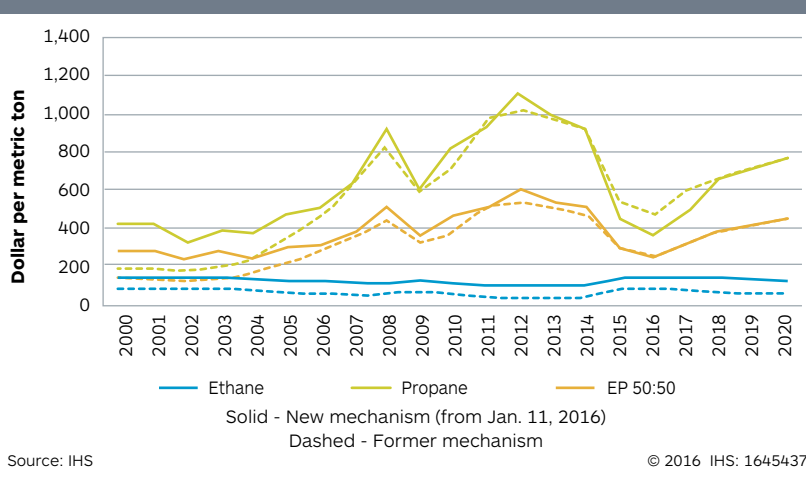
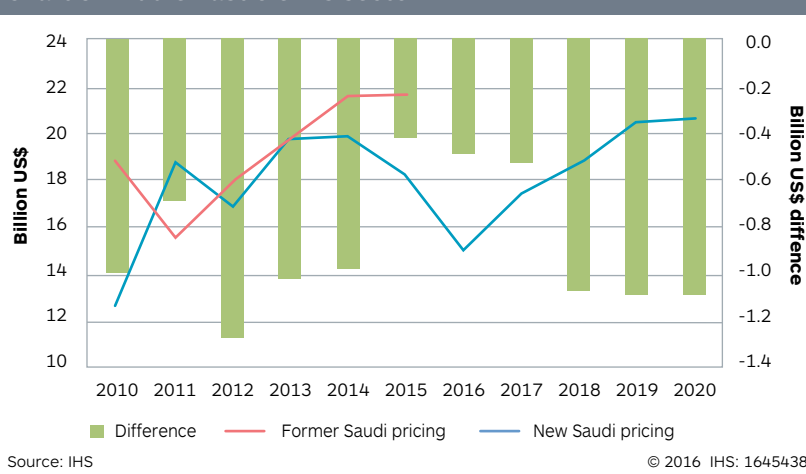


Chart 3: Middle East olefins sector EBITDA



prices in Saudi Arabia is not a simple calculation in which higher natural gas and ethane pricing automatically equal slowing petrochemical builds. To make optimal decisions, chemicals leaders must dig deeper into supply and demand fundamentals for oil, the relationship between oil and other feedstocks, and the impact of lower oil prices on the economic development of non-oil producing countries. The energy and petrochemical experts at IHS continue to sort through these points of connectivity and synthesize a longer-term view of the evolving world, which helps our clients develop strategies that enhance competitiveness and shareholder returns. ■

Steve Lewandowski is Global Business Lead for Olefins at IHS Chemical.

# Latin America: Struggles and joys with **the shale revolution**

By Raul Arias Alvarez



## “So close and so far” – A reflection on today’s Latin American petrochemical picture

Just a few years ago, Latin America was on the verge of becoming a petrochemical powerhouse. Hydrocarbon resources, significant in some cases, had lent countries in this region the self-confidence needed to dream big about the future use of their resources—and they dreamed of petrochemical mega projects.

Latin America is a very diverse region, yet one with strong similarities across its geography. It stretches from Mexico to Tierra de Fuego and encompasses more than fifty countries, including Caribbean nations. It is five times the size of the United States and with a population of about 634 million, it accounts for nearly 65% of the Americas. In 2014, Latin America’s GDP was equivalent to about 24% of the total economic output of the Continent.

Thus, with a big population, a growing middle class and rich crude oil and natural gas reserves, the moment seemed just right to ignite a petrochemical boom. By 2007, multiple petrochemical projects had been announced, and many of them were being seriously evaluated across the region.

Those times were characterized by increasingly high crude oil prices—to the point that a major consultancy infamously speculated that crude might exceed a price of 200 dollars per barrel at some point in the near future. This, as we know proved dramatically wrong soon after.

Olefins and polyolefins projects dominated the landscape, but megaprojects for integrated petrochemical complexes in Brazil, Venezuela, and later in Colombia were also announced. Venezuela declared a “Petrochemical Revolution” and analysts started referring to this country as the future “Middle East of the Americas”. The wave of actual project implementations seemed to be taking off when in late 2009 Braskem and Idesa were awarded the long sought-after ethane contract for a major ethylene/PE project in Mexico by Pemex, the State-run Mexican energy company.

With insufficient demand to absorb all planned capacity, many such projects contemplated the U.S. as the key target market. The U.S. petrochemical industry ached under the lack of investment due to the low competitiveness of its mainly naphtha-based facilities and seemed doomed to becoming a net importer of a number of commodity products.

At the same time, concerns were brewing about the potential impact of the planned Latin American capacity overflow, on the Americas and on global trade patterns.

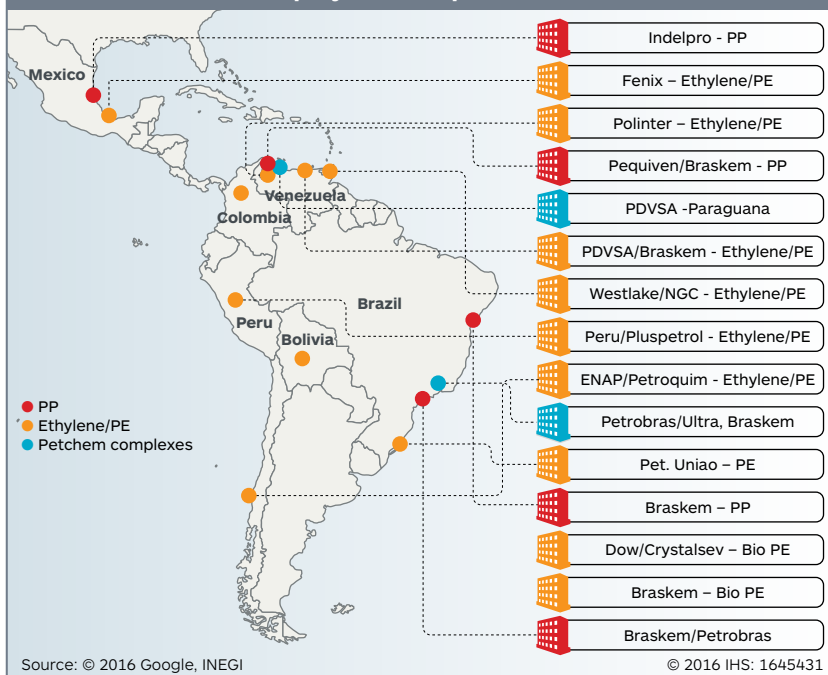
### The beginning of a perfect storm: the shale revolution

While projects in Latin America were evaluated and re-evaluated, an unexpected development was taking place in the U.S. that would reshape the global energy scenario: the combination of directional drilling and rock fracturing (the so-called “fracking”) for the extraction of unconventional reserves had evolved into a technically ripe and sufficiently economical technology. Given the existence of huge reserves in some parts of the country, a drilling and production boom would soon unleash.

Thus, in an incredibly short time, U.S. dry shale gas production had skyrocketed from historical levels of less than 3 billion cubic feet per day not so long ago to around 10 billion cubic feet by 2009/2010. Ethane from shale gas became so competitive that it caused a shift in ethylene feedstock preferences and a shift in the competitiveness of U.S. production.

And whereas the petrochemical industry was just

Chart 1: Latin America projects: Snapshot 2007





becoming aware of the aforementioned development, in March of 2011, Chevron Phillips announced a project for a world-scale ethane cracker based on shale gas, the first major petrochemical project to be announced in the U.S. in a very long time and the first of many more that would follow.

By 2011, the U.S. had made it through the worst global economic crisis since the great depression—a crisis that had started locally in 2007/2008 with the collapse of a mortgage boom and had pulled in the whole world. Latin America had weathered the storm surprisingly well. Brazil was one of the bright spots. Crude oil prices had collapsed and recovered again to a level that many thought would last forever.

Once the worst of global economic meltdown was over and the dust started to settle, companies found that the typical financiers were not ready to lend again. Sponsors of major Latin American projects could not find financial partners, not even in atypical locations such as the Middle East, India and China. Moreover, they also discovered that, thanks to the dramatic dimension of planned capacity additions, North America would become a net exporter of key commodity petrochemicals—not the net importer that analysts predicted just a few years back.

#### What does this mean for Latin America?

One may be tempted to automatically match up North American planned overcapacity with South American future demand. In reality, the answer may require some analysis. Let us take a look at methanol, for instance, one of the markets that IHS monitors closely on a regular basis.

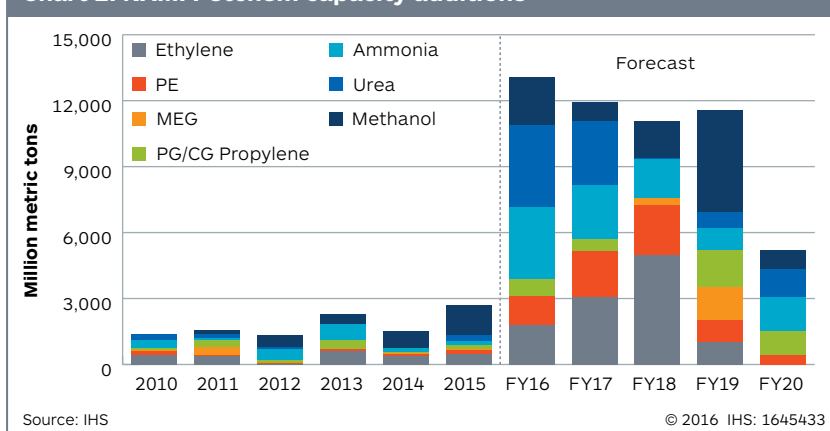
South America is a significant exporter of methanol, much of which goes to the USGC. Regional world-scale capacity is located in Trinidad, Venezuela, Chile and Argentina. There are smaller plants in Brazil and Mexico.

Trinidad is the leading global exporter. Total methanol production capacity is 6.7 million tons per year, of which 4.7 million tons was exported in 2014. Trinidad has seven plants and one major active project: a methanol and DME complex with planned startup in 2019.

It is evident that as U.S. methanol net imports turn into net exports, South America will have to shift target markets. However, with increased global capacity and competitiveness, this may be a challenge (in this particular case, there are other aspects IHS has helped companies assess, e.g. long-term feedstock and consumption balances—a whole analysis topic in itself).

If we direct our attention to polyethylene (PE), the match seems perfect. Latin America has deficit of polyethylene and with no capacity additions, the deficit will expand over time. By 2020, the region is

Chart 2: NAM: Petchem capacity additions



projected to import around 3.6 million tons of PE. Even Brazil, home of the most capacity will be unable to meet domestic demand within a few years. By 2020, demand will match or exceed the current nameplate capacity according to IHS projections. Of course, the development for specific resin types (LDPE, HDPE, LLDPE) will occur at different speeds and under different drivers across the region.

Competitive PE from North America will certainly be welcome. Nevertheless potential suppliers will have to be prepared to face competition from other geographies and to respond to the specific expectations and requirements of every country. In an effort to support a better understanding of the regional polyethylene industry, IHS recently researched the Latin American market, with strong focus on the key consuming countries, segmentation of demand using perspectives that are not traditionally covered in our annual World Analyses, such as end-markets (packaging, agriculture, construction, etc.), and comonomer and catalyst types (for LLDPE only). The insight gained from conversations with market players (to a major extent converters) has provided valuable input for the analysis and projections that IHS has cast in a special report entitled “Latin America Polyethylene Market: Supply Shortfalls, the Growing Opportunity”.

Today it appears that the dramatic metamorphosis in energy and global economy that helped shape the current Latin American petrochemical scenario has robbed Latin America’s dream of petrochemical self-sufficiency. It may also have closed a vital market for a few flourishing product sectors. Maybe it has (for some time at least) but maybe it has also brought along competitive and abundant supplies of commodity petrochemicals that will be increasingly short – sourced from within the same continent. ■

Raul Arias Alvarez is a Director within IHS Chemical’s Consulting Group based in Houston, US.

# How falling energy prices alter China's chlor-alkali and vinyl industries

By Stein Raae



➤ **After a 15-year investment binge, China now possesses the world's largest production capacity for PVC and chlor-alkali.** In fact, the nation is able to produce as much as 50% of global PVC and 42% of global liquid caustic soda (LCS). Yet, falling energy prices – combined with an overall decline in the growth of Chinese gross domestic product – are shaking up China's chlor-alkali and vinyl industries, creating implications for chemicals companies around the world.

Beginning at the turn of the century, investment in new chlor-alkali projects accelerated at an unprecedented rate, dominated by China. As oil prices began to fall, Chinese investment slowed dramatically in 2015. This year, IHS forecasts limited chlor-alkali investment, with no new projects in China.

Lack of demand is not the cause of China's shifting investment priorities. Global demand for PVC continues to rise. Yet China's planned production is not keeping pace. What is behind this deliberate lack of growth?

Declining export volumes tell part of the story. China's 2015 PVC exports were 30% lower than the previous year. Key to this decline is India's ongoing anti-dumping duties imposed on PVC of Chinese

origin, which reduced the total volume of PVC exported to India by 50% between 2014 and 2015.

In the fourth quarter of 2015, China's LCS exports shrunk by 62% from Q3 levels and 47% year over year. The major reduction in exports is attributable to Australian alumina refineries, which have turned away from suppliers in Northeast Asia and the Middle East and toward the U.S. Gulf. Japan has also emerged as a strong competitor to China, especially for smaller parcels to customers in Southeast and South Asia.

## High costs, reduced competitiveness

Falling export volumes are directly tied to the high production costs, which have negatively affected the ability of Chinese producers to compete in the export market.

Chinese companies rely heavily on coal as a source of energy to drive the chlor-alkali and vinyl industries. While producers in other regions typically use a mixture of fuel oil, natural gas, and coal, more than 80% of the PVC capacity in China is carbide-based.

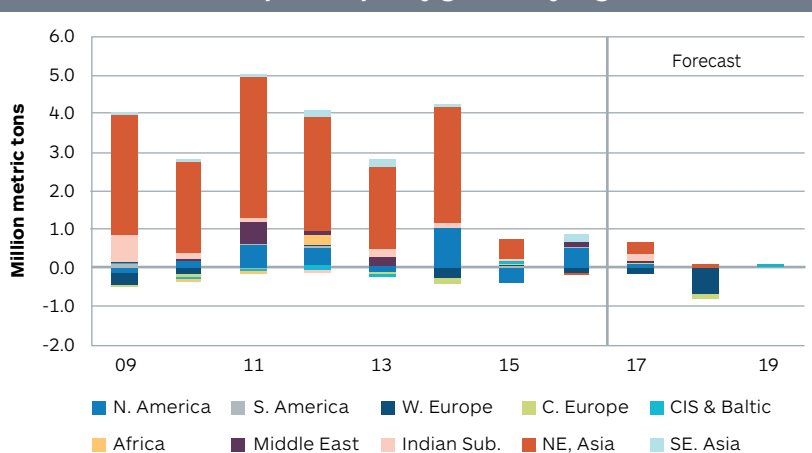
When energy prices began to decline in 2014, cost structures shifted accordingly. Although all energy prices dropped, crude oil and ethylene prices fell further than those of coal. Chinese chlor-alkali producers who once benefitted from "cheap" coal found themselves struggling to compete with lower-cost producers in the export market.

What's more, lower energy costs have allowed deep sea and other Northeast Asian producers to drive increased volumes of ethylene-based PVC into China. With severe pricing pressure exerted by these companies, many carbide-based PVC producers in China closed their plants, while others simply scaled back production rates. It is estimated that 2.7 million metric tons (MMT) of carbide PVC capacity shut down in China in the 2014-2015 time frame.

## Stricter regulatory mandates

Environmental concerns and new regulatory mandates are also contributing to China's changing strategies. Government initiatives to stem the worsening industrial pollution were beginning to add cost and complexity to production facilities. Then in August 2015, a chemicals warehouse in Tianjin exploded,

Chart 1: World: Nameplate capacity growth by region



Source: IHS

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killing 173 and injuring hundreds.

In response to the physical damage and political turbulence caused by the explosion, the Chinese government instituted stricter measures and new environmental policies to monitor the transportation of hazardous chemicals on road, river, and railway networks. More frequent inspection and stricter enforcement of rules are encouraging producers to reduce industrial discharges and comply with new environmental standards.

Close monitoring of caustic and PVC transport vehicles – which is intended to ensure compliance with more stringent rules on allowable cargo weight and road safety – has also increased. This new diligence has indirectly added more cost to the transportation of cargo. Most of this cargo must be transported from inland production sites to coastal ports, driving up costs and further reducing profitability.

Carbide PVC producers are facing even greater challenges. The Chinese government is enforcing a new deadline that requires these companies to convert existing mercury-based chemical catalysts to mercury-free production. Cheaper mercury-based processes are highly polluting and considered hazardous to human health and environmental safety. Complying with new safety standards and environmental rulings will further drive up costs for carbide PVC producers.

#### Impact on China's chlor-alkali and vinyls market

How will current economic and regulatory trends impact the Chinese LCS and PVC markets? IHS anticipates several likely outcomes. With the prevailing ethylene and crude oil pricing trend, we expect a continuous influx of ethylene-based PVC from deep sea and other Northeast Asian countries into China. Chinese carbide PVC producers will continue to struggle to compete. Chinese downstream producers will continue to choose imported PVC for their own consumption.

Pricing pressure on carbide PVC producers may worsen further as newly built ethylene cracker capacities come online in the U.S. between 2017 and 2018. By producing cheap ethylene and pushing more PVC into the export market, this new capacity may further depress ethylene prices and increase the influx of deep-sea ethylene-based PVC into Asia.

IHS forecasts that crude oil prices will gradually recover over the next five years. If coal prices remain flat, the competitiveness of Chinese producers could improve compared with companies in Korea and Japan that rely on fuel oil. China's vast production capacity and availability would provide a regional advantage against these smaller producers. In the broader market, U.S. Gulf producers would likely retain a price advantage over the Chinese. U.S. producers would move any excess LCS volumes into the Australian and U.S. west

Chart 2: PVC global demand trends

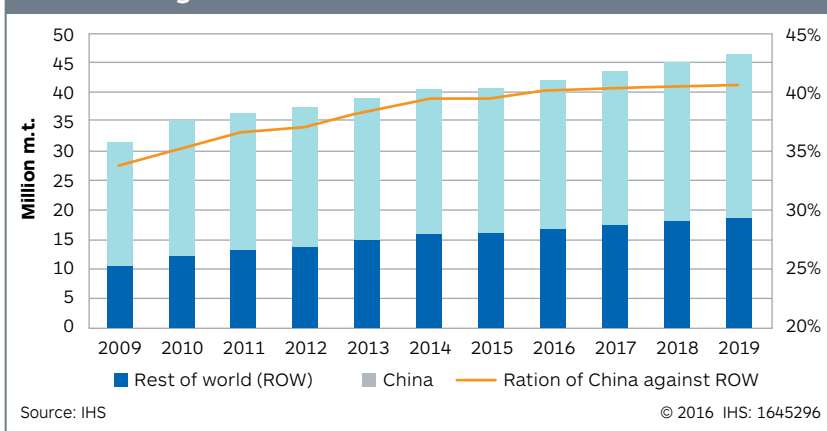
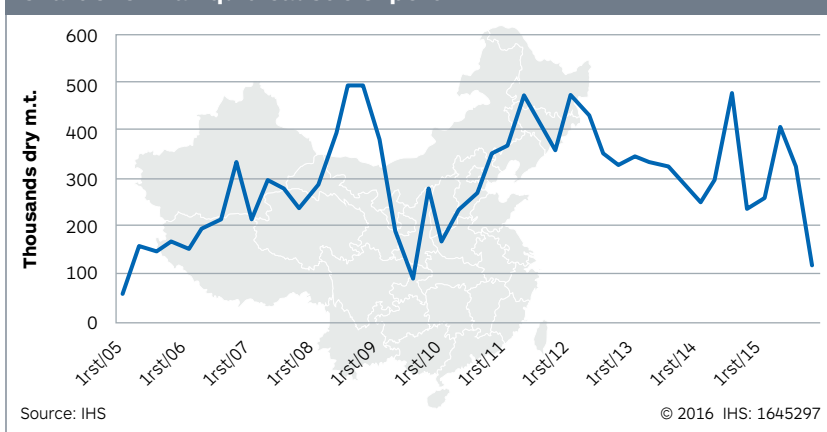


Chart 3: China liquid caustic export



coast markets, potentially displacing products from Northeast Asian producers. Furthermore, the lifting of sanctions may help Iran aggressively ramp up its exports, creating another competitor for Chinese producers.

For the last two decades, coal has been a key driver of China's economic growth. But as lower oil prices upend the production economics and the operating environment becomes stricter and more costly, change is unavoidable. Could China find itself with an energy cost advantage that reignites the demand for coal-based chlor-alkali and PVC? Would the Chinese government downplay the effects of coal on the environment and reopen closed coal-based chlor-alkali and vinyls production sites? Firms in the chemical supply chain must watch developments closely so they can anticipate and respond to market change. ■

Stein Raae is Global Business Director Chlor-Alkali/Vinyls/Inorganics at IHS Chemical.

# Gasoline pumps up the **pressure** on paraxylene

By Duncan Clark



➤ **With the build up of significant paraxylene capacity in South Korea, Saudi Arabia and India during 2014, well above market demand growth, 2015 was always going to be a challenging year for global paraxylene producers. However, they probably would not have anticipated that the most significant challenge could come from feedstock sourcing as a result of competition from the gasoline pool.**

## Paraxylene capacity build

During 2014, a number of large new paraxylene plants came online in order to serve the growing import needs of Asia, particularly China. At the beginning of 2014, SATORP started up their 700 kt plant in Saudi Arabia. This was followed in June by the SK JX Nippon 1 million mt plant in South Korea and then the Samsung Total 1 million mt and SK Global Chemical 1.3 million mt plants in July. India's Mangalore Refinery brought online a 920 kt plant in September at a similar time to Jurong Aromatics' 800 kt plant new plant in Singapore. All these new plants added 5 times the paraxylene capacity needed relative to global demand growth in 2014.

## 2015 outlook

With the excess new capacity and pulled even lower by falling crude oil prices, global paraxylene spot prices fell from \$1200 per mt at the start of 2014 to just \$800 per mt by December of that year. Excess nameplate

capacity in the paraxylene industry had jumped from a stable 6 million metric tons in 2013 to around 10 million tons in 2014, pushing the average global operating rate down to just 77%. With the fall in crude oil prices in Q4 of 2014, the polyester industry suffered a significant degree of destocking as producers were concerned about inventory devaluation. The uncertain direction of crude oil prices made polyester feedstock buyers more hesitant, and paraxylene demand growth fell to its lowest level since 2008 at 2.8%. The margin outlook for 2015 seemed quite difficult for paraxylene producers and Jurong Aromatics of Singapore stopped producing in December 2014, with plans to modify their plant to use naphtha rather than condensates. However, as crude oil prices stabilised, and polyester producers needed to restock their inventories, paraxylene demand improved in the first half of 2015. Unfortunately, the reporting of China's economic woes on a daily basis affected market confidence in the second half of 2015 and this was compounded by further falls in crude oil prices. The result was a significant slow-down in polyester consumption compared to first half of the year. Despite this, paraxylene demand growth was significantly better than in 2014.

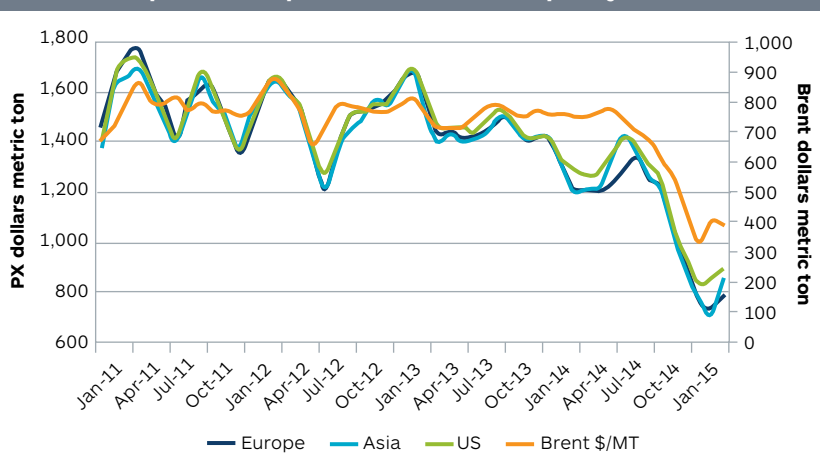
## Unexpected outages

As the year progressed, some paraxylene assets were subject to unexpected outages. Dragon Aromatics in China experienced a fire in their naphtha storage area which took their 1.6 million mt plant down in April 2015 and it is yet to restart. The new Zonghjin 1.6 mt plant in Ningbo was delayed until September and faced start up issues, which continued throughout the year. A smaller plant in Chita, Japan was kept offline as well and Jurong Aromatics went into administration signalling a significant delay to their restart. With China representing the largest global automotive market, surging domestic gasoline demand was keeping some of the Chinese state refineries focused on meeting increased gasoline demand rather than paraxylene. Despite significant excess nameplate paraxylene capacity, the Asian paraxylene market was actually quite balanced due to the downtime of a number of major production units and the focus on reformat consumption in gasoline for China.

## Competition for feedstocks

Similar gasoline growth dynamics were also

Chart 1: PX prices collapsed under excess capacity & lower crude



Source: Polyester Raw Materials

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experienced in the US. A consequence of lower crude oil prices in 2015 was that gasoline prices collapsed, boosting demand in an economy which was growing well and US consumers felt more affluent and who were pocketing the gasoline discount each time they filled up their vehicles. Despite an increased differential to regular gasoline, premium gasoline demand also increased as this grade appeared more affordable to consumers than when crude oil prices were above \$100 per barrel. This pushed up the price for high octane reformat at refineries and, with it, the alternative blend value for mixed xylenes, the primary feedstock for paraxylene production. This created feedstock competition for paraxylene producers in the US, who were unwilling to pay the same premium for mixed xylenes as that commanded by the gasoline alternative blend values. The net contract price for paraxylene in the US moved up to accommodate the higher feedstock costs and the US paraxylene price disconnected from Asia and Europe.

#### Change in paraxylene trade

The US paraxylene premium price allowed some US producers to start sourcing paraxylene from Europe and the Middle East in order to meet their contract obligations in Mexico and on the East coast of the US. With a favourable freight rate compared to US Gulf shipments, exports from Europe to the US East coast (and Mexico) almost doubled to 370 kt in 2015. Additional shipments arrived in North America from Algeria, Saudi, Turkey and Oman. With unfavourable production economics, exports of paraxylene from the US Gulf coast to Asia fell. In fact, initial exports of 20 kt paraxylene from South Korea to the US occurred and this appears to be a trend which will continue in 2016. South Korean and Japanese paraxylene companies want to reduce their exposure to the uncertain

Chinese market in 2016 and movements of 150-200 kt contract volume are expected to the US from these countries in 2016.

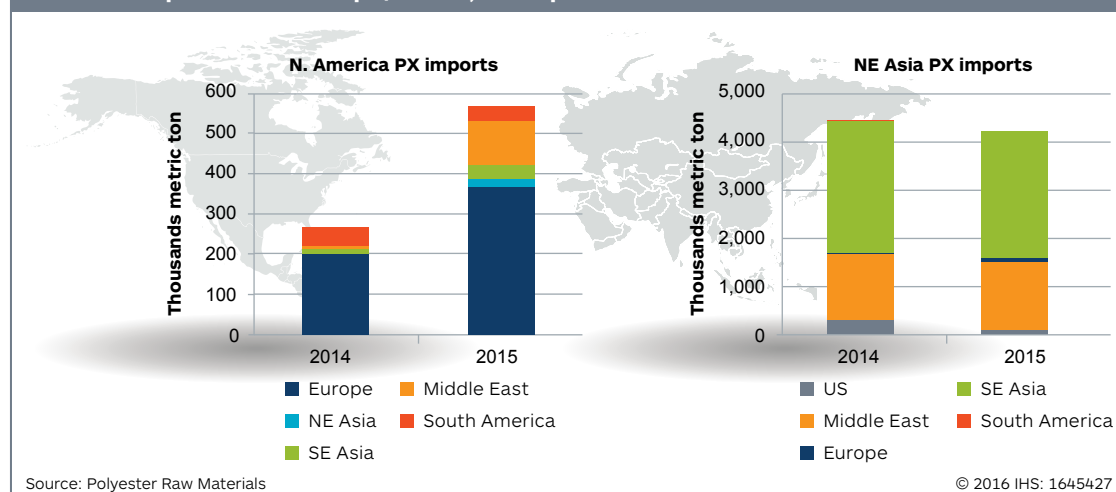
Despite significant excess nameplate capacity, the Asian paraxylene market was quite balanced due to the downtime of a number of major units

#### Delayed projects improves outlook

Given the difficult market conditions experienced by paraxylene producers during 2015, some future planned projects have been re-evaluated and deferred or cancelled altogether. New assets that were due to come on stream in the Middle East in 2018 have been cancelled and a major project in Saudi Arabia appears delayed until beyond 2020. Other planned projects in South Korea and Brunei have also been impacted. Last year's assessment that excess paraxylene capacity would continue to rise until 2019 now appears pessimistic. In fact, the average global paraxylene plant operating rate should start to improve from the end of 2017. Whether this allows an improvement in paraxylene margins remains to be seen. With crude oil prices expected to be at an average low in 2016, strong demand for gasoline will remain although not at the premiums seen in 2015. Pressure is expected from mixed xylenes blend values again and the US will probably increase imports even further this year. Despite the cancellation of new projects, excess nameplate capacity will weigh on market profitability for a number of years. ■

Duncan Clark is Global Business Lead for Aromatics at IHS Chemical.

Chart 2: US pulls more Europe/ME PX, US exports to Asia decrease



# Advanced fertilizers for improved nutrient-use efficiency

By Dr Evgenia Apostolopoulou



➤ **Measured nutrient uptake can be achieved** through modification of fertilizer products – either chemically to reduce their solubility or physically e.g. by coating encapsulation. These fertilizers are known as slow- and controlled-release fertilizers (SCRF) and belong to the wider category of Enhanced Efficiency Fertilizers (EEF). EEF are designed to promote the maximum efficiency of the fertilizer and minimise wastage either through loss of nutrients to the soil or via drainage water. The vast majority of EEFs are focused on Nitrogen (N).

Slow-release fertilizers (SRF) allow for slow nutrient release to plants via production of materials with controlled- or low-water solubility. They are produced by reacting urea with various aldehydes such as urea formaldehydes (UFs), methylene ureas (MUs) and isobutylidene diurea (IBDU). The slow release can be either a delayed initial availability of nutrients or extended time of continued availability.

Coated products such as sulphur-coated urea (SCU) and polymer-coated products are known as controlled-release fertilizers (CRF); they have a physical barrier that controls diffusion through the membrane.

There has been increased interest in these products year-on-year as these specialty fertilizers have certain advantages compared to conventional products such as significant savings in labour, energy and time as the rate of N application or the number of applications during the growing season can be reduced. Furthermore, they reduce toxicity in plants caused by the quick dissolution of nutrients and high ionic concentrations in the soil but more importantly they cut down nutrient losses preventing nitrate leaching, evaporative losses of ammonia and increase the N use efficiency (generally only 25-50% of applied N is taken up by plants). The main drawback associated with their use is their price which is considerably higher than conventional fertilizers. And thus, the relative high cost/benefit ratio has restricted the use of these products to non-agricultural sectors and high value specialty crops, particularly in European and North American markets.

#### Key applications – coated fertilizers

Sulphur-coated urea (SCU) results from the coating of urea with molten sulphur and sealing with a polyethylene oil or a microcrystalline wax. The product releases N through biological oxidation of the sulphur coating which is an impermeable membrane which slowly

degrades into the soil through microbial, chemical and physical properties. Nutrient availability depends on the destruction of the S coating and, thus, N release depends on the thickness of the coating in relation to the size of the granule or prill, the quality of the urea substrate and environmental conditions such as the biological activity in the soil and the soil conditions in terms of temperature and pH. SCU is primarily used for turf fertilization. The total N and S content can vary from 30-42% and 6-30% respectively. Overall, SCU products have good slow-release properties with N released typically over a period of up to six weeks. However, resistance of the coating to impact and abrasion is low.

In addition to S, urea or other soluble fertilizers can be coated or 'encapsulated' with a polymer or resin coating. The mechanism of nutrient release for polymer-coated urea (PCU) involves the water moving in through the coating to dissolve urea and N diffuses out through the porous-polymer membrane. The release rate is determined by the polymer chemistry, the polymer thickness and the coating process as well as the temperature and it can be predicted within certain limits. PCU is mainly used for turf fertilisation and contains 42-44% N which is released over a period of eight to 12 weeks.

Primary uses include fairways, stadia, sports fields, school grounds and home lawns but PCU or PC fertilisers in general can also be used for conventional agriculture like corn, barley, potato, wheat, rice, cotton as well as vegetable and melon, leafy greens and tree & vines. These products can also be mixed with conventional fertilizer providing the starter effect from a partially coated product, allowing the adaptation of the fertilisation to the local and seasonal climatic conditions.

#### Key applications - slow-release urea-aldehyde condensation products

Organic-N low-solubility compounds are formed by condensation products of urea and urea aldehydes of which isobutylidene diurea (IBDU), urea formaldehyde (UF), methylene urea (MU) are the most readily available types. These products belong in the slow-release fertilizers (SRF) category and their nutrient release pattern depends on soil and climatic conditions and cannot be predicted. They can be combined with conventional urea or other fertilisers resulting in

products with different N compositions and release patterns.

IBDU has 31-32% N content of which 90% is insoluble. It provides nutrient supply for up to three months without phytotoxic damage and is used for turf, horticultural applications and nurseries or as a raw material for bulk blending. It can also be moulded with other fertilizers to make NPK compounds of different granule size. Small-sized moulded fertilizer especially formulated for nursery plants, flowering trees and shrubs, and potted plants can provide sustained plant growth for eight to 12 months while IBDU briquettes can be applied for tree growth, providing nutrient release for 1.5 to three years.

UF products were historically the first SRF produced in the mid-1950s. Ureaform was the first product in this category and typically contains 38% N of which 70% is water insoluble. It is used as a raw material to make complex fertilizers (NPKs) that frequently contain also micronutrients such as Ca, Mg, S and sometimes traces of water-soluble boron and zinc. Nutrient release usually lasts between 12 to 16 weeks and is recommended for turf grass, ornamental crops, horticulture and fruit cultivation.

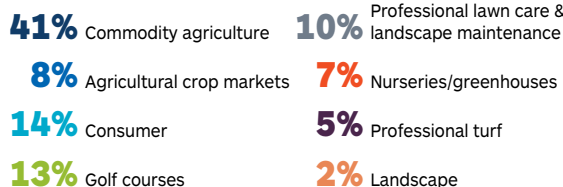
MU is another slow-release fertilizer and contains 37-38% N of which 25-60% is water insoluble. It is used for the production of NPK with/without trace elements or as straight N. When used as straight N, nutrient-release periods range from 10 to 16 weeks and main applications include outfields, fairways, sports fields, school grounds and home lawns, turf and amenity areas and special horticultural crops. NPK products based on MU can be in granular form or tablets. Granular products provide nutrient supply for eight to 18 weeks and are used for ornamental, tree nurseries, cut flowers, vegetables, potted plants, seedling production and shrubs and amenity areas. Tablets typically provide release for four to five months and are mainly used for top dressing of container-grown plants but special formulations ensure nutrient supply for one to three years and are recommended for woody plants, forestry and landscaping.

#### Outlook and prospects

Despite their numerous advantages, SCRF have been limited to niche non-agricultural markets or high-value crops due to their much higher price that can be several times that of traditional fertilizers. Currently, their share is limited to less than 1% of the total fertilizer consumption worldwide. However, there has been a recent increase in their use, particularly for the coated products due to a push led by governmental policies in Asia. The key driver behind the bullish demand growth in China is the initiative to reduce the environmental impact of conventional fertilizers and improve crop yields to achieve self-sufficiency in grain production. In

Chart 1: Breakdown of SCRF demand by end use - USA

2014 demand = 0.9 million m.t.



Source: IHS

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India, since 2015, all urea consumed should be neem-coated urea which seems to improve the rice crop yield by 10-15%. Elsewhere, new coated products produced on a larger scale have been shown to be profitable in the USA for broad-acre agriculture and commodity crops such as potatoes, corn, wheat and rice.

Coated products are the fastest growing group of SCRF in the USA on the back of improved economics in production, the possibility of controlling the release of nutrients other than N and the greater flexibility in determining the nutrient release pattern.

In other key agricultural regions, SCRF are receiving varied acceptance by farmers. In South America which is a developing fertilizer market, an increased interest in SCRF use is supported by product substitution trends. Conversely, in West Europe - a mature agricultural market - healthy demand growth is forecast in the Southern part of the region while slow growth or stagnation is expected in Northern Europe.

Overall, as farmers appreciate the multiple benefits of SCRF in crop production which include yield increases, improved crop quality, management flexibility, reduced environmental losses and improved nutrient efficiency, there should be increased interest in their use particularly when the whole issue of sustainability in agriculture and improvement of environmental standards is gaining importance worldwide - support from governmental policy will be a key factor to this. SCRF could be the answer to the continuous challenge faced by the fertilizer industry to improve its products and increase their use efficiency in order to reach the target of feeding more than 9 billion people by 2050 and at the same time minimise agriculture's environmental footprint. IHS Chemical has been covering the markets for conventional and specialty fertilizers as part of its multi-client reporting and single client consulting work over many years. Fertilizer producers, agribusinesses and financial institutions leverage these services to make strategic investment decisions. ■

Dr Evgenia Apostolopoulou is a Senior Consultant in IHS Chemical Consulting based in London.

# Specialty chemicals – The search for **stability and value**

By Adrian Beale



➤ **The global chemical industry has been through** a period of dramatic change over the last decade with, amongst other shifts, a fundamental transfer in the global industry's critical mass to the rapidly growing China economy and the successful exploitation of unconventional energy sources, especially in North America. These shifts had a dramatic impact on both global supply and global demand and they continue to evolve. China's economic growth has slowed, and the initial abundance of shale gas which gave enormous competitive advantages to the US petrochemical industry, especially in the ethylene chain, has now transmuted into an equal abundance of shale oil, which has contributed to lower global crude oil prices and hence has levelled the playing field between the US petrochemical industry and the rest of the world, which relies to a much larger degree on crude oil-derived naphtha as a petrochemical feedstock. Collapsing oil prices and slowing demand from China have also contributed to both weakness and huge, unexpected volatility in global financial markets in early 2016.

## Where should the global chemical industry focus now for stability and value?

We are once again starting to see signs of a flight to the safety of specialty chemicals markets, not experienced on a grand scale for the last 20 years. As costs collapse throughout the chain, commodity chemicals businesses find it much more difficult to retain value. Pricing and costs are transparent, and as most

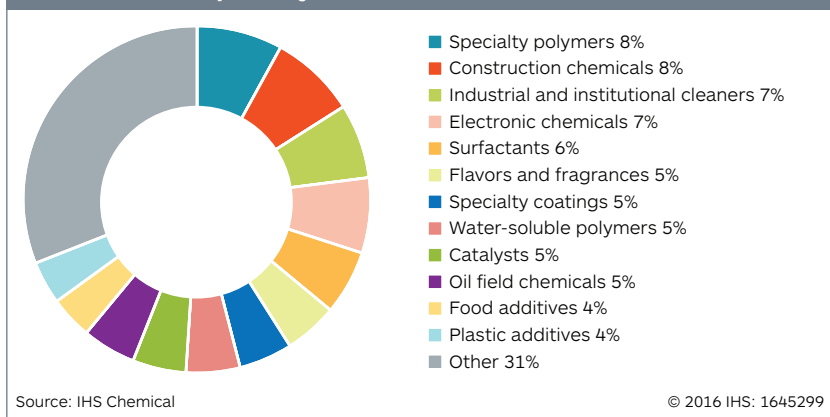
transactions are between industrial buyers and sellers, any advantage on raw materials is quickly passed on. Specialty chemicals markets however have more complex costs and market structures, so product prices are more closely related to value and technical performance. This allows much greater potential to retain the benefit of falling raw material costs. (Although in some markets we do still see countervailing power from huge buyers such as Walmart negatively impact the margin position of suppliers and specialty chemical producers). However end-consumer markets remain relatively healthy worldwide, and margins are usually better, and almost always more stable, than in commodity chemicals. The other major attraction for commodity chemical producers is that specialty chemicals are less capital-intensive.

## How is this shift from commodity to specialty chemicals manifesting itself?

There has been a huge amount of mergers and acquisitions activity in the chemical industry globally in 2015 and early 2016, in terms of total deal volume and also with some mega transactions, as the industry tries to focus on higher value specialty businesses. The increasing influence of activist shareholders continues to drive this transformation. Even in the absence of specific deals, public announcements by major chemical companies indicate the direction they are heading in:

- In Europe at the end of 2015 Solvay upgraded its advanced materials portfolio with the acquisition of US-based Cytec for US\$6.4 billion, and Platform Specialty Products Corporation made a US\$2.3 billion acquisition of UK based supplier of advanced surface treatment plating chemicals and electronics assembly materials - Alent Plc - in order to reach "another milestone on our path to building a leading, global diversified specialty chemicals company".
- In Japan the same trend is evident: Mitsubishi Chemical is shifting focus from commodity to specialty chemicals with closure of ethylene crackers in 2015 and 2016 (Japanese ethylene production overall is down by 1.4 million tons or almost 20% from 2007 to 2015) and investment in high growth businesses such as carbon fiber and composites, LED lighting, and next generation businesses – organic photovoltaic modules and organic photo-semiconductors.

Chart 1: Global specialty chemical = \$545 billion in 2014





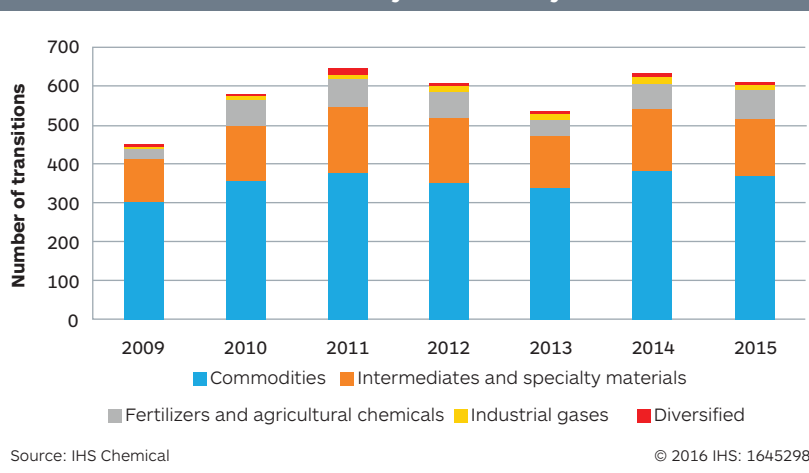
- Dow and DuPont's recent announcement of a merger and refocusing into 3 business units is a great example of this shift. Their rationale for the merger - Liveris: "This transaction is a major accelerator in Dow's ongoing transformation, and ... significantly enhances the growth profile for both companies". Breen: "For DuPont, this is a definitive leap forward on our path to higher growth and higher value".
- In announcing its Q4 2015 financial results Huntsman stated that "EBITDA from our cyclical businesses, which include our MTBE, ethylene, and TiO<sub>2</sub> products, decreased approximately \$78 million compared to the prior year. This overshadowed the real strength of our portfolio which is in our downstream differentiated businesses".

#### What regional factors are influencing this shift?

China has had a huge influence on the development of the global petrochemical industry since the start of this millennium and its influence on the development of the global specialty chemical industry is likely to be equally dramatic. In China the current drive towards specialty chemicals can be traced to 3 main factors: Firstly the slowdown in heavy industries such as construction, mining and heavy manufacturing is reducing the demand for basic chemicals and prompting a diversification in portfolios. Secondly societal factors such as demand for a more environmentally-conscious way of life have resulted in new environmental protection laws requiring increased use of specialty chemicals for water treatment; chemicals to combat hazardous air pollutants and many new industrial and institutional cleaning chemicals. Thirdly there is a highly consumer-driven shift as the rapidly growing middle classes require more consumer goods such as electronics, personal care, high-end cosmetics and food & nutrition products stimulating demand for the specialty chemicals which are used to produce them. All of these factors are encapsulated in China's recently approved 13th 5 year plan which will also shift emphasis from investment and exports to domestic consumption and innovation in many of these specialty areas.

However most Chinese chemical companies are still relatively weak in specialty chemical R&D capabilities. They lack experience in developing specialty chemicals and have little familiarity with diversifying products and developing close technical partnerships with consumers – both of which are essential factors for success in the industry. In addition China still has relatively poor intellectual property protection and a shortage of some key high quality specialty chemical raw materials - this is especially an issue in sectors where chemical active ingredients (AI) have to meet strict purity criteria, such as pharma and plant

Chart 2: Global chemical industry M&A activity



protection. All of these factors are contributing to a critical need for China to partner with, or acquire, specialty chemical producers outside of China in order to obtain not only strategic resources but also to secure greater advanced technology and market access.

Facing overcapacity in commoditized segments and pressure on returns, Chinese chemical companies therefore have an urgent need to upgrade their portfolios and move towards end market customers with formulation and service capabilities. Most recently, in early 2016 ChemChina offered to buy agrochemicals giant Syngenta in a deal worth \$43 billion. If the deal goes through, it will be the biggest acquisition of an overseas company by China, and the second biggest takeover in the chemicals sector in the past year, after the Dow-DuPont mega-merger. So far most China M&A activity has been domestic, but the spotlight is moving.

#### What should we expect in 2016?

In 2016, we expect that further core strengthening plays will be evident with chemical companies interested in moving downstream into those industry sectors which have stringent quality requirements, which require materials with specific high performance characteristics and which have relatively high barriers to entry. We expect that China will play a major role in this global chemical industry shift in focus from commodity chemicals to specialty chemicals in 2016 and beyond. Until the global economy moves back into a period of greater stability, we expect that many chemical companies will increasingly focus on the stability and value that these downstream markets afford. ■

Adrian Beale is Vice President at IHS Chemical and leads the Specialty Chemicals business.

# Asian players set to broaden SAP supply chain

By Michelle Lynch



➤ **Manufacturers of superabsorbent polymer** (SAP) have enjoyed rapid market growth and relatively high product margins over the last decade. Globally, the good fortunes of SAP currently reside with a relatively small number of large established producers mainly making SAP for hygiene applications, e.g. diapers. However, the potential game changers of the industry are newer players in growth economies: Northeast Asia and South America. Expanding SAP niches for non-hygiene markets such as horticulture are also set to outperform more traditional hygiene applications.

This article examines the current state-of-play and developments anticipated for SAP markets, technology and value-chain innovations. Existing and potential new suppliers to the SAP value chain may benefit from considering the impact of these changes on their respective business plans.

## Global Overview

Superabsorbent Polymer (SAP) is a cross-linked, partially neutralized polyacrylic acid. Several generations of SAP have been developed over the last 20 years and current versions can absorb as much as one thousand times their own weight in fluids.

The market for SAP has seen consistent growth and IHS estimates that consumption reached around two million metric tons in 2015 compared with 1 million tons in 2000, an average annual growth rate (AAGR) of 5.5 percent per year; and annual growth above 5 percent is forecast for the next five years.

The majority of SAP consumption (96 percent) is for hygiene applications, with the biggest sector (baby diapers and training pants) accounting for 71 percent. Hygiene applications have been driven by increased

birth rates, ageing populations, higher disposable incomes and product innovations. SAP has many different tunable properties such as absorbency, liquid retention under load, liquid transport and absorption rate, to name a few. Tailoring of these parameters has resulted in a broad SAP product range which has not only provided more sophistication to existing products (e.g. thinner baby diapers with improved dryness and better odour control), but has also extended the range of market applications e.g. adult incontinence and non-hygiene applications. The latter account for just 4 percent of demand and include water irrigation in agriculture and horticulture, (an area which is expected to grow strongly), residual floodwater removal, electrical cable protection, food packaging, firefighting, dust control, medical waste removal and decorative applications.

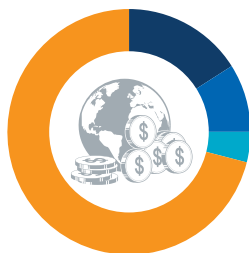
Capacity has developed rapidly to keep pace with market demand and 1 million metric tons were added globally between 2005 and 2015. Global operating rates remained close to, or in excess of 80 percent over this time period. Production bases for SAP are highly consolidated with less than 50 plants operating globally and with over 50% of global capacity held by just three producers (Evonik, BASF and Nippon Shokubai). Successful scale-up of polymerization technology has enabled these companies to become the largest, lowest cost producers and consolidation of smaller players. The sector is also categorised by high levels of innovation and advances in both SAP and end-use product design. Combined, these factors have served to maintain healthy profit margins for much of the SAP product slate.

Asian competition is growing and there are many SAP manufacturers operating in the region. Nippon Shokubai is the largest and most established. Newer Asian players include San-Dia Polymers (SDP), LG Chemicals, Formosa Plastics Corp (FPC) and Yixing Danson, all of whom have expanded production significantly in the last five years. The customer base for SAP is also shifting – with traditional diaper manufacturers such as Proctor & Gamble and Kimberly-Clark now having stronger competition from domestic Asian producers (e.g. Japan-based Unicharm and Hengan in China). Unicharm is successfully competing in China and is targeting business growth in South America where it is building a diaper plant. These trends will be accompanied by concurrent shifts

Chart 1: World: 2015 SAP demand

Demand = 2.3 million m.t.

<b>16%</b>	Adult incontinence
<b>9%</b>	Feminine hygiene
<b>4%</b>	Technical/industrial
<b>71%</b>	Baby diapers



Source: IHS

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in SAP capacity location and trade patterns.

#### SAP Manufacturing Technology

SAP is made by cross-linking polymerisation of hydrophilic reactive monomers (mainly glacial acrylic acid) followed by partial neutralization. Sodium polyacrylate is the major commercial product, but the potassium salt is also used. SAP is a 3-dimensional macromolecule which results from chain growth and crosslinking polymerization.

The process requires high quality (glacial) acrylic acid with more than 99.5 weight percent purity. This is produced by a multi-stage crystallisation of crude acrylic acid, which is then produced by catalytic oxidation of chemical grade propylene over proprietary multi-component metal oxide catalysts. Acrylic acid production is mostly co-located at SAP manufacturing sites, where it is captively consumed in the polymerization stage. Originally the polymerization was carried out at small scale (10,000 to 25,000 metric tons per year) on shallow horizontal trays which were loaded onto conveyor belts and fed through ovens operating at modest temperatures. SAP forms as a sticky, wet gel with high viscosity which is not easy to pump and this impeded progress towards a continuous process. However, from around the 1980s, technology advanced and each of today's main producers (BASF, Nippon Shokubai and Evonik) all published patents detailing continuous processes. Nippon Shokubai was the first company to introduce continuous SAP technology. BASF made several innovations to its own continuous process and in particular, its co-kneader concept which allowed for much easier SAP processing and larger single line capacities.

#### Value Chain Innovations

The SAP value chain from feedstock through to end-use application is replete with research activity and new technological innovations. Currently acrylic acid is virtually all produced from propylene but there are many other routes being investigated, including direct and indirect routes from propane, routes from C1 feedstocks (carbon monoxide/ethylene, formaldehyde) and biobased acrylic acid. So far none can compete with the existing route. There is also much interest in and benefit to be realised from incremental innovations. Glacial acrylic acid production is a difficult process to run, as is SAP, and improvements, for instance to plant safety, reliability and on-stream factor, offer significant benefits to existing plants. BASF for instance has made successive improvements to its acrylic acid process, improving yields while reducing CAPEX and energy requirements.

BASF has also recently commercialised a new SAP process based on droplet polymerization. This process makes round, microporous SAP particles with improved

liquid transport properties. BASF is marketing this product under the brand name SAVIVA™ and is citing a host of benefits including lower SAP and fluff requirement per diaper resulting in lower carbon footprint, cheaper logistics and improved dryness. Evonik is carrying out R&D in several areas including odour-reducing SAP, zero-fluff diapers, high stability SAP with more rapid fluid uptake and specialty non-hygiene grades. Nippon Shokubai has also introduced several new SAP grades for horticultural, industrial and electrical applications.

Diaper design is an area of intense innovation, and ever newer features are added as manufacturers look to maintain their competitive edge. Diaper comfort is a key differentiator and newer products offer thinness, leak-proofing and “underwear-like” comfortable fit. Pull-up diapers, swim-proof diapers and even “smart-diapers” which alert parents via text that their baby needs changing are amongst the latest designs to be brought to market. Asian diaper manufacturers have made rapid progress with product design – Hengan has already introduced leak-proof, and pants-fit diapers while Unicharm has introduced its own version of pull-up diapers.

#### Effects on Supplier Strategies

SAP production has high barriers to entry due to the need for local access to high quality glacial acid feedstock, the complexity of manufacturing processes and high technical demands of the end-use applications. A key barrier to entry is the breadth and depth of the intellectual property position and know-how of existing players along the value chain. Several hundred patents in the area of SAP are filed every year by a relatively small number of companies and competition is fierce. Infringement cases are not uncommon and third-party licenses are not available. Relationships along the value chain are very close and long-standing. This makes it tough for new entrants; unless they offer a specific advantage e.g. technology, feedstock or local production base and supply channels. Both new and existing companies face changing landscapes from new diaper manufacturers, and growing non-hygiene markets for SAP. Considerations include process capabilities, need for some smaller batch processing for niche grades and continued cost reductions for processing on larger lines, choice of plant capacity locations, product trade destinations, supply channels and customer base.

IHS can help with decision making processes and offers consulting studies on the SAP market, technology, process economics, innovation and intellectual property screening. ■

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