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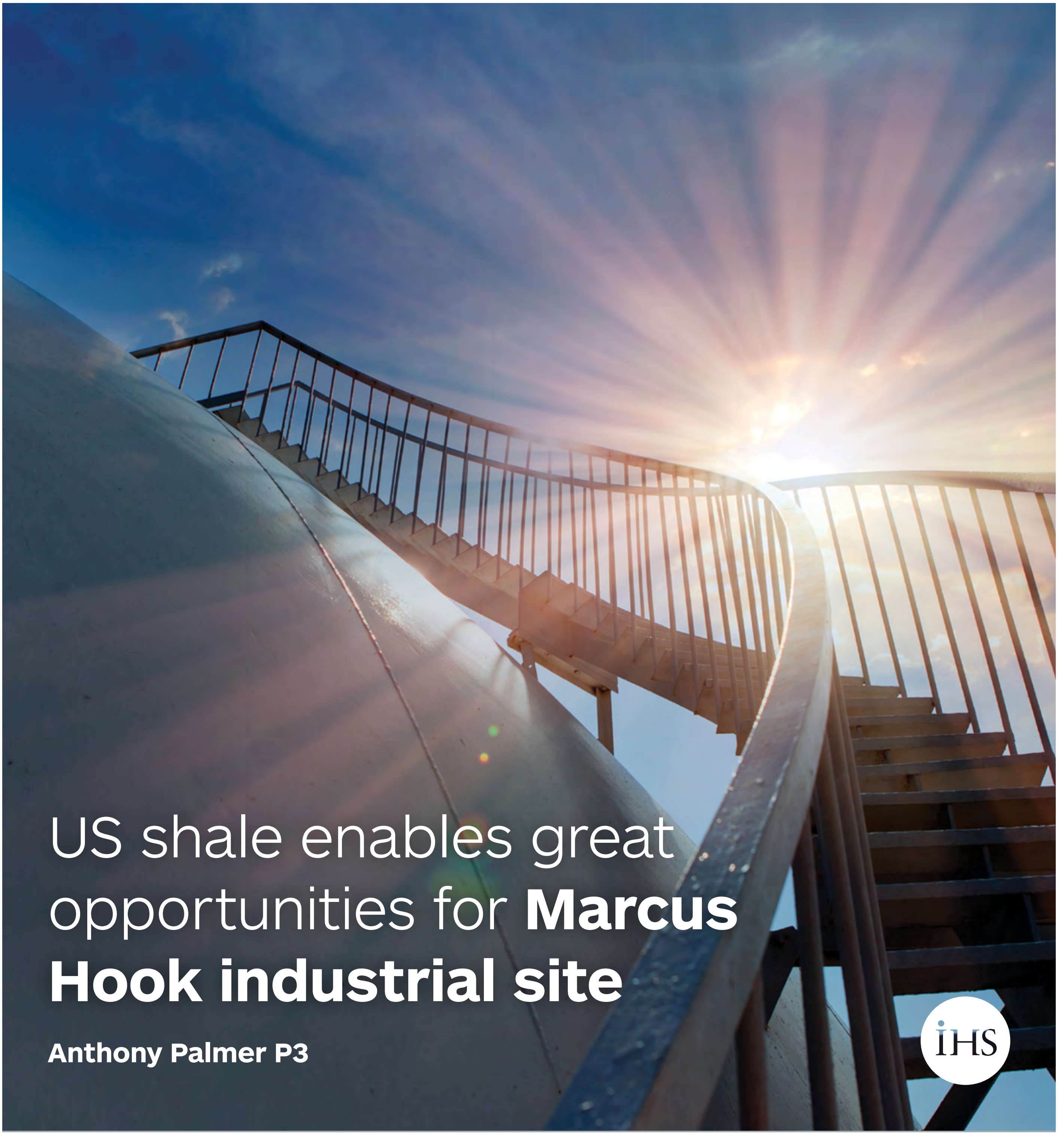

US shale enables great opportunities for **Marcus Hook industrial site**

Anthony Palmer P3

Vison & contents

The Temperature is Rising in the **Boardroom**

Roger Green, VP Europe & Africa Consulting, IHS Chemical

As we look to 2016, we can reflect that seldom have there been more challenging times in the boardrooms of the chemical majors than at present. The environment continues to throw up new challenges and opportunities as feedstock advantage continues to shift yet stubbornly maintaining its separation from major growth markets. The majors continue to pursue value addition in specialised products from high performance composites to life sciences. This makes for complex business models and adds an innovation imperative into the mix. This raises the profile of companies' IP estates and ratchets up the pressure on technology via R&D programs or acquisitions to deliver bottom line results.

If the challenge of managing strategic development in a changing economic environment is not enough, there is now increasingly a tension between the short-term aspirations of shareholders and the longer term vision of company management. The recently announced merger of DuPont and Dow will create a chemical behemoth that results in both efficiency gains and spawns three separate businesses with a leading position and laser sectoral focus. It is no coincidence that both of the partners can count an activist investor amongst their shareholder register.

Activist investors can be benign business owners which believe in the longer term value creation potential of the business (Carl Icahn's holdings in Apple). They can be more disruptive influences seeking the short term unlocking of corporate value, potentially to the detriment of longer term investment. Either way, management need to remember that they are employed by the shareholders as stewards of the business and true success is possible only through alignment of owner and management.

In a nutshell, we find our clients driving product value delivery up and manufacturing costs down; realising the full value of their intellectual property, whilst innovating as never before.

In this issue you will find our thoughts on feedstock pricing and supply, siting new investments and a look at innovative technology and the value of intellectual property. The team at IHS Chemical is here to make your business more successful.

In this issue

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US shale enables great opportunities for **Marcus Hook industrial site**

By Anthony Palmer

Several factors – including the phenomenal, enduring growth in natural gas liquids (NGLs) production from the U.S. shale plays and significant pipeline capacity additions – have combined to make redevelopment of the Marcus Hook Industrial Complex (MHIC) in Delaware County, Pa. more favorable. Delaware County Council commissioned IHS to conduct both an initial (2012) and updated (2015) independent study to identify potential redevelopment concepts that could best utilize the site's assets to maintain employment levels and perpetuate a sustainable local economy.

Influencing Factors

A number of factors have become more favorable for redevelopment of the MHIC in terms of the market, logistics, energy resource supply, and ongoing site improvements being made at MHIC since IHS conducted its initial reuse assessment.

Some of the initial recommendations we made, such as its use as an export facility for natural gas liquids, are even more significant now due to the incredible productivity of the U.S. shale plays, and in particular, the volumes of natural gas liquids coming out of the nearby Marcellus and Utica formations. That bounty, combined with the impact of considerable new pipeline infrastructure, attractive ethane prices, and the site's closer geographic proximity to major markets, make the U.S. ethane production accessible and cost-competitive for European and some Asian petrochemical producers.

These low-cost, shale-gas feedstocks have given the U.S. a competitive edge in chemical derivative markets that use NGLS as a feedstock, enhancing its viability for ethane cracking and derivatives operations.

Furthermore, ongoing site improvements are enabling more efficient land-use at MHIC, which increases the scale of reuse options that were limited (in capacity) in 2012 by the lack of usable space at the site. In addition, the high capacity of on-site infrastructure can accommodate most re-use options, and sufficient capacity of public utilities also exist onsite to accommodate increases in demand from the proposed reuses.

Original Examination

In our original IHS assessment, we examined 7 potential reuse options for the Marcus Hook facility, 5 of which were energy-based options: 1) Natural gas liquids processing and fractionation facility; 2) Gas-to-liquids (GTL) production and storage facility; 3) Liquid natural gas liquefaction and export terminal; 4) Refined petroleum products and NGLs terminal; 5) Natural gas-driven power generation, as well as two Marcellus shale chemical-based options: 1) Ethane cracking and derivatives; and 2) Propane dehydrogenation (PDH). Three of the reuses with high market viability – a PDH plant, a NGLs fractionation facility, and a NGLs export terminal - are currently being pursued at the MHIC.

Splurge of New Investment

In just three years since the initial reuse study was done, MHIC has attracted millions of dollars in new capital investment. In response to the development interest, Sunoco Logistics (SXL) has made, and continues to make, major enhancements to the site, creating new opportunities for industrial development in the area.

For chemicals development options, we continue to recommend a propane dehydrogenation plant and an ethane cracker, which were assigned a market viability rating of high and medium, respectively, in 2012, and again in the updated study.

The higher than anticipated growth in the volume of NGLs being produced in the Marcellus shale formation is, in turn, driving the substantial increase in the volume of NGLs that will flow to MHIC via the Mariner East pipeline projects. These factors increase the potential for exports of natural gas liquids.

In 2015, we continue to recommend the construction of a propane dehydrogenation plant to make propylene for Braskem's existing polypropylene plant at the Marcus Hook site, using shale-based propane from Marcellus shale. Propylene supply limitations have constrained regional demand growth, driving propylene prices up. IHS forecasts that global polypropylene demand growth is expected to average 4.9 percent during the next five years.

The current market viability of a PDH plant at the MHIC is high, according to our report findings, the same as in 2012 study. We estimate that a proposed

PDH plant could have an annual capacity of up to 400,000 metric tons if most of its output is sent to the adjacent Braskem polypropylene plant. While a PDH plant is currently in the works at the site, if Sunoco Logistics is able to find other customers for the propylene, the capacity of the PDH facility could be substantially higher.

In terms of logistics, the MHIC site has excellent transportation accessibility as it sits on the river, is served by rail, located only a few miles from an interchange on I-95, and it is close to operating oil and natural gas pipelines. The completion of Mariner East 1 pipeline has the capacity to deliver 70,000 barrels per day (bpd) of ethane and propane from the Marcellus, and the next phases involving two new pipelines could increase the supply of NGLS available at MHIC to as much as 750,000 bpd.

> The redevelopment of Marcus Hook Industrial Complex represents a rebirth for the site, but more importantly, it represents renewed economic opportunities for the community who've relied on it for their livelihoods

It should also be noted that MHIC is significantly closer to European, South American, and Southern and East Asian markets for NGLs than are the major exports terminals located along the U.S. Gulf Coast (USGC) (combined pipeline and marine distances). Shorter transport distances generally mean less cost and quicker delivery times for importers of these products.

European-based petrochemical producer INEOS has already taken steps to leverage this advantage. Its twin fleet of specialized tankers will begin shipping ethane from Marcus Hook to its refineries in Norway and Scotland later this year. As a result, the economic benefit is fueling a dual rebirth, not only for the communities around Marcus Hook, but also the recently threatened–with-closure refinery town Grangemouth, Scotland's largest industrial complex, which will now be on the receiving end of the Marcus Hook exports.

Much like the U.S. petrochemical industry, which has been revived by the nation's bounty of shale-derived feedstocks, the MHIC and its adjacent assets have emerged as symbols of economic promise and industrial revitalization made possible by the U.S. energy renaissance.

Finally, our research found that MHIC's likely role as the central component in a world-class petrochemical complex along the Delaware River will enable the creation of a large number of additional direct jobs. An ethane cracker, however, is an important component for long-term economic development of an integrated petrochemical production complex along the Delaware River.

In terms of challenges, a few key disadvantages exist for the MHIC, with the most critical likely to be the fact that the site competes with investment alternatives closer to the Marcellus field (thereby reducing the cost for delivered ethane and propane) or near the large, established petrochemical industry on the USGC. In addition, the MHIC site has no access, other than by rail, to discounted mid-continent crude oil.

In addition, another potential concern is the state of the I-95 corridor. While it is a major interstate connector with the capacity to accommodate additional truck traffic to deliver new freight to markets, the roadway is challenged by congestion and needed road maintenance, and will require route management to optimize its expanded use.

Conclusions

The difference between 2012 and 2015 for the Marcus Hook site is pretty stark. Three years ago, the MHIC faced two possible futures–survival or closure. Today, it would be fair to say that the Marcus Hook Industrial Complex has been revived by Marcellus and Utica shale—and through the cooperative efforts of government, industry and the local community. In 2015, thanks largely to an influx of new infrastructure investment, increasingly supported by the rapidly growing flow of NGLs, numerous opportunities exist for the industrial site, but they come with complex choices.

While there is an immediate demand for additional quantities of propylene to supply Braskem's polypropylene operations at the site, we at IHS believe that expanding the propylene supply in the Philadelphia area offers the potential for investment to produce other propylene derivatives that have synergies with the area's refining operations, most notably cumene, which is used by Honeywell at its phenol production facility in the area. Similarly, the ethane cracker would be accompanied by downstream derivatives, such as polyethylene, which have large, regional markets nearby, and have the potential to spur additional investment in the plastic converting industry.

For MHIC investors and community planners, having such multiple, complex options are good problems to have. They are happy to have viable, positive choices focused on growth and expansion—not shut-downs and closures; a vastly different story than a few years ago. ■

Anthony serves as Vice President of IHS Chemical and is primarily responsible for the overall management of the Valhalla office operations for the proprietary studies.

Site selection, a critical component of **project evaluations**

By Jesse Tijerina

Introduction:

↘ Looking to take advantage of the low-cost feedstocks offered by the North America shale gas revolution, many petrochemical companies have been evaluating investments in North America. For established producers, with existing petrochemical complexes in the US, the market, logistics, and economic data is already available to them from their on-going operations allowing them to make an informed decision about where to build their next plant.

There are, however, a surprisingly high number of new entrants to the US chemical industry looking to develop their first petrochemical complex in the US. These new entrants are often international chemical companies or small US companies who are tenants at existing host sites and lack the real estate for expansion. New entrants can also be new project developers looking for their first site. For these companies, site selection is a bit more complicated. When evaluating alternative sites, several key questions need to be asked:

- Do we build near the source of feedstock or near the market place?
- Which site provides us the best overall competitive advantage?
- What factors should we use to arrive at our decision?

To answer these questions, companies will endeavor into a site selection study early in their project evaluation. Inevitably, it's realized that a great deal of market insight is needed to be able to make the best informed decision. IHS Chemical consulting has been helping many of its clients answer these questions. At a high level, a site selection process will generally include the following steps:

- Selection of the alternative sites to be evaluated.
- Determining the factors (key attributes) to be used for the site selection process, including their relative importance (weighting).
- Collect the needed market information for each site to perform the individual site analysis.
- Apply findings into a site selection matrix for relative comparisons and to arrive at a decision.

Case Studies:

For a petrochemical investment in the US, the key attributes for site selection are often economic in nature and typically include; land availability and cost; raw material availability and cost; availability of major utilities (mainly electricity, water, steam); logistics and logistics costs (both raw material procurement and product to market); presence of a local petrochemical infrastructure (skilled workforce availability, maintenance shops, etc.); availability of federal, state, and local incentives; site environmental permitting and regulations. Several case studies follow outlining typical site selection projects:

Case Study #1

Consider an international polyolefins producer evaluating the feasibility of a polyolefins project in North America who approached IHS to assist with the site selection by providing market insight on the various key attributes for plant site selection. Typical attributes examined include:.

1. Availability and accessibility to key raw materials

For each of the sites under evaluation, what is the expected availability of the key raw materials for the next 15-20 years?; How accessible are the raw materials and what is the delivery mode (pipeline, rail, truck) and cost structure? For most petrochemicals, raw material costs typically account for 70-80% of the production cash costs. Thus it is very critical that the chosen site offers competitive delivered (plant gate) costs.

For each alternative site, IHS mapped all raw material producing locations and pipelines; determined pricing benchmarks; and contracting structure appropriate to these areas. We confirmed raw material availability and provided estimates of delivered cost (plant gate) to each location relative to price benchmarks.

2. Logistics costs

What are the available modes of transportation?; What is the access to rail and is it single served or dual-served?; Is there barge access and is it deep-water access?; How is the highway access and what is proximity to nearest export port? Logistics requires a robust and resilient transportation system that facilitates low cost raw material sourcing and low cost delivery of product to the market place. The location of infrastructure and intermodal connections, and quality of service will impact logistics costs.

Using our services and close relationships with trucking, rail, and waterway companies, we delivered a comprehensive analysis of the logistics

> Most petrochemical-friendly states provide very competitive state and local incentives

opportunities, constraints, and costs for each of the locations. Using our in-house knowledge of freight services and costs, IHS completed a freight costing study for shipping raw materials into each the alternative sites and finished product the major identified markets.

3. Established local petrochemical infrastructure

Is the region actively promoting chemical producers to come build in their region?; Do they have the skilled workforce that is required to operate chemical plants?; Is there an established petrochemical presence in the region (maintenance contractors, shops)?

For each alternative site, IHS assessed the available local infrastructure to support a petrochemical complex. IHS provided an assessment on available industrial real estate, including land cost estimates. IHS also analyzed the availability of major utilities (electricity, cooling water and steam) and their expected costs; an analysis on access to a skilled workforce to operate and maintain the plant; as well as availability of contractor services and shops needed for plant maintenance.

4. Availability of local and state incentives

In the US, most state and local governments are very aggressive and competitive in incentivizing companies to invest in their region. Most "petrochemical friendly" states provide very competitive state and local incentives as part of their economic development program.

5. Environmental permitting and regulations

Not having a full understanding of the environmental permitting process and regulations can lead to serious project delays and cost overruns. In a worst case scenario, there have been instances in the US where plant startups were delayed as much as 5+ years beyond mechanical completion because of environmental permit related issues. As such, site environmental permitting and regulations should be a key attribute for site selection.

For each alternative site, IHS developed a high level regulatory roadmap that discussed the main permitting differentiators between the alternative sites. Each of the alternative sites was also reviewed in a desktop study using available information on the presence of cultural features, biological features, water quality and management, air quality, and known sources of contamination. Once a site has been selected, a draft environmental permitting matrix can be compiled for that site that illustrates the potential permits needed for a project along with the critical issues associated with obtaining these permits.

Case Study #2

Economics not always the determining factor..... In some cases, typically at the international level, other factors come into play that can have equal or greater importance to economic factors. Consider a recent IHS project where a state-owned company in a developing country was looking to monetize their natural gas resources. In this instance, social and political factors were primary drivers with an equal to higher priority than the economic factors. Social and political factors that can come into play include:

- Government looking to develop economically distressed regions of the country by means of high-wage skilled jobs creation, local infrastructure improvements, and development of supporting industries, etc. and other indirect and induced socio-economic benefits that result from a large petrochemical investment.
- Terrorist attacks - the risk of terrorists staging attacks on the site or targets in the area, or the unlikely event of a conflict with neighboring countries.
- Protests/Riots – the risk of civil unrest over issues such as land rights or pollution in the vicinity of the site and the risk that such protests will turn violent
- Strikes – the risk of strikes impacting business operations on site and the risks of such strikes turning violent and resulting in property damage
- Kidnap – the risk of site staff (local or foreign) being targeted by kidnappers

Case Study #3

Business risk can be just as important.... Consider a third scenario, where a small regional company may be trying to invest beyond its borders, for example, in Asia. For a small business, this would most likely be a huge investment that could jeopardize its future. In this case, business risk factors could have equal or greater importance to traditional economic factors. Business risk factors that come into play include:

- Political Instability – the risk of a change in government or a change in the government's overall policy position regarding foreign investment
- Expropriation – the risk that the government will seize or nationalize a private commercial asset
- Contract Frustration – the risk that the government will cancel or amend private contracts
- Bribery and Corruption – the risk that bribery practices and/or corruption within a country will impact or inhibit commercial operations
- Taxation – the risk of a change in the overall

corporate tax burden

- Currency – the risk that the flow of money into or out of the country will be restricted (particularly in terms of profit repatriation) or that companies will be unable to access hard currency
- Intellectual Property – the risk that intellectual property will be stolen or that private firms will be unable to defend their intellectual property rights in the local legal system

Site Selection Matrix and Methodology

Site selection analysis requires a great deal of market data, insight, and analysis. IHS is able to do this by means of our vast market knowledge databases and the insight of our over 300 market researchers. IHS also collects site specific information through established relationships with local, regional, and state agencies, as well as real estate and utility companies that support economic development at the local level.

Our site selection methodology combines the results of the analyses of each of the key attributes deemed important to the client and then to compare the expected relative attractiveness of the alternative sites being considered for investment. We do this by use of a weighted matrix. Working with our client, we first select the key attributes (criteria) for the site selection process. The next step is to then rank the relative importance of these key attributes by assigning a weight based on a percentage basis, with the most important attribute receiving the heaviest weight.

Next we identify a range of potential outcomes for each of the attributes. For each attribute, we will array the potential outcomes from least attractive to most attractive, assigning numerical values to each along a scale of 1 to 5, with 5 representing the most attractive outcome.

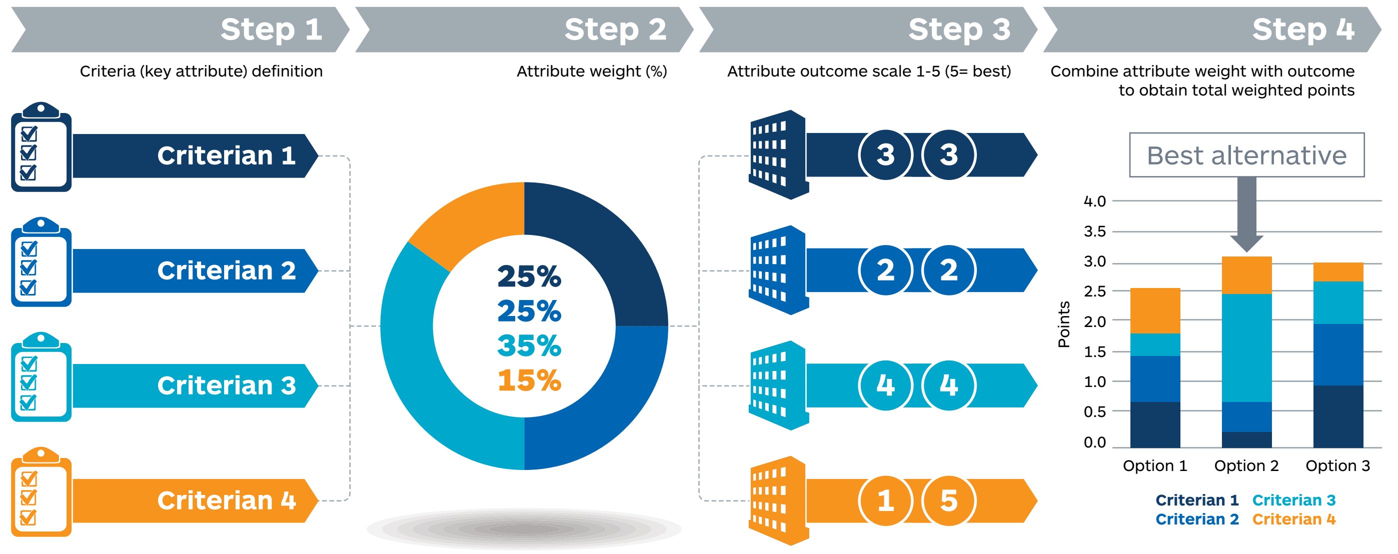
Evaluating Relative Attractiveness of Alternative Sites - The overall attractiveness of a given site is calculated by multiplying the attribute weight by the attribute outcome and summing the products to determine an overall ranking or position relative to that of other sites. The primary outcome of the analysis is a relative comparison of the sites under consideration.

Summary

In summary, site selection is a critical component of project evaluation and should not be rushed or done haphazardly. A well-executed site selection analysis, where all the right attributes were evaluated, will provide better OSBL scope definition, lead to reduced project risk, and have a positive impact on the capital and operating costs, and schedule. Ultimately, it will impact the project’s overall return on investment. ■

Jesse Tijerina is managing director within the IHS Chemical consulting practice.

Qualification and classification process



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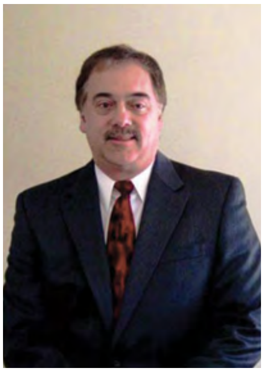
Low crude oil prices: **back to the future?**

By Don Bari



With oil price volatility complicating investment planning for petrochemicals companies, IHS cautions that an extended period of low crude oil prices could create 1980s-style economic conditions.

Falling crude oil prices have significantly affected the petrochemical industry since the November 2014 OPEC meeting, creating challenges for chemical companies that are planning investments. Yet the volatile crude oil market could have longer, even more dramatic effects on petrochemical feedstock choices, trade patterns, capital spending plans, new plant locations, operating rates, and production technologies.

What happens next will depend on what recovery path the market takes. In a recent report, "Crude Oil Turmoil and the Global Impact on Petrochemicals," IHS assessed the potential market and economic implications of three possible recovery trajectories for crude oil prices:

- V-shape recovery: Short-term return to normal pricing, where supply and demand quickly come back into balance
- U-shape recovery: Medium-term return to normal pricing, with a few years of low prices before recovery
- L-shape recovery: Long-term low prices for crude oil, where oversupply continues for five or more years, and the industry experiences fundamental changes to petrochemical feedstocks

The speed of the oil-price recovery will influence what technologies, feedstocks, chemical products, and regions can create the most cost-effective offerings.

The long-term L-shaped recovery case has the most significant implications for the petrochemicals market. Since oil dynamics drive marginal production cost and price-setting mechanisms for many chemicals, plastics, and fibers, a prolonged oil-price recovery of more than five years could somewhat shift the feedstock advantage from ethane back to more cost-competitive naphtha. Much like the DeLorean time machine from the 1985 film "Back to the Future," naphtha would be the conduit taking some petrochemicals companies and regions back to a market similar to that of the late 1980s—starring overproduction, reduced demand, and depressed oil prices.

Continuing oil glut

Current economic and political conditions set the stage for any of the three potential recovery scenarios. In the near term, IHS energy experts believe economic and geopolitical risks will continue to challenge oversupplied oil markets, as crude oil prices are posed to drop or at least remain low.

Oil producers are not yet taking action that will help speed the recovery of crude prices. In late July, IHS Energy noted that since the oil-price collapse that began in mid-2014, global oil production has actually gone up, not down. Indeed, since November 2014, when OPEC oil ministers agreed to let the market determine prices, aggregate production from the United States, Saudi Arabia, and Iraq has increased 2 million barrels per day—far more than global demand. As a result, oil markets are glutted.

Oil prices will be under downward pressure until the evidence clearly demonstrates that the glut is shrinking. This will not happen quickly, unless prices fall even further from recent levels. In fact, continued global oversupply of crude oil could keep prices from recovering for more than 10 years.

Impact on ethylene

Let us now assume that the glut begins to shrink, but that the industry still enters into a long-term oil-price recovery. In this case, IHS economists would expect moderate economic growth to continue for several years, along with slower oil demand growth. At the same time, technology would continue to reduce oil production costs and increase supply, even at lower oil prices. With these conditions in mind, how would a long-term recovery impact petrochemicals?

The first major impact would be on the production of natural gas liquids (NGLs) and ethylene in the United States. In this market, prolonged lower oil prices would slow NGL production and ethane cracker capacity expansions, potentially creating a tight market. Because ethylene is the basic building block for many downstream chemicals, plastics, and synthetic fibers, it is the largest-volume and perhaps most market-indicative petrochemical. A tighter ethylene market would not only push operating rates higher, but would also increase prices and introduce more market volatility.

Because the next wave of ethylene capacity additions is not expected to come online until after 2020, and since global ethylene demand growth will be strong, a tighter ethylene market would drive ethylene cracker operating rates to near-record highs. In the long-term recovery case, IHS forecasts that ethylene demand will grow at an annual rate of 4.5% and nearly

4.0% during 2015–20 and 2020–25, respectively. Nameplate capacity is forecast to grow at an annual rate of more than 3% and less than 1%, respectively, during those corresponding time periods. Ethylene demand is expected to grow at a higher pace than supply, which will lead to severe supply shortages similar to those experienced by the industry in the late 1980s.

Global effects

A second macro trend would be seen in Europe and Asia. With naphtha back in economic favor as a cost-competitive feedstock, the regions' petrochemical producers would be the winners, with their naphtha crackers running at high-capacity rates and margins moving back into positive territory. In response, China could be expected to build more naphtha-based crackers while other emerging countries would build a petrochemical base.

The additional ethylene production from naphtha would yield more co-production of propylene and butadiene, impacting global on-purpose producers of these substances. These companies would see their profits erode quickly because conventional production would be able to meet market demand, reducing the need for higher-cost production options.

A prolonged oil-price recovery would also dramatically impact future investment plans, as chemical producers adjust to shifting feedstock dynamics. In North America, US ethane would remain "stranded" and advantaged in the long term, as oil prices cycle and infrastructure for liquefied natural gas and ethane export and shipping is added.

Winners and losers

The methanol value chain would also be affected by a long-term oil-price recovery. For example, methanol projects with advantaged feedstocks, such as those in North America and the Middle East, would fare better than higher-cost, coal-based units in China. Methanol projects targeting energy applications. While IHS expects methanol capacity additions to occur in locations with advantaged feedstocks, the pace of these additions would be significantly delayed, and rationalizations would also be likely.

A long-term oil-price recovery would also have a profound impact on both global polyethylene and polypropylene markets. IHS anticipates that polyethylene production rates would grow, as demand expands by more than 54 million metric tons (MMT) from 2014 to 2025. This growth would be supported by a higher GDP in developed countries; improved price competitiveness that would displace conventional materials such as metal, paper, and glass; and the replacement of recycled material by virgin material.

Western Europe and Asia would benefit greatly from more competitive feedstock and buoyant demand, while North America would experience lower integrated margins. A prolonged period of low oil prices would also put new Russian polyethylene projects in jeopardy because of the poor investment climate, leaving Russia as a net importer of the chemical.

European and Asian naphtha-based producers would be the winners in a long-term recovery scenario because of their conventional cracker investments. South American polyethylene projects also would move forward, and additional Asian capacity would come online. North America would lose in this equation, since the North American export position would be negatively impacted as its economic advantage shrinks.

> As the industry plans for low price oil environments, new risks will emerge, and business and investment decisions will differ based on the type of recovery

Short-term and medium-term scenarios

Short-term recovery would help petrochemical margins and volumes remain close to the base case. Faster price recovery would create little impact on US and Middle East capacity builds, other than slight delays due to uncertainty on projects not yet under way. Europe and Asian naphtha crackers would run at high rates and experience good margins. In China, short-term low oil prices could accelerate some naphtha cracker builds, potentially leading to excess global cracker capacity.

A medium-term oil-price recovery would likely slow US oil production, according to IHS, but oil production outside the United States would offset any US decline. Low oil prices would also hold back NGL production and reduce US ethane cracker builds, preventing a second wave of ethane production from coming online until 2025. European and Asian naphtha crackers would run at high rates and experience high margins, with China adding new naphtha crackers.

Planning wise investments

Understanding the potential impact of various scenarios for an oil-market recovery is essential for petrochemical producers. In the midst of significant market volatility and a high degree of uncertainty regarding the role of OPEC in managing the global supply of crude oil, business and investment decisions must consider each type of recovery. Only with this insight can petrochemicals companies maximize profit and minimize risk, avoiding the fallout of a potential 1980s-caliber market. ■

Don Bari is vice president, technology and analytics group, IHS Chemical

US bulk liquid chemical exports **set to increase**

By Chris Geisler

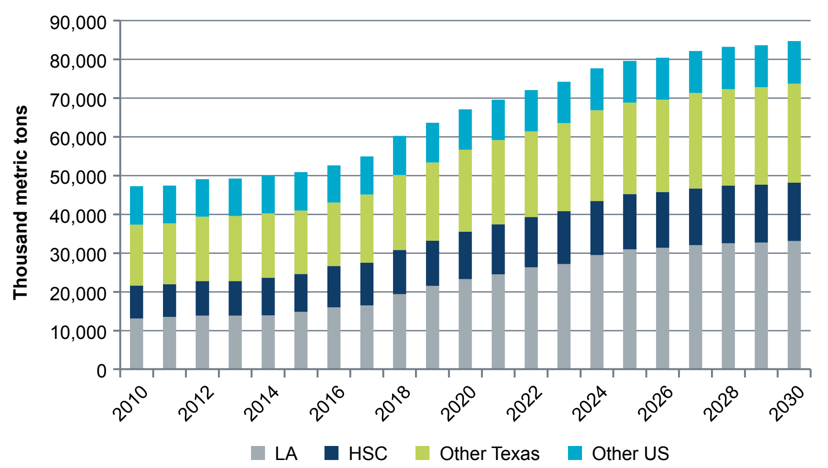
Shale gas development continues to transform the US chemical industry despite the drop in crude oil pricing. Shale gas developments in North America will result in increased ethylene, propylene, methanol, chlorine, caustic soda, ammonia and fertilizer production. IHS expects that more than 125 million m.t./year of additional chemical capacity will be added to the US chemical industry by 2030.

More capacity announcements than expected

A number of new projects have been announced in past year, which has resulted in a 10 million m.t./year increase in announced US chemical capacity over what we projected last year. The most notable has been the significant increase in announced methanol capacity. These methane-based projects are clearly looking to take advantage of the continued low prices for natural gas in the US.

The vast majority of new olefin chemical production will be converted to solid plastic resins. However, more than 30 million m.t. of liquid bulk chemicals production will be added in the United States, the majority of which is methanol. With the exceptions of ammonia and fertilizer chains, the vast majority of expansion will be centered in Texas and Louisiana. Within Texas, capacity additions stretch from Beaumont to Corpus Christi including several within the Houston Ship Channel (HSC).

US major liquid chemical production



Source: IHS

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While much attention has been centered around fertilizer and plastics trade, bulk liquids will also see significant increases. This will impact ports, terminals, logistics providers, traders, producers, and consumers alike. Substantial increases on bulk liquids chemical trade will be seen in caustic soda, methanol and later glycol and methyl tert-butyl ether (MTBE). Trade in aromatics are in decline in the United States, with the exception of slight increases in benzene imports and styrene exports.

The United States will move from a relatively balanced net trade position to a large exporter in major commodity bulk liquid chemicals. Methanol exports are the major driver of this increasing imbalance. By 2018, the United States will move from a net importer of methanol to a net exporter of methanol.   Most of these increased exports will come from the US Gulf Coast but there are plans for significant new production originating from the US Northwest.

US exports to rise

The United States imports a steady amount of benzene and we expect this to continue as the aromatics chain is relatively unaffected by shale gas developments. With low electricity pricing resulting from low gas pricing, the chlor-alkali chain is expected to increase operating rates in the near term and in the longer term expand, producing more caustic soda as a chlorine co-product.

Concluding Comments

MTBE, which is banned in the United States, is expected to see increased exports. Finally, ethylene glycol production will also increase longer term moving the United States from a net import to net export position. As other methanol, ethylene and propylene liquid derivatives are built, trade in bulk liquid chemicals will continue to increase further. We expect expansion in alpha olefins, ethoxylates, glycol ethers, MTBE, acetic acid and acrylic acid among others products. ■

Chris Geisler is Vice President of IHS Chemical Consulting for the Americas region with experience in acquisition due diligence, feasibility analysis, project finance, litigation support and strategy development for the chemicals industry.

Patents and Innovation in the **Chemical Industry**

By Michelle Lynch

Introduction

As one of several drivers of innovation and competitive advantage, patented intellectual property (IP) is both strategically and financially valuable. IP, including patents, trademarks and copyright, constitutes an intangible asset and has a financial value that can be listed on a company's balance sheet. In line with the growth of the global knowledge economy, the value of intangible assets is now in many cases vastly outstripping that of tangible assets. Ocean Tomo, a US-based Intellectual Capital Merchant Banc™ estimates that the value of intangible assets as a percentage of the overall Fortune 500 Market Value has risen from 17% in 1975 to 84% in 2015 and is likely now at its peak. A notable example of a company's patent portfolio value is that of the former Canadian company Nortel, whose 6,000 patents sold for $4.5 billion in 2011. Both internal and external factors can cause shifts in a company's patent values and maintaining the optimum patent portfolio, one that supports continued growth in revenue and profits at the lowest cost, is a key goal for chemical producers.

As profitable as patents can be, there are also considerable associated costs. These include developing the invention, filing and maintaining patents, and enforcing granted intellectual property rights (IPR). Infringement of another party's IPR can be extremely costly, both in terms of financial performance and corporate reputation. Legal costs can run into millions of dollars, but by far the largest cost is associated with loss of product and license sales, which is often in the order of magnitude of billions of dollars. Ability to mitigate infringement risks and costs depends on several factors: effective monitoring of competitor IP, access to sufficient funds to pay for infringement cases, an expert legal team and the integrity of the IP legal system. China has traditionally been criticised for poor enforcement of IPR, but reforms have been introduced and China claims to be improving this situation. One example of a dispute with a positive outcome in China is that of INEOS who filed against SINOPEC in 2014 in regards to infringement of acrylonitrile IP, a business that INEOS values at $500 million in annual profits and $3 billion in replacement value. The case is now reportedly close to settlement with the two companies continuing to work on joint chemical projects in China. Ideally, infringement cases should be limited or avoided altogether, and there are many steps companies can take to prevent them as outlined further in this article.

Maximising value and minimising cost of IPR is a highly achievable goal, provided the correct patenting strategy and IP monitoring is adopted. As an introduction, this article provides a brief background and context on the patent system. A case study is provided on the global patent landscape and trends for catalyst manufacture.

Patent Systems

Inventions arise when a researcher creates a solution to a problem. If the invention is novel then it may be patentable. A patent prevents parties other than the inventor(s) from practising the claims of the invention for a limited period (usually 20 years). The patent is considered to be a bargain (exclusivity in return for disclosure) to incentivise and advance innovation.

Patent applications are filed geographically through domestic patent offices where they are examined to see if they meet the right criteria. Searches of "prior-art" are made to establish whether the claims are novel and can be granted.

Patents can be filed internationally by using the Patent Co-operation Treaty (PCT) system which streamlines the filing process and costs. This is especially helpful when patent protection is being sort in several territories. The patent example below shows the evolution of a filing process using the PCT system. From an original (priority) filing to the German patent office (DE10252281), patents were subsequently filed internationally through a PCT application (WO2004043592) and then in a further eight territories. Currently, the patent family has three granted members that have been maintained by annual fee payment – Europe (EP), China (CN) and the United States (US). The remaining applications made in the five territories Austria (AT), Australia (AU), Malaysia (MY), Japan (JP) and Korea (KR) do not currently have patent protection. This may be a sound commercial decision if there is no business case for continuing to seek patent protection in regions where, for instance, there is no likelihood of infringement *(see table 1)*.

Case Study: Catalyst Patents

An example for catalyst manufacturing patents is presented. Catalyst related patent filings have been analysed for three five year blocks between 1990 and 2014. As can be seen from Chart 2, China's catalyst

Table 1: Evolution of a Patent Family Using the Patent Co-operation Treaty (PCT)

US7214641 B2 Catalyst and Hydrogenation of Carbonyl Compounds in the Liquid Phase Using the Catalyst, Applicant: BASF, Priority Date 11th November 2002

0 Months	12 months	12-30 months	> 30 months	Current legal status
DE10252281			DE50303747 D1	GRANTED
	WO2004043592			NOT APPLICABLE
		AT328658		CEASED DUE TO NON-PAYMENT OF THE ANNUAL FEE
		AU2003276258		APPLICATION LAPSED
		MY135620		NOT AVAILABLE
		JP2006505400	JP4608318	CANCELLATION BECAUSE OF NON-PAYMENT OF ANNUAL FEES
		KR20050086481	KR100976939	LAPSED DUE TO UNPAID ANNUAL FEE
		EP1572354	EP1572354	GRANTED, FEES PAID (some but not all states)
		CN1711133	CN1326611	GRANTED, FEES PAID
		US2006052239	US7214641	GRANTED, FEES PAID

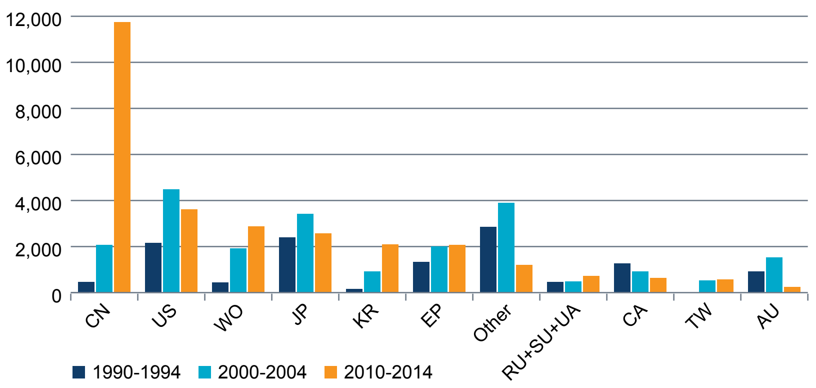
Source: IHS

patent filings have undergone exponential growth over this time period, increasing from less than 500 in 1990-1994 to almost 12,000 in 2010-2014. This trend is in line with overall patenting trends in China which have been growing at double-digit rates since 2003. However, China is also home to leading catalyst producers such as CNPC, SINOPEC and Sino-Platinum and there are many research institutes with a catalyst focus in China (e.g. Dalian Institute and Beijing University). There are also many overseas catalyst producers and researchers who have filed patents in China e.g. BASF, Johnson Matthey and UOP.

The United States is the second largest country filing catalyst patents globally, although the rate of filing has dropped in 2010-2014 compared with 2000-2004. Japan's filing rate also dropped over the same time periods whereas Europe's filing rate has remained steady. Other regions where the number of filings is on the increase include Korea and Russia/Ukraine *(see chart 2)*.

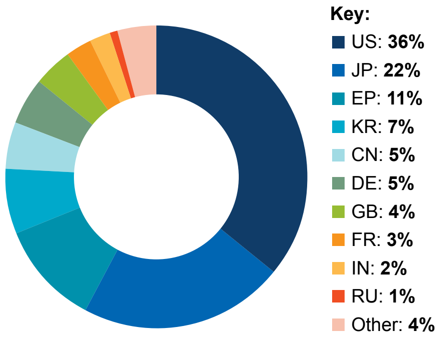
The PCT is increasingly used for filing catalyst patents and in 2010-2014 this reached 2,890 (WO) applications compared with 1,933 applications in 2000-2004. The largest domestic applications that subsequently filed through the PCT are the United States, Japan and Europe who collectively account for 69% of all filings. The most prolific applicants who used the PCT system during 2010-2014 to file catalyst patents include BASF, Shell and ExxonMobil. In 2010-2014, China represented just 5% of catalyst related PCT filings and this may be because it is not attempting to extend the legal protection for these inventions to as many countries as are other regions *(see chart 3)*.

Chart 2: Global 5-year filing catalyst patent trends 1990-2014



Source: IHS

Chart 3: Priority countries and top applicants filing catalyst patents through the PCT 2010-2014



Company:	WO patent applications
BASF	199
Shell	77
Exxonmobil	72
Toyota	68
Honeywell	68
Clariant	68
Johnson matthey	64
Chevron	54
DOW	53
Celanese	50
Total top 10 assignees:	**773**

Source: IHS

Priority Countries and Top Applicants Filing Catalyst Patents Through the PCT, 2010-2014

The most common classes of inventions being filed can be determined by examining the International Patent Classification (IPC) Codes. IPC Codes are applied to patent applications by patent examiners as language independent symbols indicating the technology areas of the document. Codes are divided

Table 4: PCT Applications Top 10 Main International Patent Classification (IPC) Code Analysis, 2010-2014

Main IPC	No of Publications	IPC Code Meaning
B01J 037/02	84	Catalyst preparation by impregnation, coating or precipitation
B01J 023/00	77	Catalysts, other
B01J 031/22	63	Catalysts with organic co-ordination complexes
B01J 021/06	62	Catalysts with silicon, titanium, zirconium or hafnium (as elements, oxides or hydroxides)
B01J 023/89	54	Catalysts of iron group metals or copper and noble metals (as elements, oxides or hydroxides)
B01J 023/63	54	Catalysts with PGM and rare earths or actiinides (as elements, oxides or hydroxides)
B01J 029/40	46	Catalysts of the pentasil type, e.g. types ZSM-5, ZSM-8 or ZSM-11
B01J 023/75	45	Catalysts of iron group metals or copper: cobalt (as elements, oxides or hydroxides)
B01J 023/46	45	Catalysts with rhodium, ruthenium, iridium or osmium (as elements, oxides or hydroxides)
B01J 023/42	45	Catalysts with platinum (as elements, oxides or hydroxides)

Source: IHS

into several sections beginning with a letter A-H. Each IPC code begins with one of these letters followed by a series of numbers. Several codes can be applied to one patent. The top 10 Main IPC codes for the patent set gathered are given in *table 4*.

PCT Applications Top 10 Main International Patent Classification (IPC) Code Analysis, 2010-2014

These codes usually relate to the composition of the catalyst or to the method in which it was manufactured. A correlation can be made between the catalyst and its intended technical purpose by looking at the secondary IPC codes listed on the patent applications. For the top main code in our list (B01J 037/02) the chart shows a number of different secondary IPC codes, and gives these codes explanations along with examples of applicants. This type of analysis can be extrapolated to an entire set of main and secondary codes and used to compare competitors' overall portfolios (*see chart 5*).

Take-Home Messages

It is essential for chemical companies to maintain cost-effective, market-aligned patent portfolios which support sustained long-term revenues and profits for their products and market sectors. Keeping abreast of competitor patent activity and early reports of competitor processes allows mitigating strategies to be developed before company performance is affected. In addition, detailed knowledge of competitor IP may prevent expensive infringement action and allow companies to become aware of potential infringers and to enforce their own IPR. IHS has employed patent analysis for many years as part of its multi-client reporting and single client consulting across several business functions. Its access to large volumes of chemical market data, chemical process technology, patent data, innovative analytical tools combined with cross-functional expertise make it ideally placed to cover IPR for a broad range of chemical industry clients. ■

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Chart 5: PCT applications: Main IPC and additional IPC code comparison

B01J 037/02
Catalyst preparation

C10G 009/16
Thermal Cracking (*e.g. GENERAL ELECTRIC*)

C10G 035/00
Naphtha Reforming (*e.g. RELIANCE, SABIC*)

C08F 004/02
Polymerization Catalysts (*e.g. PETROBRAS*)

B01D 053/94
Catalytic Engine Exhaust Gas Purification (*e.g. BASF, JM, UMICORE*)

C07C 067/055
Carboxylic Acid Ester Production with PGM Catalysts (*e.g. CLARIANT*)

H01M 004/88
Manufacture of Fuel Cell Electrodes (*e.g. TOYOTA, NISSAN*)

C07C 015/04
Benzene (*e.g. BASF*)

C10B 031/02
Carbon nanotubes (*e.g. ARKEMA, HITACHI*)

Source: IHS

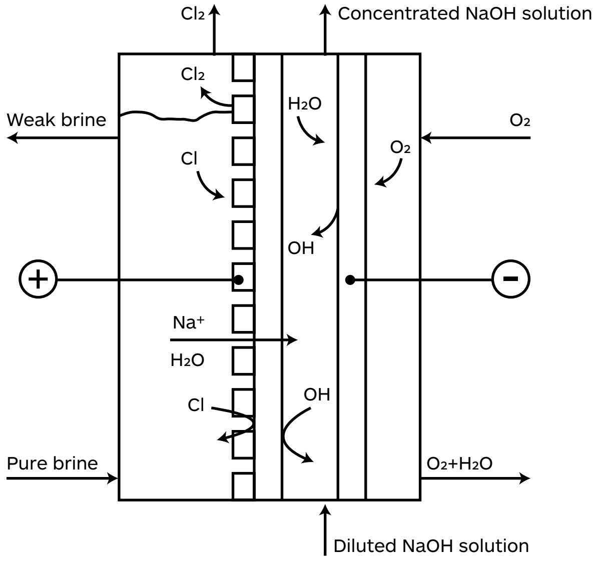
Emerging technology for lowering chlor-alkali **production electricity costs**

By Angela Tenney

Chlorine and caustic soda are commodity chemicals with myriad end uses. They are generally co-produced in the chlor-alkali process by splitting a sodium chloride molecule into chlorine gas and caustic soda solution. The primary end use for chlorine is vinyls production, particularly polyvinyl chloride. Of the approximately 70 million m.t. of chlorine expected to be consumed globally in 2015, about a third will go into the vinyls chain. Global demand for caustic soda in 2015 was approximately 95 million m.t., used primarily in the papermaking and alumina industries.

Historically, there have been three different methods for chlor-alkali production. In diaphragm cells, a purified salt mixture is run through an asbestos-based diaphragm, which divides the chlorine and sodium ions into separate streams. In mercury cells, sodium ions in the salt solution react with added mercury, allowing the chlorine ions to be separated; the sodium-mercury amalgam is then reacted with water to form caustic soda. Both diaphragm and mercury cells are being phased out globally due to environmental concerns, the former for the asbestos and the latter for mercury emissions. They are being replaced by membrane cells, first developed in the 1970s, in which a purified salt mixture enters an electrolysis cell separated by a selectively permeable membrane. A current is run through the cell, causing the negative chlorine ions move towards the anode while the positive sodium ions move through the membrane to the cathode. There, the sodium cations react with water molecules to produce caustic soda, while hydrogen gas is produced as a byproduct.

ODC membrane cell configuration



Source: ThyssenKrupp techforum, issue 1, ThyssenKrupp AG, 2013, p.21

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Production costs

The primary cost of production in each process is the electricity required to split the salt molecule. Each process development, from diaphragm to mercury to membrane, has lowered the energy requirement compared to earlier technologies. In general, approximately 3000 kilowatt hours (kWh) of electricity are consumed for each ton of chlorine, which also produces 1.1 tons of caustic soda.

Bayer is currently advertising its oxygen-depolarized cathode (ODC) process as the latest advancement in chlor-alkali production technology. Researchers were investigating using ODCs in diaphragm processes in the 1950s, and membrane processes in the 1970s, but Bayer, in collaboration with Uhdenora, itself a joint venture between Industrie De Nora and ThyssenKrupp Uhde, is the first company to commercialize it. In an ODC membrane cell, the reaction at the anode stays the same. Chlorine ions in solution generate chlorine gas. But on the cathode side of the membrane, oxygen gas is introduced, suppressing the formation of hydrogen gas. In addition to eliminating the need to process the hydrogen byproduct, the current required to drive the electrolysis is 2.1 volts, and thus less energy is required than for a conventional electrolysis cell, which generally requires a current of 3.1 volts. According to Bayer and ThyssenKrupp, the total energy required for chlorine production with their ODC cell is 1800-2100 kWh per ton of chlorine, around two thirds that of a conventional membrane process.

The IHS Process Economics Program (PEP) analyzed the production economics of a 520,000 m.t./year chlor-alkali plant using this new technology. The

> Producers looking to lower their energy costs should consider the Bayer ODC technology

energy requirement for the electrolysis cell was taken from Bayer and ThyssenKrupp materials, while the overall process – including a recycle stream for the oxygen to lower the costs to purify it – was taken from patents filed by Bayer, ThyssenKrupp, and Uhdenora. The plant used capital cost, utility cost, and labor cost estimates based on a theoretical greenfield site on the US Gulf Coast.

The results of the analysis were that the ODC process does indeed consume about 25% less energy overall: 1754 kWh per metric ton of chlorine produced, compared to the almost 2300 kWh of electricity consumed by a conventional membrane process. However, there are some important differences between the two processes beyond the electricity consumption. For one, the high-purity oxygen required by the process can add additional operating costs if the plant is not located close to an O2 pipeline. Also, while there are cost savings from no longer needing to purify the hydrogen byproduct, current conventional plants use some of that hydrogen as fuel to lower utility costs or react it with chlorine to produce hydrochloric acid for a higher byproduct credit. IHS estimates that the capex for an ODC plant is 10-15% higher than a conventional membrane plant of the same capacity, exclusive of licensing costs.

In short, producers looking to lower their energy costs would do well to consider the Bayer ODC technology. An ODC process would be recommended in regions with high electricity costs such as Europe or Northeast Asia. But in determining the overall process economics of switching to an ODC, the additional costs of oxygen delivery and the effects of eliminating the hydrogen stream should not be neglected. ■

Angela is a consultant with IHS Chemical Consulting, specializing in competitive assessments and prefeasibility market studies, and co-author of PEP Review 2015-02: Bayer-ThyssenKrupp ODC Chlor-Alkali Technology.