Chemical & Energy

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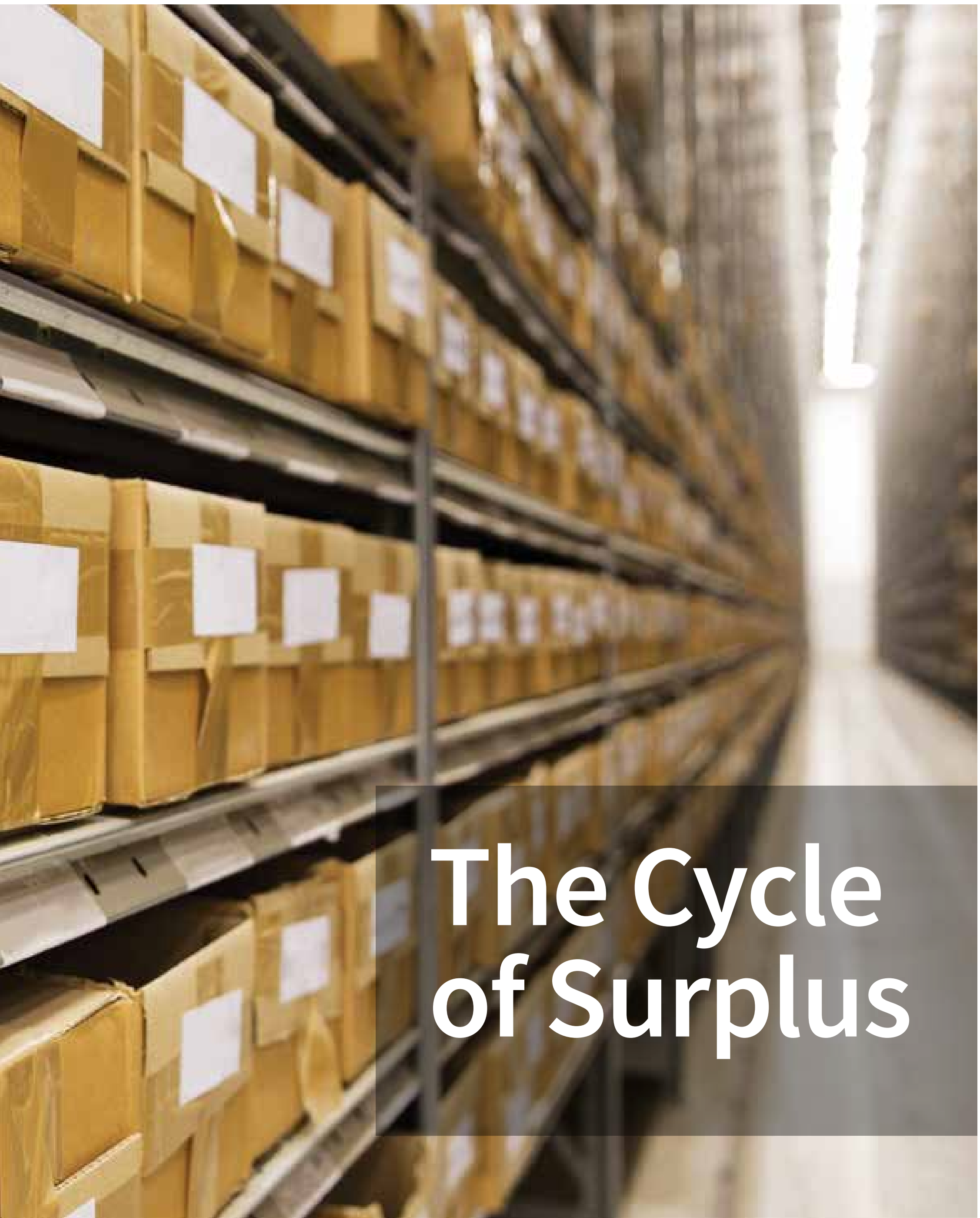

Surplus supplies seek a balanced and sustainable future

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We open this issue with a view on recent military actions in the Middle East and the global economic outlook, which sets the scene for remaining articles across IHS Markit's expertise. Three themes are evident throughout this issue: surplus, sustainability, and integration. First, markets from oil to gas to petrochemicals are in a cycle of surplus as a result of slowing demand growth, large capacity expansions, or both. Second, policymakers and companies are seeking sustainable solutions across value chains, but regulations are not always aligned to incentivize low-carbon supplies. Finally, increasing integration is needed—often to address sustainability needs—from natural gas-derived ethylene converted into gasoline to agricultural feedstocks and alcohols made into jet fuel. IHS Markit provides a uniquely integrated perspective incorporating market, technical, and commercial analysis throughout the value chain.

We forecast the oil market's current cycle of surplus will last for at least another two years, catalyzed by the stunning rise of US oil production growth. However, the future for global supply faces, perhaps, the widest array of challenges and uncertainty since the mid-1980s.

US economic and foreign policies will continue to shape the contours of the world market. The titanic struggle for supremacy between the United States and China is one example of this. And just as worrisome is the rising intensity of conflicts in the Middle East. Compounding these forces is a cyclical slow-down in the global economy that is weakening demand growth for oil products, ethylene derivatives, and other commodities.

As a result, many chemical value chains are again entering a period of surplus after years of margin growth. In this investment cycle, however, two new dynamics could change the landscape. The first is the large-scale "crude-to-chemicals" projects discussed in previous editions of Insight. The second is sustainability, a topic at the forefront of discussions and actions from consumers to governments. Single-use plastics bans, mandated recycling rates, carbon-neutral aspirations, and new chemical recycling technologies are just a few ways sustainability will shape future demand-growth and investment decisions.

A cycle of surplus is also present in the LNG industry, which is notable for counter-cyclical supply investments. How can the markets find balance? Storage plays a role, but storage post-liquefaction is in relatively short supply. A change in the market structure – ramping down the highest cost or most flexible supply – may be necessary during periods of trough demand.

As sustainability targets become a larger part of corporate strategies, the term "green chemistry" has come to the fore. The concept encapsulates various elements of natural, bio-based, renewable, bio-degradable and sustainable concepts, both in raw materials and production processes. One example is green surfactants, which offer an important, growing contribution to the $39 billion surfactant industry—although the size of the contribution can vary depending on perceptions of what is natural, bio-based, and sustainable.

Perhaps one of the most challenging sustainability efforts will be in the aviation sector, which is considering sustainable aviation fuels (SAF) as the primary mechanism to ensure in-sector decarbonization. Biojet fuel made from agricultural or waste feedstock may be the most viable route to this goal; however, current regulations do not support either its production or use.

IHS Markit teams around the world are positioned to provide companies across the energy-to-chemicals value chains with the data, analysis, analytical tools, and expert advice they need to navigate the heightened-level of uncertainty impacting the markets and the world economy.

Our goal is to enable clients to make critical businesses decisions as they navigate the surplus, sustainability, and integration challenges and opportunities of today and the coming decades.

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The Saudi attack and what it portends for security and markets

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It may have cost a few million dollars, but the September 14, 2019 drone and cruise missile attack on Saudi Arabia exacted immediate economic damages measured in billions. The burning fields and twisted metal illuminate risks that could cost the world trillions.

That very asymmetry, and the ability to circumvent traditional military defenses, may open a new era of global terrorism. In the long run, the United States, China, and Russia may have the most to lose – and the greatest incentive to create a new regime against drone and cyber terror.

In parallel with these new security asymmetries, market patterns after the drone strikes underscore a paradox for global oil prices: the vast levels of current and anticipated oil supplies relative to flagging demand have overwhelmed price premiums assumed with geopolitical risk.

We need to understand both realities. Infrastructure across the world has never been so vulnerable to attacks by state and non-state actors. Normally the real or threatened price increases associated with such risk would heighten government focus on preventive actions. Yet in today's world of well-supplied oil markets, market signals have drowned out emergent political risks – blurring the urgency of mitigating actions.

The attack on the Abqaiq processing facility and Khurais field knocked out 60% of Saudi Arabia's production, equal to 5.7 million barrels a day. In a day, the world oil price jumped 15% to over $69 per barrel. Yet, with Saudi Aramco's assurance to meet market commitments and a ready supply of global inventories, oil crawled back to the mid-$60s within weeks.

Oil markets will not always be so well-stocked, and this seeming resilience in oil markets obscures a new era of global insecurity – in the Middle East and for the world's global powers.

Start with the Middle East. Many expected Saudi Arabia to retaliate immediately against Iran. Iran has announced it would respond in turn. Washington went quickly from "cocked and loaded" to seeking a "peaceful resolution." Some question whether America is abandoning commitments to protect energy flows in the Gulf.

Concerns about America's Middle East posture only increased after President Trump announced on October 13, 2019 the withdrawal of US troops from Syria – leaving the job of combatting ISIS to Turkey, Syria, Russia, and Iran. Traditional US allies such as Saudi Arabia and United Arab Emirates continue to affirm the importance of the United States to the region, yet both have reached out to Russian President Vladimir Putin for support.

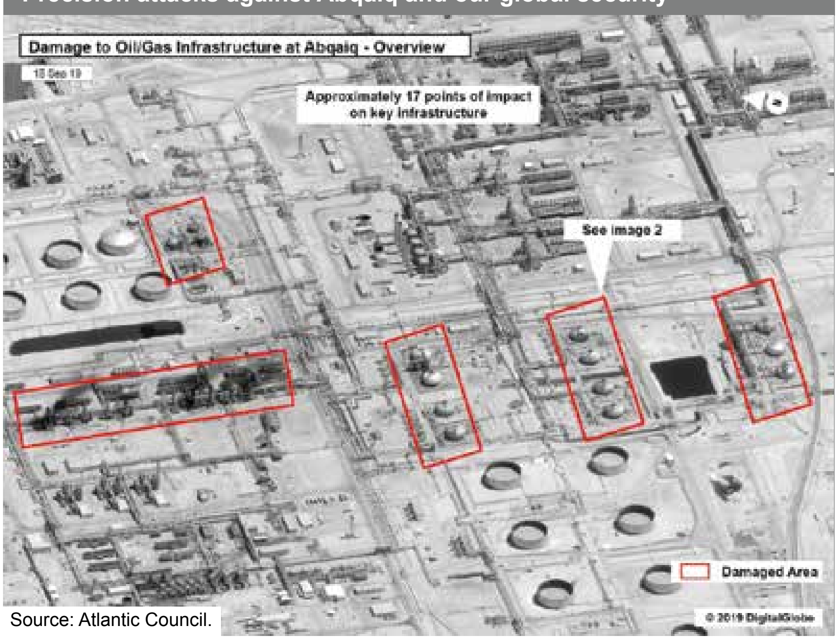
China also looms heavily in both the Middle East and in global oil markets. The US-China trade war remains the biggest factor suppressing global economic growth – in turn affecting commodity and equity markets around the world. China, as the world's largest importer of oil, remains critical to global oil demand. As trade wars caused manufacturing confidence to collapse in every region of the world (see Figure 1), so has incremental demand for oil.

Looking forward, no issue is more important and harder to predict for global oil markets than the uncertainty over demand. That uncertainty begins with the US and China. It continues with Brexit, the actual or near recessions in Europe, turmoil throughout Latin America, and the unpredictability of US politics around the 2020 US election.

Key questions remain unanswered: if the US and China reach a trade agreement and global growth stabilizes, how might risks to infrastructure and energy assets manifest themselves in global markets? Should leaders globally prepare for such contingencies?

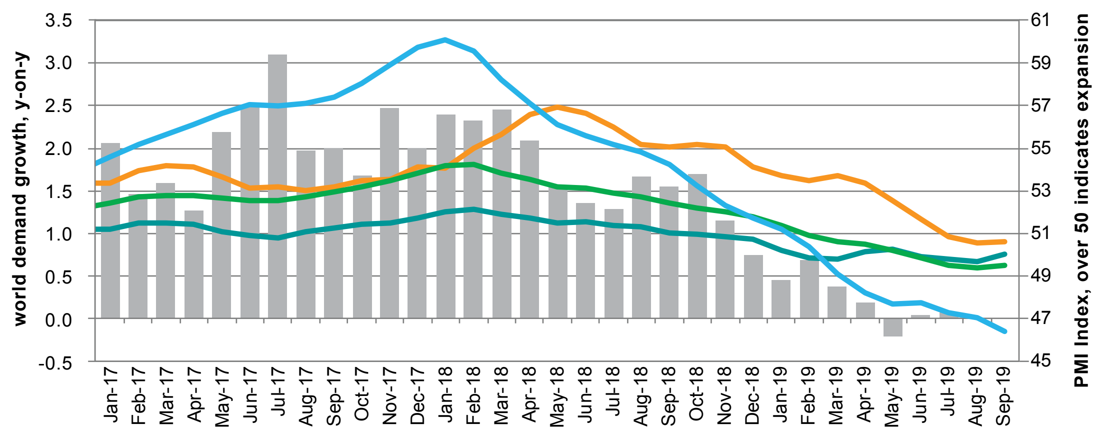
Perhaps the United States – and open societies

Precision attacks against Abqaiq and our global security



Source: Atlantic Council.

Figure 1: Manufacturing PMIs vs. total liquids demand growth (3-month rolling average)



Source: IHS Markit.

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with readily available drone technology and easy access to infrastructure – may have the most to fear and the greatest reason to act. On Amazon you can order drones capable of carrying small payloads for less than $300. For $250,000, you can buy professional drones that carry payloads of 500 pounds. Even a small payload could disrupt a refinery, power transformer, or dam.

China should shudder from the prospect of a cycle of Middle East violence, because it imports more oil than any other nation – about 50% of it from the Middle East. Disruptions in oil supply not only exact a financial price – they could literally bring parts of China to a standstill.

Russia, for its part, has a history of terrorism in the North Caucasus region. Vladimir Putin's punishing attacks on Chechnya as interim Prime Minister in 1999 helped him rise to Russia's presidency. In the wake of the Saudi attacks, Putin made clear that Russia feels well-protected from cruise missiles by its air defense systems. Yet targeted drone attacks on remote infrastructure may pose a different risk.

Beyond these threats, the United States, Russia, and China face the irony of asymmetry from the low cost of drone and cyber attacks. Drawn into such a conflict, major powers lose their traditional military superiority. Instead they fall into a narrower band of capabilities where many actors play, including non-state actors.

Put cyber and drone threats together, and we see a reverse asymmetry. The cost to disrupt is low. One hit can spread political fear and, with a careful strike, economic chaos.

Ironic as it may seem in a new era of "great power conflict," the attack on Saudi Arabia should be a wake-up call for the United States, China, and Russia to seek global action and set rules for drone and cyber warfare. When seen in the context of the Middle East, Russia, and China – allies of Iran and clients of Saudi Arabia – could prove most effective in preemptinig a cycle of debilitating retaliation.

The first step may be modest – the United States, China, and Russia using their dominant roles at the UN Security Council to call on all nations to join them in a new global initiative to control drone and cyber military uses and protect against terrorist threats. The three will need to create a credible secretariat to harness international participation and frame potential rules on technologies, how they are licensed or sold, and eligible military use.

The seeming "price complacency" in currently oversupplied oil markets may have obscured the risks facing global infrastructure, especially in the energy sector. But this is clear: the presidents of the United States, Russia, and China have no interest in seeing their military prowess undermined by easily accessible technology that can penetrate sophisticated defenses.

In a post-Abqaiq world, it may take leadership from the business sector to convince political leaders to act now on drone and cyber security – before these emerging risks penetrate both national and energy security defenses throughout the world.

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Unprecedented challenges in global crude supply impact E&P company futures

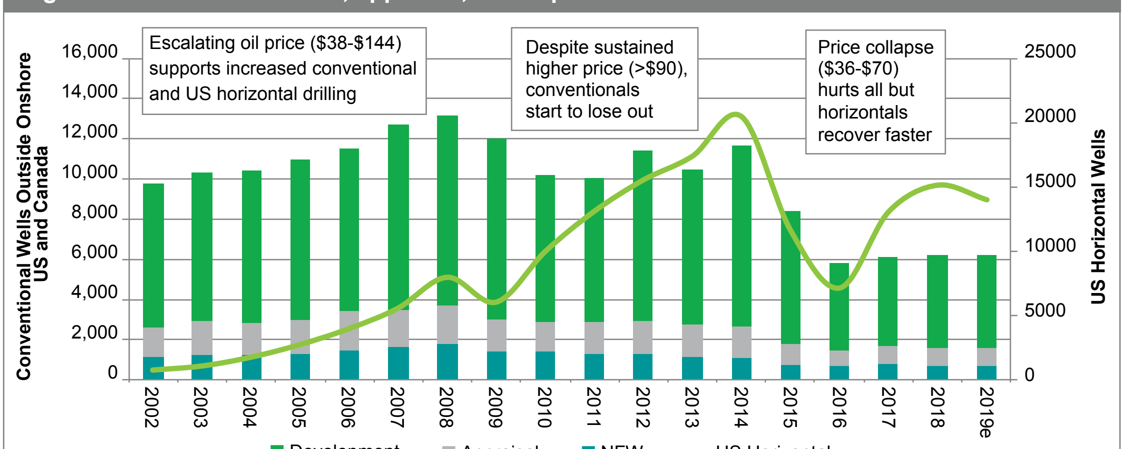
The future for global crude oil supply faces perhaps the widest array of challenges and uncertainty since the mid-1980s. Factors influencing the competitive supply of oil include: volume, quality, and cost of supply of remaining resources; investment behavior; and concerns about demand destruction or "peak oil" in a political environment focused on promoting renewable technologies.

The drive to short cycle-time, unconventional projects onshore in North America and elsewhere seemed irresistible for a large swath of publicly traded companies. This focus accelerated after the 2014 price drop albeit with a lag. The business proposition rested on dramatic performance improvements, lower risk (both actual and perceived), capital flexibility, and the transparency of activity. It was also true that a great deal of conventional activity was not making money prior to 2015, as upstream return on capital employed (ROCE) fell progressively from 2010, even with $100 oil prices.

Still, the exploration and production (E&P) business is incredibly dynamic. Disenchantment with financial returns from unconventional production onshore in North America is now reducing investment there – even as larger operators determine different development pathways that emphasize financial returns but with lower growth. Investor questions may even drive more operators back to conventional exploration in the medium term, or conversely, drive investors out of the upstream sector altogether. Offshore companies have been able to substantially reduce the costs of building and operating the offshore facilities necessary to develop resources in deeper waters. Global conventional development drilling has picked up since 2015 but only slightly, remaining well short of pre-2016 activity levels (see Figure 1). Offshore conventional new field wildcat (NFW) activity has experienced only incremental gains at best, which will create a knock-on effect on development drilling. From a global perspective, conventional exploration and discoveries are at the lowest level in seven decades. This is not due to lack of resource potential but rather to investment behavior, enforced by the financial sector.

Some larger E&P companies and a few E&P independents continue to pursue selective deepwater exploration. For example, ExxonMobil and its partners, Hess and China National Offshore Oil Corporation, have been very successful in the western portion of the Guyana Basin (offshore Guyana). Over six billion barrels of oil-equivalent recoverable resources have been discovered in Guyana since 2015, with the first volumes coming onstream at the very end of 2019. Additional discoveries by Tullow Oil and its partners have been made in more shallow water, but commerciality has not yet been established. In an environment where operators are largely focused on becoming cash flow-positive as soon as possible and financing future development activity from within the existing cash flows, these assets in Guyana represent an ideal package *(see Figure 2)*. They offer globally competitive economics with break-even points for the confirmed projects averaging around US$41 per barrel (bbl), with a range between US$23/bbl and US$60/bbl. They also offer shorter project cycle times than have existed in typical deepwater developments, with the assets returning

Figure 1: Conventional NFW, appraisal, development versus US horizontal wells



Source: IHS Markit.

positive cashflows within the first two to four years of production.

In short, there are E&P companies with engaging, financially attractive portfolios, strategies, and performance to come. But how many Guyana Basins or Johan Sverdrup's (in offshore Norway) are there? There may be other new sizeable crude streams that are highly competitive, with break-evens at $25 to $45 per bbl. However, even if volumes are 300,000 to 500,000 bbls/day, this does not make up for overall industry trends. There are simply not enough highly competitive investment opportunities for enough oil and gas companies.

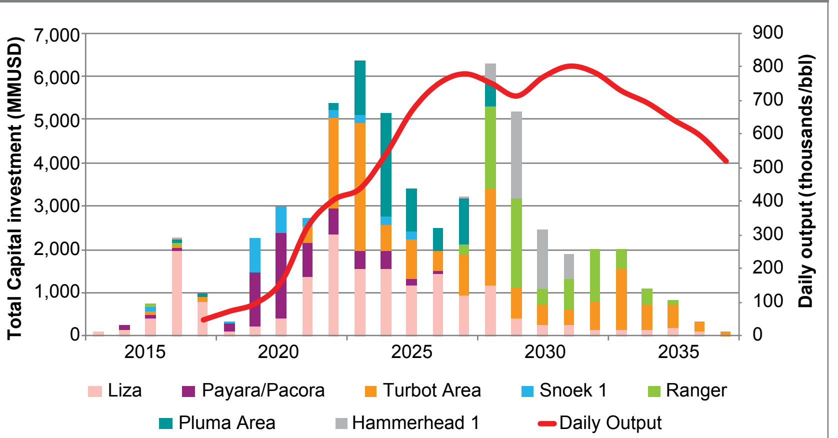
National oil companies face additional intense pressures and obligations, but mostly it is a favored few (via natural endowments and high capabilities) versus the many. Overall, the industry remains more challenged than ever. Has the global competitive landscape in E&P really changed, or is it the fact that the financial sector has less patience with E&P against the backdrop of the energy transition?

Consider the concerns about demand destruction or "peak oil" in a political environment determined to promote renewable or green technologies. Current concerns over global warming and the resulting shift to renewables have led to some scenarios that show a peak in oil demand as early as the 2020's; other scenarios show oil demand peaking beyond 2030. Given this uncertainty, the industry appears to fear over-investment rather than under-investment. We see this in diminished conventional drilling; slowdowns in unconventional drilling; seismic acquisition; new acreage acquisition; and declining investment in improved oil recovery/enhanced oil recovery projects.

Given these factors, IHS Markit predicts that the most competitive barrels in the future will be those that offer the lowest cost, lowest emission, and shortest cycle time (that is, faster time from decision to cash flow), and flexibility of capital commitment. Arguably the best short-cycle conventional resources are in the Gulf countries as well as Western Russia. Others include selected shallow water areas globally; subsea tiebacks in maturing phase deepwater basins (where infrastructure rules); and best-in-class new deepwater plays, whether in the Guyana Basin or certain deepwater basins in Brazil. Other resource classes include much lower but more profitable growth in onshore North America and big, albeit long-term natural gas plays. These opportunities and the required performance are not available to all or even many companies, however.

Large basins can provide the scale and materiality to achieve further cost reductions via improved performance, infrastructure sharing, and fiscal regime change. But, smaller, higher-cost basins may struggle to attract investment in a low-crude oil demand scenario. Most governments will not easily accept declining investment in domestic basins due the impacts on revenues, employment, and national energy concerns. But how many

Figure 2: Offshore Guyana Basin Investment Outlook



Source: IHS Markit.

governments have the capacity to sustain E&P investment in less-competitive basins for extended periods?

The E&P sector has more options than ever before from a subsurface perspective. Yet collectively it faces unprecedented challenges due to the uncertainties in future oil and gas demand and investor concerns. The industry is unquestionably resourceful. Since the oil price downturn in 2014, new approaches to project design, applications of digital and other technologies, efficiencies in the supply chain, and sharp focus on company portfolios have combined to significantly reduce costs, and create "high quality" assets which can compete in the future, uncertain business environment. For conventional offshore projects as example, it is not uncommon to see break-even costs at some 60% of the level that would have been achieved in 2014. Those companies that continue to apply these approaches relentlessly will be in the best position to appeal to investor sentiment within the financial community. But, there may well be too few "quality," competitive investment opportunities for the E&P industry as a whole; parts of the industry will not able to attract investment capital. The competitive landscape in global E&P will see further, deeply significant changes. This future E&P industry will then be able to take advantage of the inevitable opportunities that will emerge as the global energy sector continues to evolve.

Up and down with the USA: The oil market's cycle of surplus endures for a while longer

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The oil market remains in a years-long cycle of surplus. An oil cycle is an enduring period of supply surplus or tightness that is reflected in price movements. Cycles can be identified when annual average oil prices generally move in one direction (either up or down) for several years. Cycle start and end points are only evident with the passage of time.

There is no uniform definition of an oil cycle, and the true cycle length is often in the eye of the beholder. From 1999-2012, oil prices were on a clear upward path. A bull cycle was fueled by consistently strong oil demand growth from the developing world (particularly China) and a conspicuously weak pace of non-OPEC supply growth. But since 2013, oil prices have exhibited a distinct break from that trend.

The stunning rise of US oil production growth has been the most important catalyst in this newest cycle of surplus. As in previous eras, large new sources of oil supply tend to exert years-long downward pressure on prices. In the 1980s and 1990s, big discoveries in the North Sea, Alaska, and Mexico kept prices under pressure. Today, it is US tight oil, a huge new resource base unlocked by innovations in drilling technology.

How much longer will the current surplus cycle last? Our latest base-case outlook projects it to continue for at least another two years, with Brent oil prices languishing in the $50s in 2020-21. Interestingly, this surplus occurs even as US oil production growth is expected to slow during this period. We project global inventories to build over the next two years, as oil demand grows at only a modest pace and as new engines of non-OPEC supply growth emerge. Of course, surprises could lead to a deviation from our base-case oil market outlook.

Oil demand growth downshifts

Strong oil demand growth was a key support for the oil price recovery after the crash of 2015-16. From 2015-18, global oil (total liquids) demand growth grew at the exceptionally rapid pace of 1.7 million barrels per day (MMb/d) on average. This pace is notably stronger than the previous four years (2011-14), when growth averaged 1.2 MMb/d. But this year, demand has fallen well short of expectations. We currently anticipate demand will only increase by about 900,000 b/d, the weakest performance since the Great Recession of 2008-09. This mainly reflects slower growth in the global economy and a drop-off in trade activity. Key measures for global economic activity have deteriorated: world trade volumes and the global manufacturing purchasing managers' index (PMI) have turned negative in recent months—a rare occurrence.

Our current base case projects global economic growth in 2020 at 2.5% (near the level of this year), with a rise to 2.7% in 2021. Oil demand growth is expected to remain in a lower gear during this time, averaging 1.2 MMb/d, reflecting a downshifting of economic growth.

Supply remains plentiful, even as US tight oil growth slows

Non-OPEC oil supply growth remains strong, despite a long list of developments that have reduced supply or restrained supply growth, including US sanctions on Venezuela and Iran and production curtailments in Canada. Non-OPEC supply growth has soared in 2019 and will exceed world oil demand growth, as it did in 2014 and 2018.

US supply growth, fueled by ample financing from Wall Street, had been the main driver of higher non-OPEC output. But this has changed. Investors became disenchanted with US exploration and production companies (and with oil as an investment generally), especially as the energy sector has dramatically underperformed the broader stock market since 2015. Capital markets are no longer willing to finance the US upstream industry's excess spending, which was a cumulative $245 billion above cashflow from 2010-18 *(see Figure 1)*.

As a result, we expect US crude oil production growth to be weaker in 2020 than in 2019. We may see no growth or even declines on an annual average basis in 2021 and 2022, as the industry is forced to restrain spending, live within cash flow, and contend with stagnating oil prices. This does not mean the US production growth has come to an end forever—the resource base is still very large—only that growth is on "pause."

Although the United States is slowing down, production growth will pick up in 2020-21 in other places. Norway, Brazil, Canada, and Guyana (a newcomer to the world's club of oil producers) are expected to be key sources of oil production growth. Production in these countries is generally coming from long-lead upstream projects that were sanctioned several years ago. They will stream regardless of oil prices, since the capital has already been committed.

Vienna Alliance: How many more years of production restraint?

OPEC's strategy in this cycle of surplus will continue to be defensive. In January 2017, the "Vienna Alliance" emerged. The alliance includes OPEC and non-OPEC countries, headlined by Russia, that have agreed to cooperate on production restraint in order to prevent oil prices from falling even further. The alliance output cuts initiated in 2017 were conceived as a temporary arrangement; however, they have now been extended into their fourth consecutive year as rising non-OPEC supply crowds out OPEC's ability to grow.

The oil market has remained relatively calm despite rising geopolitical tensions in the Mideast Gulf between Iran, Saudi Arabia and the United States. The September 14, 2018 missile and drone attack on Saudi oil facilities resulted in the single largest overnight supply outage in history, and yet oil prices spiked for only a day. Similarly, the surprising decision by US President Donald Trump to assassinate Iran's top military leader Major General Qasem Suleimani on January 3, 2020, potentially triggered a renewed cycle of escalation between the US and Iran, but it was met with only brief upward price momentum. In the context of the ongoing cycle of surplus, the mere threat of supply disruptions is not sufficient to sustain bullish momentum.

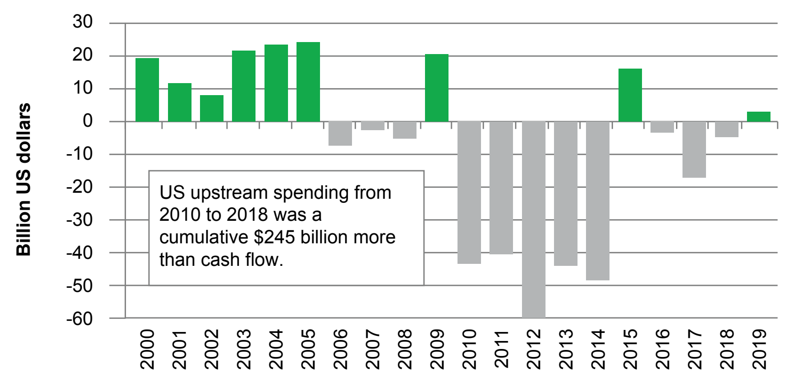
America is defining the outlook for oil

The Middle East still matters a great deal, but the United States is the most prominent variable impacting global oil supply and demand. The astonishing rise in US production is slowing, to be sure, and may even decline for a time. But the United States is sending other shock waves through the global economic and financial system that are not about to end, regardless of whether President Trump is reelected next year. The remaking of the post-World War II world order began before Trump and it will continue beyond his presidency. US economic and foreign policies will shape the contours of the world oil market.

The titanic struggle for supremacy between the United States and China is one example of this. Greater antagonism between the two powers—particularly in the form of the ongoing trade war—has clearly hurt the world economy.

On the supply side, the US is deciding unilaterally—via the blunt tool of sanctions—what other major oil producers such as Iran and Venezuela can produce and export. President Trump has also influenced the oil price and production policies of OPEC's leader, Saudi Arabia, and its close Gulf allies, all of whom depend on US protection.

Figure 1: Annual US upstream net cash flow from oil and gas operations



Note: Negative numbers mean upstream capital spending greater than cash flow from oil and gas operations.
Data reflect upstream spending for companies that publicly report their US operations.
Data for 2019 are indicative estimates.
Source: IHS Markit.

The Trump administration was emboldened to pursue its myriad economic and foreign policy goals partly because of the US's increasing energy dominance. The stunning rise in its oil output means that the United States is nowhere near as reliant on OPEC oil as it once was.

There are limits to potential growth in US oil output, although it has consistently been underestimated. This growth may reach an important inflexion point in its trajectory over the next few years. The de facto US oil production regulators—Wall Street and oil prices—will have a big say in the ultimate outcome.

A door opens: surplus ethylene to gasoline

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As the US has sought to exploit its hydrocarbon resources over the last decade, natural gas prices – which were once close to parity with oil prices in the early 2000s – have since diverged from oil prices. This shift evolved through the direct production of natural gas as well as gas production associated with oil development. The dynamic has transformed North America into a prolific producer of natural gas liquids (NGL), the feedstocks used in the production of petrochemicals.

Given the plentiful supplies of these feedstocks and their inherent advantage relative to oil-based feeds, massive investment in grassroots petrochemical capacity – namely complexes dedicated to the production of ethylene – occurred to monetize the gas-linked feedstocks. In the past five years, nearly seven million tons of ethylene capacity were added in North America. This capacity addition is considered unprecedented, given that North American chemical producers took about 20 years to reach an almost equivalent amount of new builds. Between 2019 and 2022, more than six million tons of ethylene capacity is expected to come onstream. An additional 13 million tons of capacity additions have either been announced or are under feasibility studies. While IHS Markit does not believe all this announced capacity will come to fruition, much of it likely will be added and will require a commensurate response on the demand side.

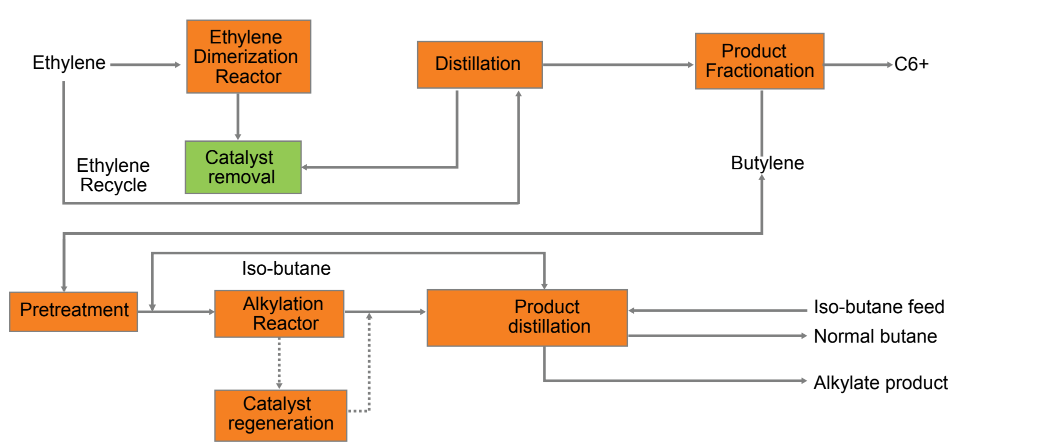
Ethylene demand has indeed been growing strongly as a result of the numerous new integrated ethylene derivative and standalone projects (mainly polyethylene and ethylene glycol targeting the export market) that have materialized over the years. Ethylene derivative exports from the US have grown. Yet ethylene molecule exports became a hot topic as the substantial increase in ethylene supply in the US as well as a structural shortfall in other regions made the molecule shipments economically viable. Enterprise Products' one million metric ton (MMT) terminal project, which commenced construction in 2018 and is now in a start-up phase, is expected to load the first cargo in December 2019.

In contrast to the accelerated project executions in both ethylene and ethylene derivatives, the overall demand growth for the derivatives is moving slowly this year – a pattern driven by a cyclical slow-down in the global economy combined with prolonged US-China trade tension. These headwinds have inevitably had a negative impact on projects geared towards export markets, particularly those destined for China. Considering this reality, there is an open question on how hard those ethylene derivative projects can operate in the near term to avoid creating an oversupply scenario. The market is now casting increasing anxiety on the potential cycle of surplus.

What is the new solution to consume ethylene?

Ethylene, often referred to as one of the key building blocks of petrochemical value chains, is typically converted to chemical derivatives such as polyethylene, ethylene oxide, styrene, ethylene dichloride, and others. Many of these derivatives will be eventually converted into plastics. On top of those conventional outlets, we now have a new home for ethylene, ethylene to alkylate, a gasoline blendstock.

Figure 1: Ethylene Dimerization and Alkylation Process



Source: IHS Markit.

Over the past three weeks, two separate announcements have been made by an investor/operator and an engineering, procurement, and construction firm, discussing a new US Gulf coast project to produce alkylate from ethylene. Although neither announcement commented about the other, IHS Markit speculates that these two announcements are linked to the same project.

The positive final investment decision made by Next Wave Energy Partners pointed out that this complex is anticipated to begin initial production by mid-2022, consuming over 1.2 billion pounds of ethylene per year (515 kilo tons per annum or kta). The expected structure of the project includes one dimerization unit to convert ethylene to butylenes and an alkylation unit that routes produced butylenes (C4) to make alkylate. From a technical standpoint, neither the involved ethylene dimerization nor the C4 alkylation process are novel technologies. However, it is certainly a unique approach that may become a new way to consume ethylene, diverting from traditional chemical use to fuel demand.

Refiners are being pressed to seek new strategies or sources to yield high-octane, clean alkylate products from diverse mandates and trends, including:

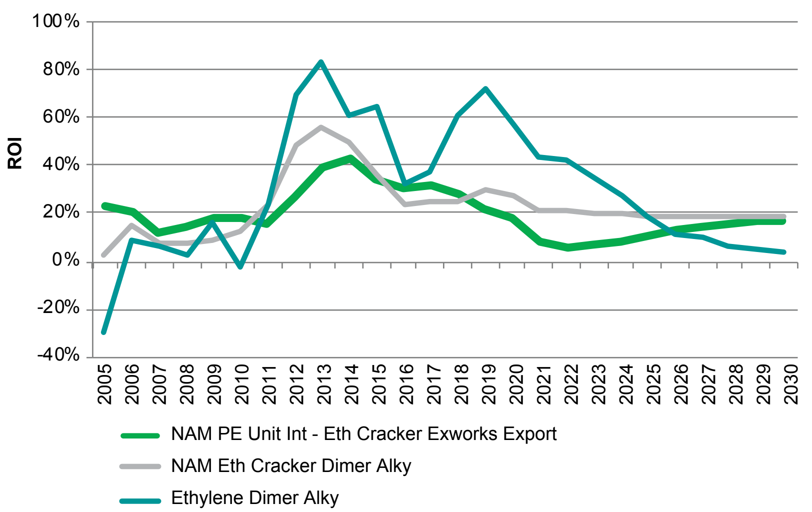
- Rising demand in cleaner-burning gasoline required by high-performance engines
- The looming International Marine Organization specification change that mandates a reduction in bunker fuel sulfur content to 0.5%
- The expiration of certain provisions pertaining to Tier 3 gasoline regulations in the US

The on-purpose alkylation technology utilizing pure feedstock of ethylene, derived from NGL feedstocks, provides a solution that produces clean, high-quality alkylate product amidst a tight alkylate market *(see Figure 1)*.

What do the economics look like?

The project is quoted at about 515 kta of ethylene consumption and 28,000 barrels per day of alkylate production at a cost just north of $600 million. We queried our technical and analytics group at the Process Economic Program to assess the economic outlook. From the point of a pure merchant buyer of ethylene priced at market price, the economics look good in the near term but a bit challenging in the outer years. (Calculation on this route is based on IHS Markit US ethylene average acquisition index.) In a second scenario, we calculated the project using ethylene priced at cash cost based on ethane feed. The ROI metrics look much better overall from a long-term perspective and compete very well versus the other key ethylene derivative, polyethylene, for the export market *(see Figure 2)*. Thus, the ethane-to-alkylate chain makes a lot of economic sense in the longer run.

Figure 2: NAM Ethylene ROI comparison



Source: IHS Markit. © 2019 IHS Markit

Both routes to alkylates, whether on merchant ethylene or priced at cost, yield a positive process scheme in the short term from today to 2026, with the excess ethylene capacity and traditional derivatives coming onstream. A player long in ethylene that blends gasoline could be a likely supplier or offtaker in an investment of this nature.

It is unknown whether this new ethylene demand will lead to continued investment in ethylene-derived gasoline blendstock or if it is just one-time occurrence. However, it is clear is that the surplus of ethylene production paved the way for a new source of demand.

Chemical surpluses create opportunities – and costs

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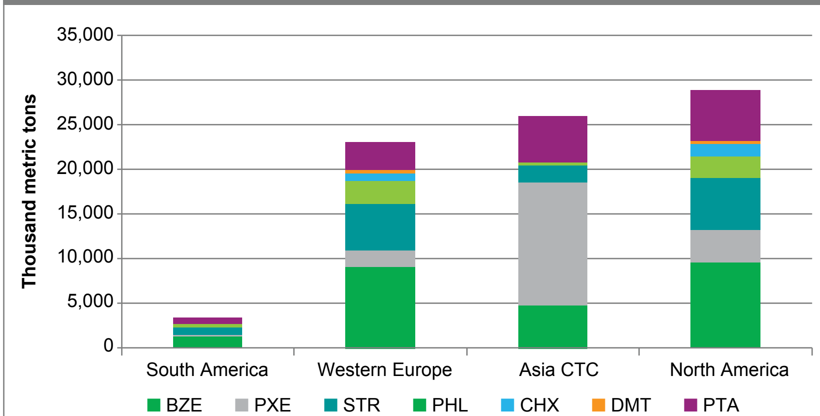
Chemical demand continues to be robust across most sectors, with growth rates at gross domestic product (GDP) or multiples of GDP around the globe. Manufacturers continue to develop new products using plastics and other chemically derived materials, while growth in existing products remains strong in developing markets with a growing middle class. This robust chemical demand growth must be supplied by new chemical production investments. These investments can be located where there is strong demand growth, where ample low-cost feedstocks are available (such as North America with ethane from shale gas), or where capital cost advantages exist (such as China, where building costs can be 60% of US costs). Because these new production investment decisions generally come in waves – with margins supporting capital outlays – chemical markets tend to have supply-driven surplus cycles. Margins are eventually impacted by surplus capacity, which causes capital investments to slow. Demand growth along with industry consolidation and closures of high-cost assets eventually mop up the surplus capacity. This shift drives margins back above reinvestment levels, triggering a new investment cycle and eventual surplus.

Many chemical value chains are again entering a period of surplus after margin growth in previous years encouraged new investments. In this investment cycle, however, new dynamics are coming into play that could change the landscape over the long term. Although sustainability is top-of-mind for consumers and governments, refinery-scale investments in crude-to-chemicals assets have the potential to create substantial oversupply situations. These investments are being driven by changes in fuel demand and the need for large oil producers to ensure a home for their crude oil. As fuel demand growth slows, strong demand growth in chemicals creates an avenue for refinery assets to diversify their production portfolio. Multiple examples are currently playing out, with announcements from national oil companies and major oil companies such as Saudi Aramco, Reliance Petroleum, and Exxon Mobil. In a recent Chemical Week magazine article, "Shifting Sands: Saudi Arabia Leads Middle East Downstream Push to Add Value Through Chemicals," Saudi Aramco CEO Amin Nasser says, "The company's ambition is to integrate up to 30% of its crude output into chemicals." In another Chemical Week article, Reliance said recently that it has developed a strategy to transform the Jamnagar refinery from a fuels producer to a chemicals producer. The company eventually wants to achieve more than 70% conversion of crude refined at Jamnagar into the key petrochemical building blocks: olefins and aromatics.

These crude-to-chemicals investments are also being driven by large conglomerates looking to ensure production economics for their main feedstocks. Examples in China include large polyester conglomerates building world-scale crude oil refineries, which are equipped to produce paraxylene at production rates that are multiples of current paraxylene annual global demand growth rates. Margins in the polyester chain are forecast to remain under significant pressure for multiple years. Yet three separate companies are building refineries that are in various stages of completion, each with eventual paraxylene capacities near 4 million metric tons per year. Figure 1 compares the size of these production capacities in total aromatics and aromatic derivatives compared with the current production capacities of entire continents. The benzene and benzene derivative markets are forecast to see significant margin pressure from these investments as well.

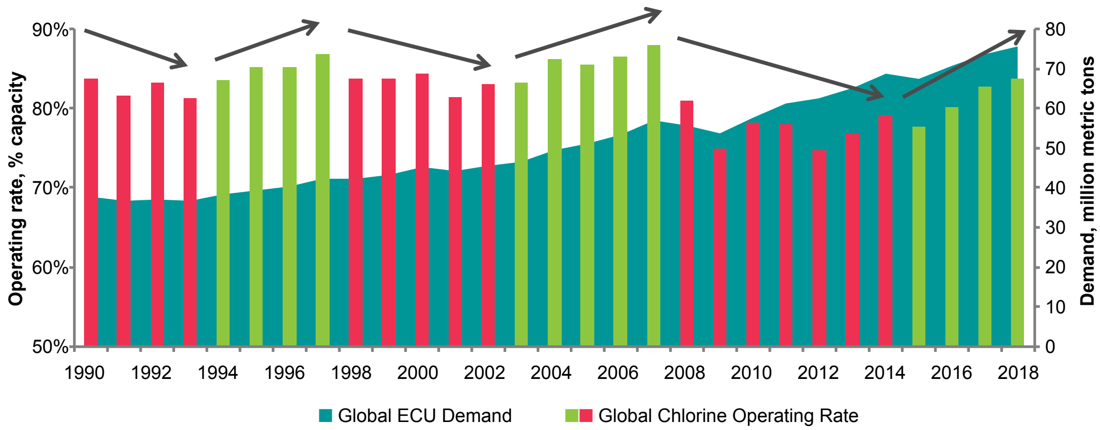
While these crude-to-chemicals investments are a big part of the aromatics overbuild, ethylene investments into traditional naphtha crackers are forecast to move most chemical and derivative chains into a

Figure 1: Increasing Asia crude-to-chemicals capacity overtakes West Europe capacity



Source: IHS Markit. © 2019 IHS Markit

Figure 2: Global chlor-alkali operationg rate cycles, 1990-2018



Source: IHS Markit.

supply surplus environment over the next few years. Outside of North America, companies have been holding back on ethylene investments as North American investments in shale gas ethane crackers and ethylene derivatives accelerated. However, the pace of these investments has been insufficient to fully supply the global market demand growth. Thus, margins moved to levels that support new China naphtha cracker investments. As these assets start production, margins in nearly all the chemical chains will be under pressure. Unlike ethane crackers that yield minimal co-products, naphtha crackers yield large quantities of co-products.

One area where investment is limited compared to annual demand growth rates is the chlor-alkali chemical chain. The margins in this chemical chain are dependent on many downstream derivatives on both the chlorine and caustic side of the equation. The main derivative for chlorine, polyvinyl chloride (PVC), makes up only about one-third of total chlorine demand. Compare that to the main derivatives for ethylene and propylene, where polyethylene (PE) and polypropylene (PP) make up 60% to 70% of total demand. Chlorine demand is more closely tied to construction, where demand growth has been relatively slow since the global recession a decade ago. Caustic soda demand is even more diverse, with the largest segments being in the alumina and pulp and paper sectors. Together these sectors make up only about 25% of the total global caustic soda demand. The chlor-alkali chemical chain continues to mop up excess capacity. While there are new chlor-alkali-related projects under construction, margins that would catalyze an investment cycle are not forecast to appear until the mid-2020s. Figure 2 shows the trend in chlor-alkali operating rates and cycles over the last two decades.

As mentioned earlier, sustainability is at the forefront of discussion and action from consumers and governments. Single-use plastics bans, mandated recycling rates, carbon-neutral aspirations, and new chemical recycling technologies are just a few ways that sustainability will shape future demand-growth and investment decisions. Looking at the entire supply chain picture, expected low oil and natural gas prices will make these sustainability decisions come at a cost to consumers. Just developing the necessary infrastructure to collect, separate, reprocess, and reuse plastics will require a large capital outlay, which must compete with investments to produce virgin raw materials. Technology and innovation will likely have a major impact on how these investment decisions are made. IHS Markit is well-positioned to look across not only all the major chemical chains, but also at how the energy market and any sustainability initiatives impact the future.

Assessing the sustainability and performance of green surfactants

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As sustainability targets have become integral to corporate strategies and consumers take a greater interest in the impact of formulations on themselves and the environment, we're often asked about the market for green surfactants. The answer is usually "it depends," based on your understanding of the term "green." The concept of green chemistry encapsulates various elements of natural, bio-based, renewable, bio-degradable, and sustainable concepts, both in terms of raw materials and production processes.

Surfactants are an important class of chemicals with applications in household detergents and cleaners, personal care and cosmetics, industrial and institutional cleaning, and an array of industrial processes. The 2019 global market for surfactants, worth an estimated $39 billion, is expected to grow at 2.6% per annum over the next five years to reach $46 billion by 2024. The industry produces over 17 million metric tons of surfactants annually, some of which comes into personal contact with consumers and much of which is ultimately discharged as effluent. Considering this volume, addressing green issues is an important topic for an industry facing increasing legislation and consumer concern.

A vast array of surfactants is available, produced from natural and petroleum-based feedstocks and combinations of both. In this highly competitive market, price and efficacy remain key drivers. Therefore, renewable feedstocks and process economics must compete with petroleum feedstocks that often serve multiple markets beyond surfactant production. Fatty alcohols and acids derived from natural fats and oils – such as soya, palm and palm kernel, rapeseed, sunflower, tallow, and coconut oils – are a major source of feedstocks for the manufacture of surfactants. They also form the cornerstone of the green contribution to the industry.

How Green is Green Enough?

There is much concern regarding the sourcing of natural oils, especially tropical oils. While producers have joined organizations such as the Roundtable on Sustainable Palm Oil (RSPO), there remains considerable debate on the true cradle-to-gate impact of land use for renewable chemical feedstocks. Interestingly, Clariant launched its GlucoPure Sense surfactant in 2017 that uses European sunflower oil rather than tropical-sourced oils. BASF has also commercialized amphoteric betaine surfactants that use microalgae oils derived from fermentation of sugar instead of coconut oil-derived cocamidopropyl betaines for use in hair care formulations.

In 2019, detergent alcohols using bio-based renewable feedstock accounted for 80% of the 3 million metric tons produced. Synthetic alcohols, produced predominantly from ethylene but also from n-paraffins and coal-based Fischer Tropsch processes, still provide cost-effective alternatives to natural feedstocks, especially in regions where ethylene feedstocks are economical, such as the United States. Companies are still investing in synthetic alcohol capacity. For example, Sasol will start up a 160 kilo tons per annum (kta) total capacity facility for Ziegler, alumina, and Guerbet alcohols by early 2021. Recent expansions of linear alpha olefin capacity in the United States and planned expansions in the United States (ExxonMobil) and Saudi Arabia (INEOS) will seek value from the full range of C4-C20+ olefins produced, including the C12-C18 mid-cuts used for detergent alcohol production.

So, does this mean all renewable-based surfactants are green? Most applications require further processing of biobased feedstocks to include moieties that provide the functional properties of the surfactant, resulting in a range of anionic, cationic, nonionic and amphoteric products. Most of these processes involve the incorporation of petroleum-based feedstocks or moieties that would not necessarily be considered green. To help assess individual green qualities, the European Commission of Standardization has devised classifications for biosurfactants, including >95% wholly biobased; 50-94% majority biobased; 5-49% minority biobased; and <5% nonbiobased.

Consumer Demand Drives Change

Anionic and non-ionic surfactants together account for 88% of total global surfactant consumption. Nonionic surfactants are dominated by alcohol ethoxylates (AE), which are used across the spectrum of household, personal care, institutional, and industrial applications. Sorbitan esters, such as sorbitan monostearate, are produced from fatty acids and sorbitol. They represent an important class of non-ionic surfactants derived from renewable feedstocks that are typically used in food and cosmetic applications for their emulsifying properties. Anionic surfactants are dominated by petroleum-based linear alkyl benzene sulfonates, but they also include major products such as alcohol sulfates (AS) and alcohol ether sulfates (AES). AS and AES are produced by sulfation of the corresponding alcohol or its ethoxylate with sulfur trioxide or chlorosulfonic acid followed by neutralization. A fatty alcohol sulfate consequently may have a renewable carbon index of 100% but may not be considered by consumers to be particularly natural or green. Alcohol ether sulfates are predominantly used in personal care and household dishwashing liquids, where the ethoxylation is milder than the alcohol sulfates that are known to irritate skin. Despite this, consumers are increasingly looking to formulations that are completely sulfate-free.

Cationic surfactants such as fatty amines and quaternary compounds are largely used in fabric softeners, while mild amphoteric surfactants such as cocoamidopropyl betaines are mainly used in personal care products. Together they only contribute 12% of the total surfactant consumption by volume.

AE and AES are produced by reacting alcohols, most commonly in the C12-C16 range, with ethylene oxide (EO). They provide products with a wide range of molar ratios of EO to detergent alcohol. Obtaining a 100% renewable carbon index for AE and AES requires the EO moiety to be derived from bio-ethylene oxide, which in turn is derived from bioethanol that is usually produced from sugar cane, via bioethylene.

Numerous bio EO plants exist, although they represent less than 2% of the total EO global production. The largest plants have traditionally focused primarily on the manufacture of bio ethylene glycol. In 2017, Croda International commissioned the first bioethylene oxide unit in North America at Atlas Point and began offering its so-called “ECO range” of ethoxylated surfactants. However, the company has not operated the bio-EO unit consistently since its commissioning. There are several bioethylene oxide plants in China of similar design and scale (30-75 kta EO) as the Croda unit. These plants were mostly built to eliminate long and expensive supply chains for EO, but they also can tout the benefit of offering bio-based products. It is important to note that bioethylene oxide has higher cash cost of production than petrochemical-based processes, due to smaller unit scale and generally higher-cost raw material, bio-ethanol.

High Demand, Low Availability

Personal care applications represent 14% of the total volume consumption of surfactants but will experience higher than average global growth rates of 3.1% over the next five years. They also can offer greater opportunities for green surfactant solutions. Consumers are increasingly discerning regarding products that contact skin, such as shampoos, shower gels, soaps, cosmetics, hand dishwashing products, and household cleaners. Personal care applications also offer greater opportunities for producers to meet consumer demands for more natural ingredients.

The use of glucose moieties in combination with fatty alcohols offers a range of surfactants that have found commercial success, particularly in the personal care and hand-dishwashing markets. Alkyl polyglucosides (APGs) produced by companies such as BASF, Nouryon, and SEPPIC and alkyl glucamides produced by companies such as Clariant have shown tremendous growth over the last five years. Their natural appeal, low toxicity, and effective surfactant properties boosted growth rates above those seen for traditional surfactants. In November 2019, BASF announced expansion of its production capacity for APG at Jinshan, China. Further expansions are planned to meet growing domestic demand and relieve pressure on its facility in Germany. Total global consumption of APGs is now estimated at around 140kmt (100% active).

Sugar feedstocks also provide the basis for a range of amino acid-based surfactants, such as disodium cocoyl glutamate. These anionic surfactants are used in cosmetic and personal care products where mild, natural, sulfate-free ingredients are increasingly valued by consumers. Ajinomoto, a major producer of amino acid-based surfactants, this year announced expansion of its Amisoft® glutamates capacity at a new plant in Brazil, to be commissioned in 2020.

Green surfactants offer an important, growing contribution to the industry – although the size of the contribution can vary depending on perceptions what is natural, bio-based, and sustainable. Furthermore, while many personal care and consumer goods companies have expressed interest in 100% bio-based surfactants, the market has not so far tested consumers’ willingness to pay premium prices for otherwise commodity products. This is due to lack of widespread availability of green commodity surfactants to date as much as any other consideration. It is clear that global demand for both petroleum- and bio-based surfactants will continue to grow with increasing hybridization of formulations to meet consumer, legislative, and sustainability demands – all while challenging manufacturers to balance cost-effective formulations with the ability to perform effectively.

LNG: The counter-cyclical build

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An extraordinary counter-cyclical build is under way in the world's liquefied natural gas (LNG) industry. Over the last year, a surplus has emerged and global spot prices for both gas and LNG have more than halved. Aside from the usual disclaimers about market uncertainties, the current market weakness is widely expected to continue in 2020 and possibly beyond.

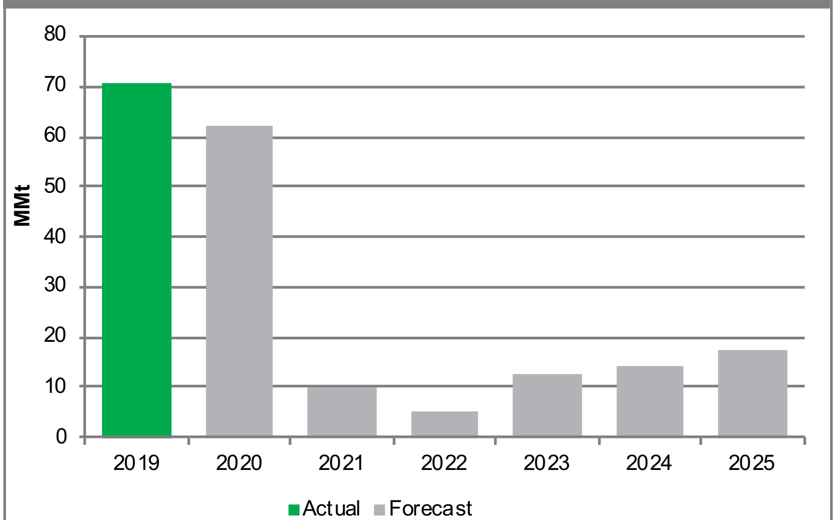
Yet producers are not deterred. On the contrary, they are showing a willingness, indeed a determination, to look beyond the present cycle and invest for the future in the belief that the long-term demand for their product is growing and robust. The year 2019 set a new high-water mark for the volume of global LNG capacity reaching final investment decision (FID). A further substantial tranche is expected in 2020.

For those who decry short-termism in business decisions, this should be welcomed. It is unusual and striking to see companies able to allocate big capital expenditure budgets at a time when current earnings are under pressure and there is a focus on capital discipline and returning money to shareholders. However, it takes approximately four to six years to build a new LNG train from the point of FID to the point of commercial start-up, so it is unquestionably correct that today's market environment is of little relevance for future projects and their returns.

Success will depend on the ability to read and ride the cycles—both the cost cycle during construction and the price cycle during operation. LNG is a high-capex business. Historically LNG has been able to avoid or moderate excessive price cycles because of a reliance on rigid long-term contracts. Investments in LNG were only made after demand was committed through a 15- or 20-year purchasing contract. Customer demand effectively rationed supply. This is changing as the industry commoditizes, companies make speculative investments, and short-term trading grows. Therefore LNG is likely to see many of the cyclical features of other high-capex businesses, such as refining, petrochemicals, and oil.

The question comes to the fore: Is the counter-cyclical build a wise strategic move to position for the future? Or is it simply setting up the next boom and bust?

Liquefaction FID forecast



Source: IHS Markit

Going contract-free

In early 2018, the LNG industry was at an investment impasse. IHS Markit put forward three pathways:

- Buyers returning to the long-term contract market
- An investment freeze
- Sellers moving forward without long-term contracts

In the last 12 months, the investment impasse has been broken dramatically. Buyers have partially returned. We have seen projects move forward with traditional long-term contract backing by buyers, most notably in Mozambique and the US (Calcasieu Pass LNG and Cheniere Energy). Perhaps more striking is that the three largest FIDs of the last year or so (LNG Canada, Golden Pass, and Arctic LNG 2) have been made largely in the absence of long-term contracts.

IHS Markit has revised our supply and demand outlooks – both upwards. However, based upon the investment boom of 2019 – which is forecast to continue in 2020 with impending Qatari expansion – we continue to anticipate supply outpacing demand.

Based on our expectations for FIDs until the end of 2020, our analysis suggests that no further FIDs would be required for the following three years in order for demand to catch up with supply. This halt to new project investment will not happen. The momentum and strategic drivers behind many of the world's LNG projects mean that there will be continued investment, although at a much slower pace *(see Figure 1)*

The Qatari bombshell

The risk of future oversupply increased in late November following a major announcement in Qatar. Qatar currently supplies about 77 metric tons (mt) of LNG, about 20% of global LNG. Qatar Petroleum (QP) announced that the country will increase—again—its LNG output target. In 2017, QP stated that it would raise capacity from 77mt to 100mt. The following year it raised that target to 110mt. In the November 2019 statement, the target was further raised to 126mt, an increase of 64% by 2027 over today. As the low-cost producer, the Qataris are apparently undeterred by risk of cycles and oversupply; indeed, they may see a strategic imperative to pre-empt and choke off higher-cost competitors. It is important to recall that a self-imposed moratorium on expansion by Qatar in 2005 was what partly enabled Australian and US LNG to become major players.

The headline announcement of an increase in LNG capacity investment was accompanied by a second far-reaching development. QP announced an effective doubling of their gas resources from just under 900 trillion cubic feet (Tcf) to 1,760 Tcf. It is important to emphasize that the degree of appraisal of these reserves is unclear, and it is not known to what extent they have been externally certified. They may not reach the standard of certainty to be classified as "proven reserves." Nevertheless, the reality is that Qatar is signaling a newfound confidence and desire to expand on a huge scale. The new target of 126mt may be just the first step in a new drive upward.

One consequence is that the cyclical global investment is happening in reverse – in the sense that the higher-cost projects have gone forward first, and the lower-cost projects (including the Russian Arctic) are piling in later.

Building demand

One possible positive scenario is that the producers will use the time that they have between project FID and project start-up to "build demand," by which we mean investments downstream including regasification, bunkering, and power generation. However, the experience to date of forward integration has produced limited and disappointing results, despite efforts by leading international oil companies. The large growth in LNG demand in recent years was a policy-driven demand shift in China, which led to exceptional buying from Chinese importers. This unexpected or exogenous factor was much more significant than the results of downstream investments by the industry across Southeast Asia, for example. On the assumption that demand cannot be firmed up more quickly, it appears that the industry could be set for a second cycle, with surplus capacity emerging around 2025.

This second cycle of surplus capacity will be different from the current one. In the first oversupply period of 2019-20, it is primarily the off-takers/buyers who are exposed. In the second cycle, increasingly it will be the producers who face any exposure. This shift in exposure should be seen as normal in the transition to a commoditized market.

How will the market balance?

As traditional long-term contracts play a less important role and as buyers assume less volume risk, the LNG market will need to find a new mechanism for balancing supply and demand.

With most commodities, storage plays a fundamental role in matching supply and demand. For LNG and gas more generally, storage post-liquefaction is in relatively short supply and at high cost.

In practice, the global LNG market is balancing seasonality in Europe, using European gas storage and coal-to-gas switching in the power sector. However, surplus LNG capacity will be difficult to place fully in the European market. IHS Markit continues to believe that during periods of trough demand, the highest cost or most flexible supply may be forced to ramp down. We have already seen several sell-side tenders cancelled because of low prices. A large proportion of this swing capacity is likely to be located in the United States, because of its ability to arbitrage sales between the large US gas market and the international LNG market. But other plants around the world may also have a swing role, such as the coal-seam gas projects in Eastern Australia and aging depreciated plants with declining upstream gas reserves such as those in Indonesia.

Therefore IHS Markit is expecting swing supply to become a new feature of the market. It is the logical outcome of the shift away from relatively rigid long-term contracts with high take-or-pay obligations to projects without any underlying long-term commitments. And cycles look set to be a structural feature of the industry.

This article is based on the strategic report, "Finding Balance: LNG in a World Beyond Contracts" by Michael Stoppard & Shankari Srinivasan, October 2019

Biojet for aviation – A growth story for the 2020s?

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Aviation has moved center stage in the climate change debate. A major challenge for the aviation industry is how to simultaneously meet the increased demand to move people and goods by air while also decarbonizing. In its study on the future of aviation, Reinventing the Aircraft, IHS Markit expects the demand for aviation to almost triple between 2018 and 2050. At the same time, the International Air Transport Association (IATA) has set an aspirational goal to halve CO_2 emissions generated by international aviation by 2050, compared with 2005 levels. Unlike other industries where there are multiple viable decarbonization pathways, the options in aviation are limited – not only by economics, but also by what is physically possible and can be certified as safe in time to be commercialized at scale before 2050. These challenges have resulted in a focus on sustainable aviation fuels (SAF) as the primary mechanism to ensure in-sector decarbonization[1] by the International Civil Aviation Organization (ICAO), the United Nations body that oversees international aviation.

Today the bulk of fuel demand in aviation is kerosene. International aviation demand is approximately 4 million barrels per day (b/d), with domestic aviation accounting for a further 3 million b/d. IHS Markit estimates that total CO_2 emissions from international aviation are approximately 600 million tons, close to 1.5 times the 2005 levels. SAFs have the potential to curb emissions from the sector due to their lower carbon intensity. There are essentially two main SAF options. One possibility is biojet fuel made from agricultural or waste feedstock using various production pathways. A second option is low-carbon intensity synthetic fuel, made from hydrogen. This fuel is produced via large-scale electrolysis, which is fed by renewable energy and carbon, captured either directly from the air or from a concentrated source such as a large industrial installation. Low-carbon intensity synthetic fuels have the largest potential to reduce CO_2 emissions from aviation due to their very low – potentially zero or even negative - carbon intensity. In fact, the IHS Markit study found that if the aviation sector is to achieve the aspirational goal of a 50% reduction in CO_2 emissions by 2050 versus 2005 levels via in-sector developments, low-carbon intensity synthetic fuels will have to account for a significant share of fuel demand in 2050. However, the key technologies required to develop these fuels at scale – large-scale electrolysis, direct air capture of carbon, and carbon capture and storage – are still either unproven at scale or prohibitively expensive. Although this is expected to change in time, these challenges mean that in the short to medium term, biojet will be the most viable SAF option.

Biojet can take several forms and can be categorized by both feedstock and production pathway. To date four

Figure 1: Sustainable Aviation Fuel (SAF) Standards

ASTM D7566 Annex	Abbreviation	Conversion process	Possible feedstocks	Blending ratio (volume)	ATSM Qualification
1	FT-SPK	Fischer-Tropsch hydroprocessed synthesized paraffinic kerosene (syngas to kerosene)	Coal, natural gas, biomass	50%	Sep-2009
2	HEFA-SPK	Synthesized paraffinic kerosene produced from hydroprocessed esters and fatty acids (lipids from plant and animal sources)	Vegetable oils and fats, animal fat (tallow), recycled oils (UCO), algae	50%	Jun-2011
3	HFS-SIP	Synthesized paraffinic kerosene produced from hydroprocessed fermented sugars	Biomass used for sugar production	10%	Jul-2014
4	FT-SPK/A	Synthesized kerosene with aromatics derived by alkylation of light aromatics from non-petroleum sources (syngas to kerosene and aromatics)	Coal, natural gas, biomass	50%	Nov-2015
5 / 6	ATJ-SPK	Alcohol-to-jet synthetic paraffinic kerosene (through dehydration of the alcohol to an olefinic gas, followed by oligomerization to obtain liquid olefins of a longer chain length, hydrogenation and fractionation)	Biomass used for starch and sugar production, cellulosic biomass for isobutanol production, ethanol. Category can be expanded to include any C2-C5 feedstock	30% isobutanol 50% ethanol	Apr-2016 for isobutanol Apr-2018 Ethanol

biojet pathways (leading to six sustainability certifications) have been approved by standards organization ASTM International[2] for blending with conventional jet fuel as outlined in the table.

IHS Markit estimates that the current demand for SAF is approximately 150 thousand tons per year, well less than 1% of total aviation fuel demand. Today, beyond the mandated levels in Norway and Sweden, uptake of SAF has been very limited. SAF demand under the US Renewable Fuel Standard (RFS) amounts to volumes contracted by United Airlines in California, while demand in the EU has so far been limited to volumes associated with marketing initiatives launched by certain airlines, such as KLM and SAS. The reasons for the limited uptake of SAF are threefold: SAF are more expensive than conventional alternatives, there is limited dedicated production capacity, and existing regulation incentivizes or mandates pushing biofuels into the road sector.

For SAF to take off, regulators need to create a framework that mandates their use and incentivizes production of biofuels for use in aviation. The ICAO previously tried and failed to implement a global SAF blending mandate. However, regulators at the regional, national, and local level are starting to develop policies to support the penetration of biojet. Aviation is included in the EU's Emission Trading Scheme (ETS) and SAF made from non-crop feedstock can also be used to meet the targets under the EU Renewable Energy Directive (RED I until 2020; RED II for 2020-2030). Norway and Sweden have also imposed SAF blending mandates to cut greenhouse gas (GHG) emissions from aviation. In the US, SAF can be used to meet the advanced biofuel targets under the Renewable Fuel Standard (RFS), a federal mandate for the road transport sector. In California, the Air Resources Board (CARB) has approved a pathway that allows the voluntary use of hydroprocessed esters and fatty acids (HEFA) under its Low Carbon Fuel Standard (LCFS). This cap-and-trade system targets a 7.5% decline in the carbon intensity of its transport fuel emissions from 2010 levels by 2020 (-20% by 2030). In Southeast Asia, governments and researchers are discussing the use of palm oil in aviation, although this remains a highly controversial pathway for many airlines and aircraft manufacturers.

Although directionally positive for SAF, most of these policies stop short of imposing the mandates that will be necessary to boost demand for SAF. Even if that were to happen, regulators would also need to consider that SAF supply has been limited. In fact, standalone SAF plants are hard to find. Part of the reason for this is that although large volumes of HEFA could be supplied by various hydrotreated vegetable oils (HVO) plants[3], legislation currently incentivizes the use of these biofuels in the road transport market. They also compete there with fatty acid methyl esters (FAME) and other liquid biofuels. Worldwide, more than 5 million tons per year of HVO production capacity is available. Part of that could switch to SAF, but only if regulation is supportive.

Despite the headwinds, the number of standalone projects with industrial-scale SAF production has grown in recent months. IHS Markit identifies two projects in the EU: the Altalto project in the United Kingdom, which is due to produce SAF from 500,000 tons of solid waste per year and is backed by Velocys, British Airways, and Royal Dutch Shell); and the Delfzijl project in the Netherlands, which has a planned output of 100,000 tons per year and is run by a consortium consisting of SkyNRG, the Amsterdam Airport, and KLM. In the US, fuel ethanol and isobutanol supplier Gevo is targeting industrial-scale alcohol-to-jet (ATJ) production, and BP and Fulcrum BioEnergy are building a waste-based SAF plant in Nevada.

Theoretically, global SAF production could be significantly higher than today's 150,000 tons per year. However, legislation will also have to secure feedstock. This mainly relates to the waste feedstock category in the EU and partly also to the US. In terms of tonnage, IHS Markit estimates that more than 10 million tons of biodiesel were produced from waste feedstock worldwide in 2018. Of this, almost 4 million tons were made from used cooking oil (UCO). Increases are expected, especially in the EU, where the RED II asks for higher renewable energy shares with caps for crop-based products.

The bottom line: despite biofuel-derived SAF currently being the sole viable route to in-sector decarbonization of the aviation sector, regulation does not currently support either the production or use of biojet in the aviation sector. As a result, a quick build-up of SAF plants cannot be expected. If the road sector electrifies faster than expected, some biofuel currently being blended into road fuels could be rediverted to the aviation sector. However, at the moment, this is more a faint opportunity than a credible growth story. In the longer term, if biojet and SAF more generally are to gain a significant share of the market, usage mandates will be required.

1-The ICAO is also proposing a market-based mechanism, the Carbon Offsetting and Reduction Scheme (CORSIA) as a means to offset emissions from international aviation outside of the sector.
2-ASTM D7566 Annexes 1-6
3-The often-used term HVO is misleading as these plants also process other feedstock like animal fat, UCO, etc.


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