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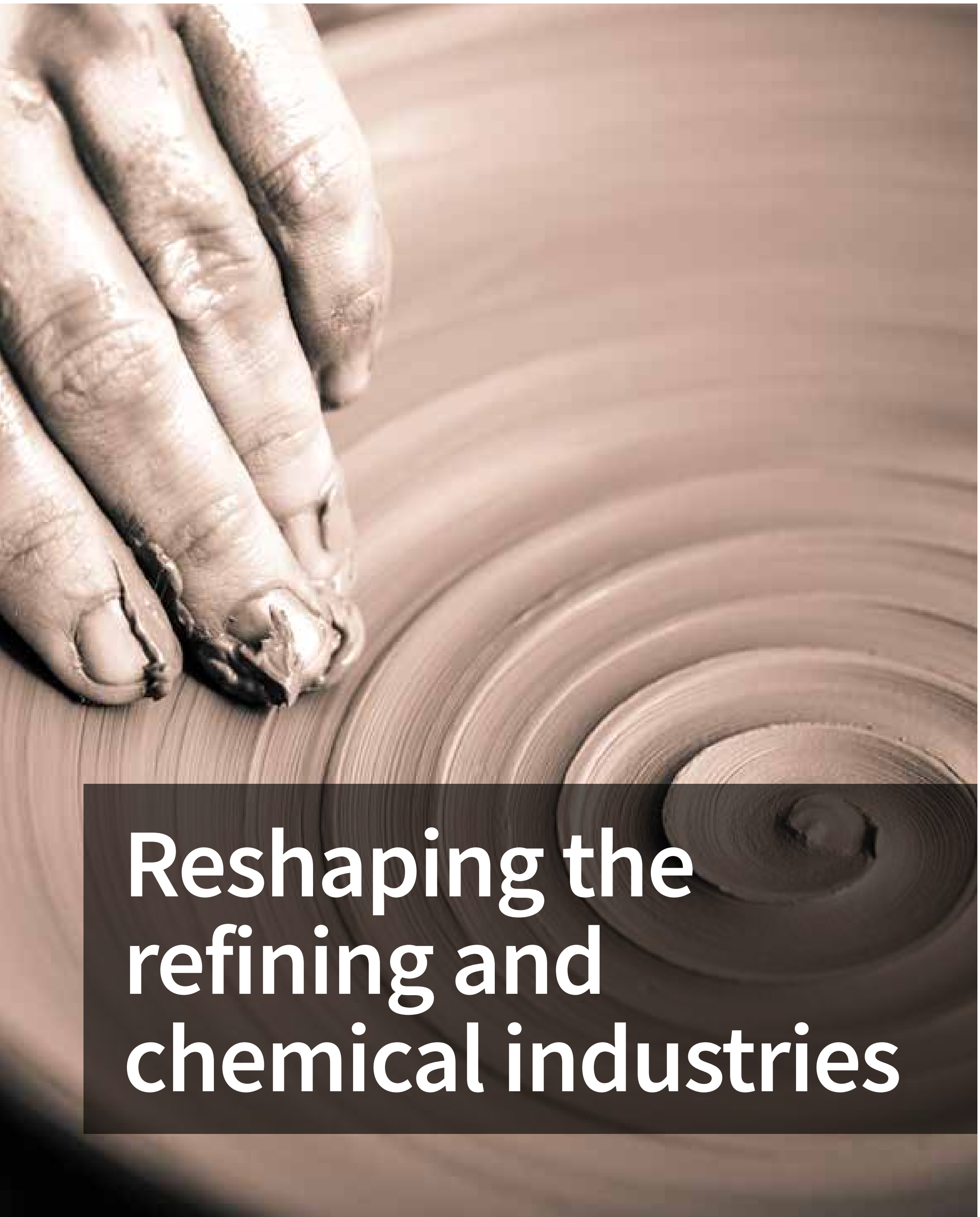

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Global chemical industry outlook: Assessing today's strong markets and preparing for the 2020s

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The year 2018 represents the sixth year of an extended upcycle in global chemical markets – characterized by robust demand, tight supply, and strong profitability. This extended period of profitability has caused a surge in reinvestment planning activity in North America, the Middle East, China and other Asia locations. Even in Europe, thought to be disadvantaged- companies are pursuing investments in new capacity.

The forecast for new petrochemical investments integrated with refining could result in capacity additions that overwhelm trend line demand growth in many markets. At the same time, many risks are developing that represent potential drags on global growth. Key issues include rising crude oil prices, domestic fiscal policy and currency fluctuations, geopolitical tensions, and a variety of trade disputes. Slowing economic growth in the early 2020s represents a threat to strong chemical market conditions. As the industry rides a wave of high profits, IHSM is tracking the emergence of several trends that will reshape refining and chemicals industries during the 2020s:

- **Mobility trends and refinery/petrochemical integration:** A forecasted decline in the rate of growth for transportation fuels is causing many refining companies to re-think their petrochemical strategy, seeking a higher conversion of crude oil into chemical products.
- **Plastics recycling and waste**: these are perhaps the most critical issues that will influence the industry during the 2020s. Globally, communities are exploring bans on single-use plastic applications, while the visual of plastics waste in the oceans is now an international media issue. A slowdown in demand growth for commodity plastics resulting from increased recycling and application bans, must now be considered in long-term forecasting.
- **Evolution of the Chinese chemical industry:** The solidification of China as a global force in chemicals continues, as many changes are occurring in China's domestic market. Key areas to watch include: economic transition, environmental protection, fuel standards, private ownership, self-sufficiency goals, conventional/non-conventional technology, capital cost advantage, an advancing specialty chemical sector, and international trade ambitions.
- **Heavy-versus-light feedstock competitive environment:** Crude-to-chemicals technology is emerging in all regions while investments in gas-based chemicals in North America continue. Regional competitiveness will be significantly influenced by the price of crude oil. Ethane is no longer a "trapped" feedstock in North America, as companies have invested in the infrastructure to bring this low-cost feedstock to the international market.

During the decade of the 2020s, investors in the chemical industry will seek to balance the "petrochemical trilemma,": economic benefits of investment in the chemical value-chain, a sustainable approach to the consumption of natural resources, and offering sound environmental stewardship that is responsive to societal demands for a healthy and clean environment.

The images of smog-filled air and beaches filled with plastics trash are moving local communities and political leaders to take actions that are not always the best solution to the problems at hand. The chemical industry must continue to proactively engage on all fronts – seeking cooperative, fact-based solutions to these challenges and working side-by-side with local communities and government.

IHS Markit can support your need to understand how your business can thrive in the 2020's. Reach out to the experts in this issue to start the conversation.

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Crude oil-to-chemicals projects presage a new era in global petrochemical industry

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Several crude oil-to-chemical (COTC) projects being planned or started in Asia and Saudi Arabia threaten to reshape the global petrochemical industry in the coming years. COTCs configure a refinery to produce maximum chemicals instead of traditional transportation fuels. Since refinery processing capacity is approximately 10 times higher than the current world-scale petrochemical plants, COTC in effect raises petrochemical production to an unprecedented refinery scale.

COTCs also produce at least twice as much chemical volume per barrel of oil as a state-of-art, well-integrated, refinery-petrochemical complex. Under the current industry structure, a refinery provides naphtha to a petrochemical plant, where steam cracking operations produce chemicals. The current global average is to produce about 8% to 10% naphtha from each barrel of oil. At a very well-integrated plant such as Petro Rabigh, a joint venture between Saudi Aramco and Sumitomo, the refinery produces about 17% naphtha for petrochemical production. Yet every announced COTC produces at least 40% of chemicals per barrel of oil, a quantum leap from any state-of-art integrated complex.

Four Asian COTCs – including three in China and one in Brunei – are configured to produce maximum volumes of para-xylene (PX). In China, Hengli Petrochemical is constructing a refinery-PX complex that can process 20 million tons per year (equal to 400,000 barrels per day) of medium and heavy crudes. From these raw materials, the complex can produce 4.3 million tons of PX plus benzene and other chemicals. The conversion is estimated at 42% of all chemicals per barrel of oil. Construction is progressing well, and Hengli obtained a crude oil import quota from the Chinese government. The first oil shipment from Saudi Arabia is expected in July 2018, with a trial run planned for October 2018, and production of PX beginning in the second half of 2019. Figure 1 depicts the configuration of Hengli's refinery-PX complex.

Zhejiang Petroleum and Chemical, a $26 billion joint venture among Rongsheng, Tongkun Group, and Juhua Group, plans to convert 40 million tons of crude to about 8 million tons of PX per year in two phases. Each phase will offer approximately the same capacity. The first phase, which will produce 4 million tons of PX plus other chemicals, is expected to come online later in 2019. The conversion is estimated at 40% of all chemicals per barrel of oil. Shenghong Petrochemical plans to build a refinery-PX complex starting with 16 million tons of crude oil to produce 2. 8 million tons of PX and other chemicals annually. The project obtained environmental approval but construction has not started yet. In Brunei, Chinese company Hengyi Group is constructing a nearly $20 billion refinery-PX plant that will convert 8 million tons of crude oil and condensates, producing 2. 8 million tons of PX and other products per year. Operations should begin in 2020, and the manufactured PX volumes are expected to export back to China.

COTC projects in Asia are driven by the major producers of polyethylene terephthalate (PET) and purified terephthalic acid (PTA) in China -- including Hengli, Rongsheng, Rongkun, Juhua, and Henyi. These companies are expected to back-integrate their PET and PTA projects to PX for their captive use. In China, 2017 PX demand was 23 million tons, but its capacity was only 12 million tons. The 11 million ton per year supply gap is filled by imports, mainly from Korea, Japan, and Taiwan. When the first wave of these COTCs begin operating, they will add 11.8 million tons of new PX capacity, which will largely close China's supply gap by 2020 and limit market access for current exporters.

COTC Projects in Saudi Arabia

In Saudi Arabia, Aramco and SABIC formed a joint venture to develop a COTC complex in Yanbu, which should be complete by 2025. The complex plans to convert 20 million tons per year of light crude to produce 9 million tons of petrochemicals, which equals a 45% conversion to chemicals per barrel of oil. Aramco/SABIC also entered into front-end engineering and design (FEED) and technology selection contracts.

Furthermore, Aramco has signed a joint technology development agreement with Chevron Lummus Global (CLG) and CB&I (now McDermott) to integrate CB&I's ethylene cracker technology, CLG's hydroprocessing technologies, and Saudi Aramco's Thermal Crude to Chemicals (TC2C™) technologies with a target of converting 70–80% per barrel of oil to chemicals. If a COTC complex is built based on this future technology starting from 20 million tons of crude oil, it would produce 14–16 million tons of chemicals per year, taking a large share of the annual growth in chemical demand.

To put it in another perspective, a COTC project based on Aramco's optimized technology would produce more chemicals than all eight first-wave ethane-based steam crackers in the United States, which have a combined production capacity of 11 million tons of ethylene per year.

Aramco's COTC projects are driven by the company's goal to better monetize its oil assets. In the next decade or two, global demand for chemicals -- driven by the population growth – is projected to increase more than 4%. That rate is higher than global GDP growth rate of about 3% per year. Demand for transportation fuels, on the other hand, is expected to grow only slightly more than 1% per year during the same period. This growth will be hampered by better fuel efficiency and the substitution of non-fossil fuel vehicles. While oil prices remain at relatively low levels, Aramco has a strong incentive to start COTC projects that will help the company push deeper into chemicals, which provide higher value and demand growth than transportation fuels.

Competitive Factors in the New Market

Having advantaged feedstock has been the most important competitive factor in the past one to two decades, but in the new era feedstock alone won't be enough to compete. COTC redefines global scale at the refinery level. The sheer scale will be an additional competitive factor, and COTC producers will realize advantage over current "world-scale" petrochemical producers.

Due to high investment costs, capital efficiency will also become a critical competitive factor. Hengli and Aramco/SABIC both start from 20 million tons of crude oil, a similar scale; however, the announced investment cost is $11.6 billion for Hengli versus $20 billion for the Aramco/SABIC joint venture. Due to the large amount of chemicals produced, having accessible markets will become a major consideration. In these aspects, COTCs in Saudi Arabia will benefit from advantaged feedstock in terms of price and choices of crude including using condensates, while China seems to have the advantages of better capital efficiency and access to growing domestic markets.

Technology is yet another competitive factor. Because COTCs are more complex to operate, choosing the best process configuration and technologies will ensure operability and productivity. This will favor the technology licensors that can provide the best integrated technologies to convert heavier crude assays and produce maximum chemicals with the fewest utilities and the least hydrogen consumption.

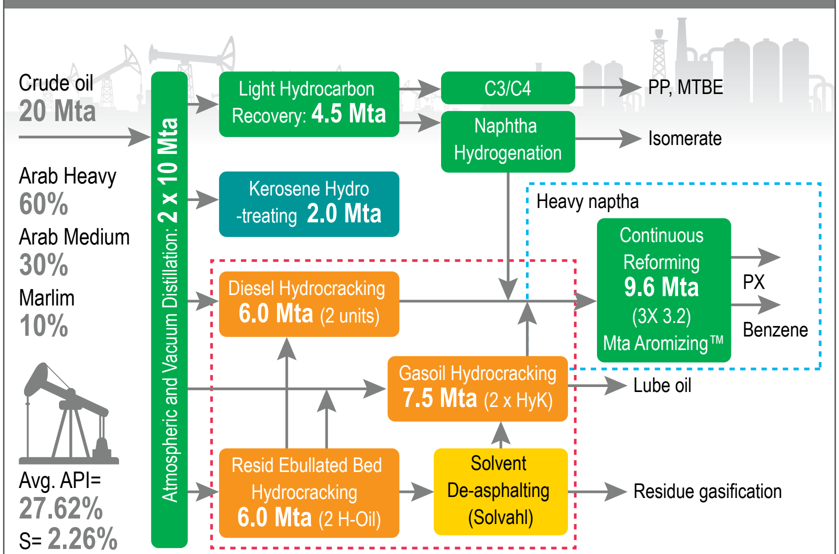
The future of COTCs will be mainly determined by their production economics relative to naphtha steam cracking. While Aramco's COTC process configuration is still unknown, IHS Markit Process Economics Program developed a conceptual design based on Aramco's COTC patents and compared its production economics to naphtha steam cracking under high oil and low oil price scenarios. The analysis showed that in the high oil scenario ($118/bbl) as in 2013, Aramco's COTC (based on PEP's conceptual design) would offer 61% lower cash cost and about 24% higher ROI (return on investment) before taxes. In the low oil ($50/bbl) scenario as in 2015, Aramco's COTC would have 33.7% lower cash cost and 1.7% higher ROI before taxes. Production economics of Hengli's refinery-PX complex are being investigated, and the estimates will be available in Q4 2018.

Final Considerations

Two other major trends that will help define the new era are big oils pushing deeper into chemicals by investing in large, state-of-art, well-integrated refinery-petrochemical complexes and the proliferation of ethane as feedstock outside of North America and the Middle East.

Aramco is not only investing in COTC projects; it also recently announced a joint venture with a consortium of three Indian oil companies. The goal: building a giant refinery-petrochemical complex to process 60 million tons of crude oils, which will produce 9 million tons of chemicals per year. The announced investment is $46 billion. Aramco is not alone in this push. Abu Dhabi National Oil Company (ADNOC) just announced plans to invest $45 billion to build a major complex in Abu Dhabi, hoping to become a leading petrochemical player. Meanwhile, China National Offshore Oil Corporation (CNOOC),

Figure 1. Configuration of Hengli Refinery-PX Complex



Note: Mta=million tons per year. Key technologies supplied by Axens.
Source: IHS Markit

China Petroleum & Chemical Corporation, (Sinopec), and PetroChina continue to expand their petrochemical production in China. Big oils are becoming big chemicals.

Exports from the US will help ethane proliferate in Europe, India, and China. With the freight and termination feed added, the delivered ethane price will be roughly doubled when it arrives in China, compared to the price in the US. US producers will enjoy a continued advantage when compared at cash cost basis. But due to its capital efficiency advantage, China might be quite competitive in terms of return on investment. Exporting ethane may also drive up its price in the US. What's more, Russians are coming. Russian gas processing and petrochemicals company Sibur is planning the Amur gas chemical complex (GCC) project in the Far East, which will produce 1.5 million tons per year of PE from ethane, to be supplied by Gazprom. US companies working on the second wave of ethane crackers need to minimize construction costs while maintaining low ethane prices to sustain its competitive advantage.

Figure 2 shows the global refinery-petrochemical snapshot in the new era.

Interest in understanding COTC complexes is rising quickly as new facilities come online. COTCs are live now in China and will soon be followed by facilities in Saudi Arabia. Due to the huge scale and volume of chemicals each COTC can produce, COTC ushers in a new era characterized by unprecedented production scale and a few dominant players. The impacts of this change are imminent and will be profound, including a major shift in the landscape of global competition.

Having advantaged feedstock alone will not be enough in the new era. Competitive advantage will expand to a newly elevated scale that values accessible markets, capital efficiency, and technology optimization for converting maximum volumes of crude into chemicals.

Webinar to watch: Crude Oil To Chemicals

- Evaluate opportunities to configure your complex refineries into crude-oil-to-chemicals plants.
- Learn what plant configurations and technologies are required for achieving maximum chemical production.

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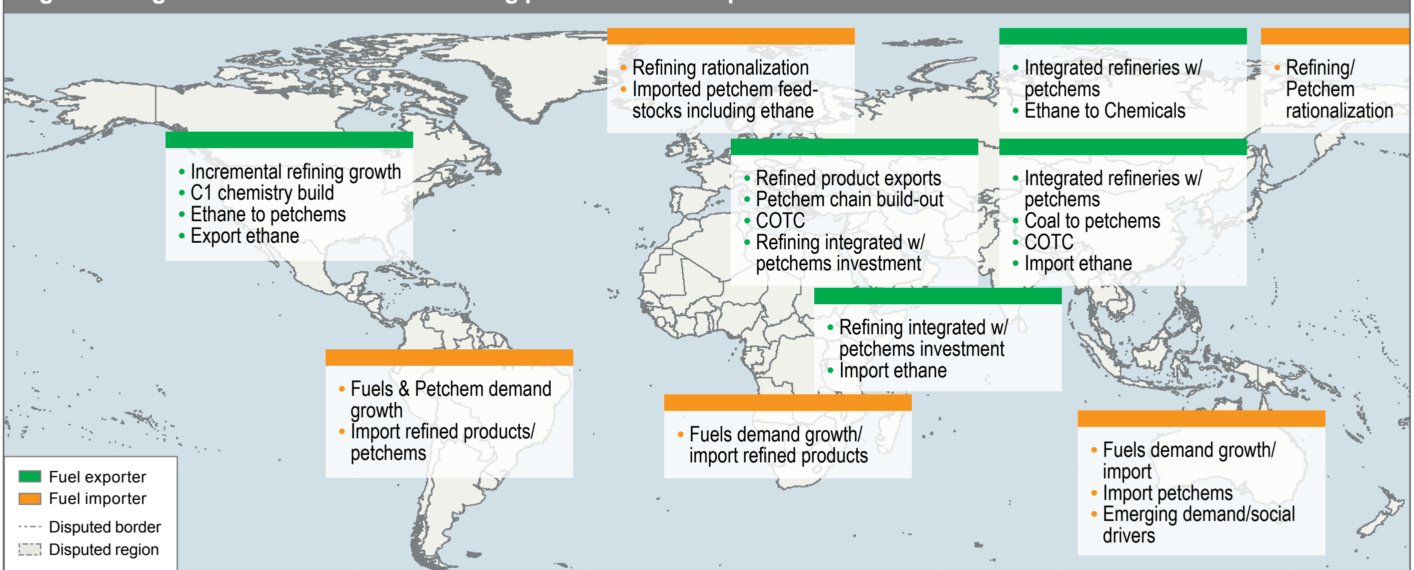
Figure 2: Regional initiatives – Global refining petrochemical snapshot in the new era



Source: IHS Markit

Crude quality and trade

How growing US crude exports are changing global balances

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The lifting of the US crude oil export ban in late 2015 has resulted in a growing role for US exporters in global markets. The light crudes, condensates, and natural gas liquids (NGLs) produced with unconventional development techniques have saturated US markets, but they are well-suited for growing markets in Asia and elsewhere. At the same time, imports of heavy sour crudes into the US have remained steady, with growing Canadian Oil Sands production finding a ready home. This US "quality arbitrage" – exporting light sweet crudes while importing heavy sour crudes – creates a new dynamic in global crude markets, with implications for both refining and petrochemical operations.

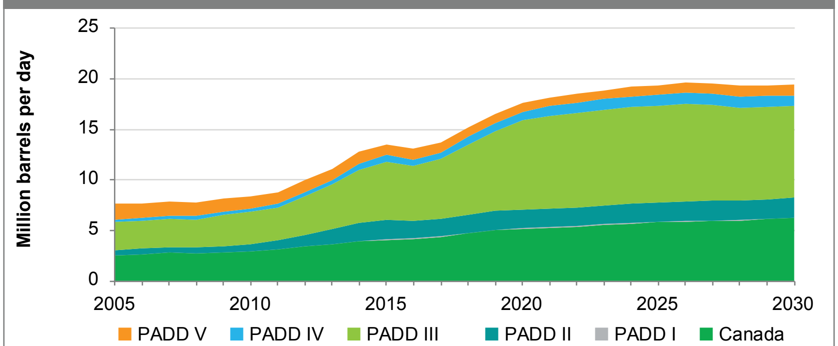
US unconventional crude production economics are strong, and growth will continue

The oil price decline that began in late 2014 was due in part to the rapid expansion of US unconventional production. In response to sustained $100+ per barrel crude oil prices and technological innovation, US producers had unlocked the secrets of shale oil (see Figure 1). The shale revolution raised production from 5.6 to 8.8 million barrels per day (b/d) over four years. However, the 2014 price collapse was widely viewed as the beginning of the end for US unconventionals.

The rig count dropped and production slumped from its April 2015 peak of 9.6 million b/d to 8.6 million b/d in September 2016. Austerity forced producers and service providers to sharply reduce costs, with breakeven prices in key basins falling from the $70-80 per barrel range in early 2014 to $30-40 by the end of 2017. As costs fell, unconventionals became economic at prices in the $45-55 range, and production responded. US crude production grew to 10.5 million b/d by March 2018, with recent weekly estimates approaching 11 million b/d. Industry concerns are now focused on the capability to transport growing production from the Permian and elsewhere.

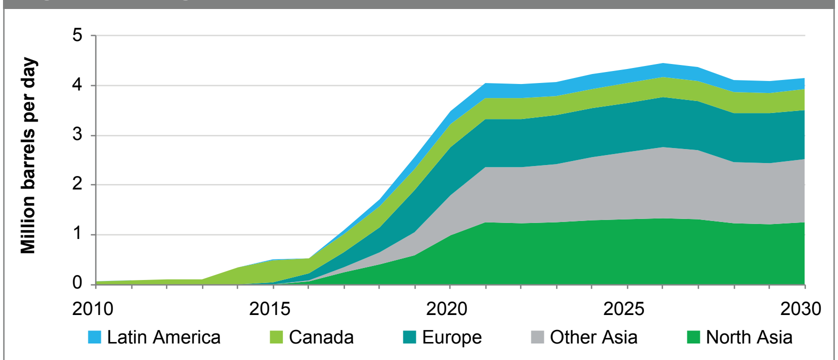
The quality of unconventional production has remained very light and very sweet, but the bulk of new production falls into the "light crude" category, with gravity in the range of 32-50° American Petroleum Institute gravity (API). While each basin has its own profile, light condensate (at 58+° API) and heavy condensate (at 50-58°API) account for only about 15% of wellhead production in the key unconventional plays. However, since much of the produced condensate is blended with other light crude streams for logistic and commercial reasons or moved to Canada for diluent use, the volume of segregated condensate available for overseas export is much lower than wellhead production.

Figure 1. North American crude and condensate supply by petroleum administration for defense districts (PADD) region



Source: IHS Markit Crude Oil Markets Supply Supplement

Figure 2. US light sweet crude and condensate exports



Source: IHS Markit Crude Oil Markets Supply Supplement

US light crude refining is near its limits, but light crude exports will grow with production

US refiners have continually adapted their crude slates to changing crude availabilities. Sweet crude runs fell steadily through the mid-2000s, while heavy runs ramped up as Mexico and Venezuela placed their growing production with US refiners. Heavy runs shifted toward Canada as Latin American availability faltered, keeping overall heavy crude runs roughly flat. As the unconventionals revolution spread, US refiners increased total runs and light crude runs in response to steep discounts for US production, and offshore imports fell to less than 30% of runs.

Crude exports were allowed in phases, but all restrictions were removed at the beginning of 2015. US crude and condensate exports averaged 1.1 million b/d in 2017 and 1.5 million b/d in the first quarter of 2018. With the rest of the world welcoming US light crudes, exports are now moving to Canada, North Asia, South Asia, Europe, and South America (see Figure 2). China and India are becoming large importers of US crude, and the US will be one of the top five global crude exporters.

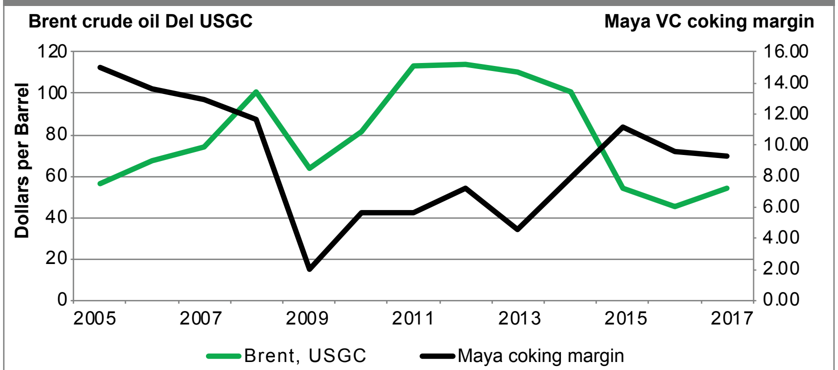
US refiners will see strong coking economics, supporting crude imports and product exports

From 2005 to 2015, global crude oil prices moved through a complete cycle, from the $40 range to well over $100 in 2011-2014, and then back down into the $40s.The cycle was interrupted only by the 2008-2009 financial crisis. However, refining profitability followed a more volatile and countercyclical path. From 2005 to 2008, the industry enjoyed a “golden age” of high margins and wide light-heavy spreads. The financial crisis initiated a steep decline, and margins improved only slowly through 2014, when the price collapse helped to trigger much stronger profitability in 2015-2017. Figure 3 compares the international crude oil price to refining margins for Maya crude oil on the US Gulf Coast.

Margins for processing US domestic sweet crude oils followed a very different path. As shown in Figure 4, the variable cost margin for processing Light Louisiana Sweet (LLS) crude oil in cracking mode was far lower than Maya coking in 2005-2010; the margin then accelerated in 2011 and exceeded Maya margins through 2014. The lifting of the US export ban in 2015 resulted in higher prices for US crudes. As LLS prices moved toward export parity, margins declined to levels well below Maya coking; however, these margins were still quite strong relative to imported sweet crudes. The extraordinary profitability for domestic sweet crude processing created by the export ban is now gone, but US refiners still enjoy higher margins than European and Asian competitors, due in part to significantly lower energy costs.

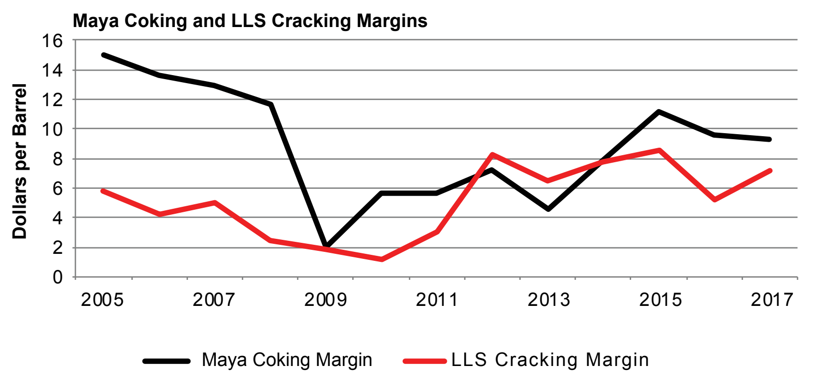
The combination of high complexity, low energy costs, and heavy crude supply from Canada and Latin America will maintain a strong position for US refiners. As a result, imports of heavy sour crudes will continue to flow into the US Gulf Coast. Global markets for light sweet crudes will sustain US export, causing those crudes to continue flowing out. Asian consumers will be the major source of export growth, as US light crudes will fit well into Asian refinery crude slates. However, the relatively small contribution of heavy and light condensates to US unconventional production may disappoint some potential buyers, particularly petrochemical producers in North Asia. For those consumers, a strategy of naphtha exports combined with selective light crude purchases may be the best approach to meet their feedstock needs.

Figure 3. US Gulf Coast crude price versus variable cost margin



Source: IHS Markit. © 2018 IHS Markit

Figure 4. US Gulf Coast variable cost margins



Source: IHS Markit. © 2018 IHS Markit

The US is now a key global exporter

Through its exports of crude oil, refined products, and NGLs, the US is now a large and growing presence in world energy supply. US unconventional production economics are strong, and they will drive growth in crude oil, gas, and NGL supply. Strong US refining margins will support growth in crude runs and refined product exports. The US resource abundance and cost advantages will drive petrochemicals production as well as refining, helping cement the US position as a key global supplier of feedstocks, refined fuels, and petrochemicals.

Venezuela production decline threatens to starve heavy refiners, but importing countries are turning to other suppliers

Refiners stung by declining Venezuelan exports

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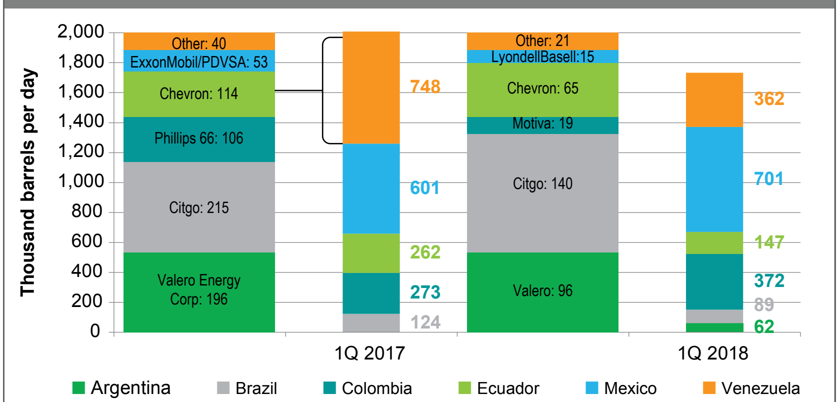
Venezuelan production has faced an unprecedented decline in recent months, June 2018 production is estimated at only 1.1 million barrels per day (MMb/d), which is a 280,000 barrel per day (b/d) or20% drop from the previous month and a yearly decline of 920,000 b/d (46%). The sanctions put in place by the Trump administration directly preceded the decline in production; however, they were simply the straw that broke the camel's back. The seeds of decline were sown in decades of heavy-handed political intrusion into the operations of Petróleos de Venezuela, S.A. (PDVSA), the Venezuelan state-owned oil and natural gas company. This interference beganwith the socialist leader Hugo Chavez, whose policies have continued and intensified under the rule of his protégé, current Venezuelan president Nicolás Maduro.

The decline in Venezuelan production clearly affected the crude slate of US Gulf Coast refiners in first quarter 2018. Several major refiners, built to process heavy crudes, have either reduced imports of Venezuelan crude or stopped imports all together. Refiners in China, India, and the United States have replaced the Venezuelan imports with a mixture of different crude types. In cases where they continue to accept Venezuelan crude, many refiners are requesting discounts to compensate for deteriorating crude quality, including unacceptable water and metal content, which is likely linked to operational problems at Venezuela's heavy oil upgraders.

Figure 1: First quarter 2017 versus first quarter 2018 Latin American exports to United States



Source: IHS Markit, Tariff Information System via Internet (SIAVI)

Phillips 66's Sweeny refinery imported an average of 123,000 b/d of Venezuelan crude from 2012 through 2017, yet imported no Venezuelan crude in first quarter 2018 (see Figure 1). Instead, the refiner took to increasing Canadian imports, predominately heavy and light synthetic crude oil, and supplemented with Mexican Maya and Colombian Castilla. Similarly, the PBF Energy refinery in Chalmette, Louisiana, United States, began continuously importing Colombian Castilla in August 2017 and imported Mexican Maya every month during first quarter 2018. Citgo's US refineries in Corpus Christi, Texasand Lake Charles, Louisiana, have employed different tactics. Their Venezuelan crude imports remained flat, due to the refineries' physical proximity to PDVSA. However, both refineries took in 11 shipments below 40,000 b/d of various crudes, including Chad's Doba, Colombian Castilla, and Brazilian Marlim.

The Mexican and Colombian energy sectors are in a strong position to take advantage of the decline in Venezuelan crude. Mexican crude exports have remained relatively high, even while production continues to decrease because of the declining domestic refinery utilization rates, which has been below 40% since July 2017. Mexico exported 1.5 MMb/d of crude in February 2018, the largest volume since at least 2012, and shipped 833,000 b/d of that volume to the United States (the largest volume since November 2014). Colombia, which has been struggling with low crude prices since 2014, has also begun to increase exports in the recent higher-priced environment. Exports to the United States averaged 372,000 b/d in the first quarter 2018, compared with 273,000 b/d in first quarter 2017. The 2017 volume wasthe lowest export level to the United States since the general strike in January 2003.

China's crude imports also reflect the shift away from Venezuelan products. Venezuelan imports decreased by 10%, or 390,000 b/d, during first quarter 2018. China normally uses this sour crude for asphalt production. China has recently increased imports from medium, sour Kuwait Blend from Kuwait and medium, sweet Libra from Brazil (see Figure 2). In fact, Kuwait recently outranked Venezuela as the ninth-largest exporter to China. In the past five years, China's crude imports have been slightly lighter, as US unconventional production and Brazil's pre-salt production increased and as China has boosted imports of African light, sweet barrels. From now until 2040, Chinese and US imported crude are expected to contain more bottoms and higher sulfur content.

India's imports from Venezuela have slipped from third to fifth place since 2017. Estimated delivered imports for July are approximately 240,000 b/d, or almost 50% lower than August 2017. Iran will be another unstable source of heavy crude to India in the next few years. The country's refiners will have to rely on their largest heavy importer, Iraq. India has increased crude consumption of Middle Eastern sour crudes, which will continue to displace Latin sours over time.

Coker capacity runs tight

Global heavy, sour crude (HSR) production – which involves -crude streams with quality properties of less than 24° American Petroleum Institute gravity (API) and sulfur content greater than 1%- was slightly more than 9.0 MMb/d in 2017 and should grow to 12.7 MMb/d by 2040. Major HSR producing regions are Canada, Latin America, and the Middle East. IHS Markit expects Latin HSR crude supply to decline as upstream resources deplete and Venezuela's economic crisis continues to unfold

The world's heavy sour crude production contains roughly 3 MMb/d of vacuum bottoms, most of which is consumed in the world's 7.8 MMb/d of coking capacity, about 75% of which is located in North America and Asia (see Figure 3). Vacuum bottoms from medium and light sour barrels fill the remaining capacity. Venezuelan production declines to zero in 2019 and thereafter, IHS Markit estimates that ~400,000 b/d of vacuum bottoms – equal to about 5% of global coking capacity - would be removed from the market. This would result in a significant shortfall of feedstock for coking operations and likely cause a notable reduction in light-heavy price differentials compared to the IHS base forecast.

Sour price differentials

Western Canadian Select ([WCS], which includes crude streams with quality properties of 22.2°API and 3.95% sulfur, competes with other Latin heavy, sour crudes such as Mexican Maya (21.5° API, 3.40% sulfur), Venezuelan Merey (18.0° API, 2.30% sulfur), and Colombian Castilla (18.8° API, 2.00% sulfur). WCSLatin HSR differentials narrowed from $30/bbl in 2012 to $9/bbl in 2017 due to recent pipeline expansions in the United States. As a result of regulatory delays, both the Kinder Morgan's Trans Mountain pipeline expansion and TransCanada's Keystone XL pipeline are now expected to start up in 2021.Considering these conditions, we expect marginal barrels of heavy supply to clear through the US Gulf Coast in 2021 and beyond. IHS Markit expects the WCS–Latin HSR differentials to narrow by approximately $6/bbl after both pipelines start up. WCS imports will continue to displace Latin HSR imports as more Latin HSR barrels shift to Asia.

Figure 2: Imports of crude to China in first quarter 2017 versus first quarter 2018

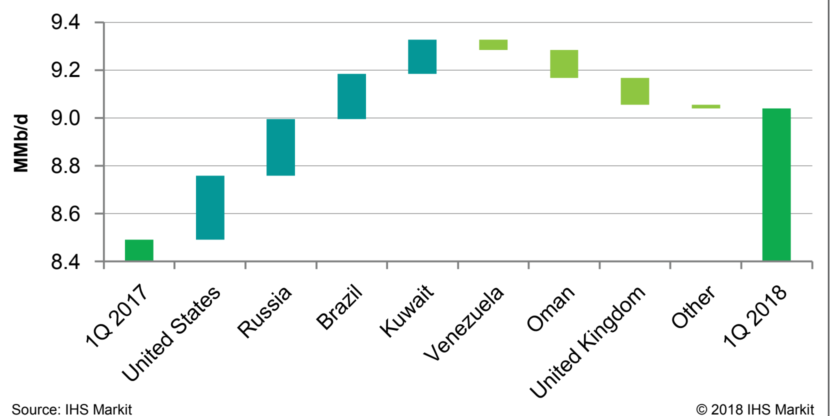


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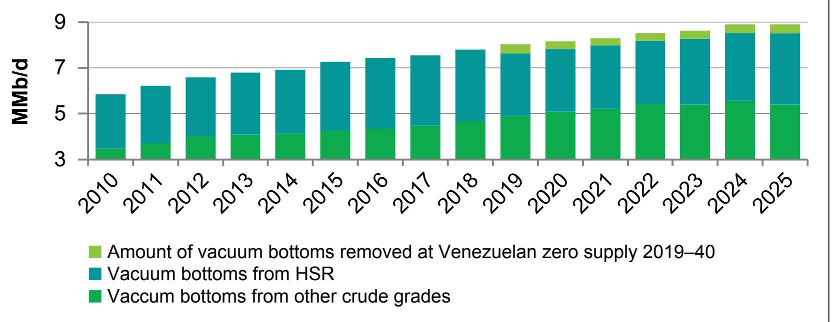
Figure 3: Global vacuum bottoms supply



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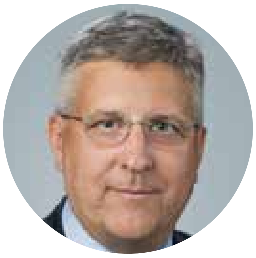
The next wave of regional ethylene capacity additions



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Do we anticipate another regional wave of ethylene production capacity additions like those we have seen historically in the Middle East, Asia, and currently in North America? The base case view for the coming three to five years is that global ethylene demand growth will remain strong. This case is based on a few key drivers:

- General health of the global economy
- Short-term shifts in China's recycled plastic processing
- Environmental policy enforcement in China, which is shutting down some of their high CO_2-emitting plants
- Move from the lower class to the middle class in a large chunk of the global population, especially in developing regions around the world

Our expectation is demand growth in the range of 6.5 million metric tons per year (see Figure 1). To meet this demand, we need 7.0 million tons per year of capacity additions when we take into account sustainable operating rates near 90%.

This capacity growth must be covered by new ethylene production assets, as the base load system during 2016/17 was barely sufficient to keep pace with demand. In short, we cannot depend on existing spare capacity to cover some of the shortfall. Rather, we need new builds to address growth and maybe more capacity to offer some buffer. If this build were ethane-fed crackers alone, at 1.5 million tons per year of capacity for a world scale unit, we would need five new units each year. If the build were only naphtha-fed crackers, the build requirement is more likely to be seven new units per year.

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Criteria for Capacity Investment

Where will this capacity be built? Four key drivers help determine this outcome:

- Nearby stranded feedstock, offering low-cost production
- Proximity to a high-demand region, supporting the offtake
- Regions with advantaged cost of construction
- Locations that offer a legal, political, and social framework to support a long-term investment

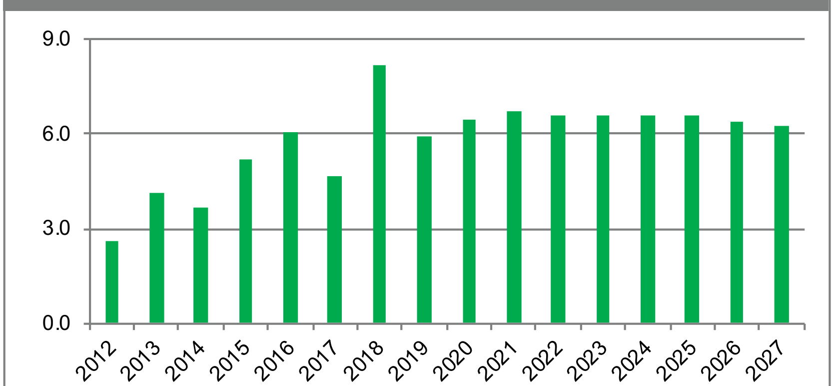
The least risky projects would have all of these key parameters in their favor, but having two or three of the four could be sufficient to drive the investment decision. The current forward view, taking into account these four key variables, is an expected "wave" of capacity coming to China. In fact, nearly a third of all new assets are expected to be built there over the next 10 years (see Figure 2).

Why is China a likely site for capacity investment? Let's consider how it performs against these four criteria.

Ranking China as an Investment Location

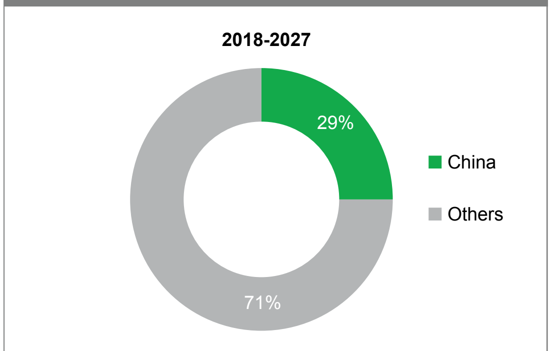
As a major energy importer, China falls short on the first key driver: feedstock advantage. China does

Figure 1: Global Ethylene Annual Demand Growth



Source: IHS Markit

Figure 2: Likely locations for developing additional ethylene capacity



Source: IHS Markit.

have a large reserve of coal, but the processes required to convert this to chemicals need b oth high oil prices and improved environmental footprint technologies to make coal viable.

From a demand standpoint, China is a very large importer of ethylene and ethylene derivatives. In 2017 alone, China imported two million tons of ethylene monomer, 13 million tons of polyethylene, three million tons of styrene, and eight million tons of monoethylene glycol. Although China has added capacity over the last decade and growth will continue in the future, ethylene self-sufficiency remains low – in the range of 50% to 60%. China continues to grow in internal demand; to meet global supply needs, however, it will need to add low-cost labor to upgrade ethylene derivatives to finished goods.

From a legal, political, and social perspective, China continues to progress. New investment for chemicals is coming more from the private sector than state-owned entities. Confidence is improving, thanks to a more open market with a very large labor pool looking for employment in petrochemicals.

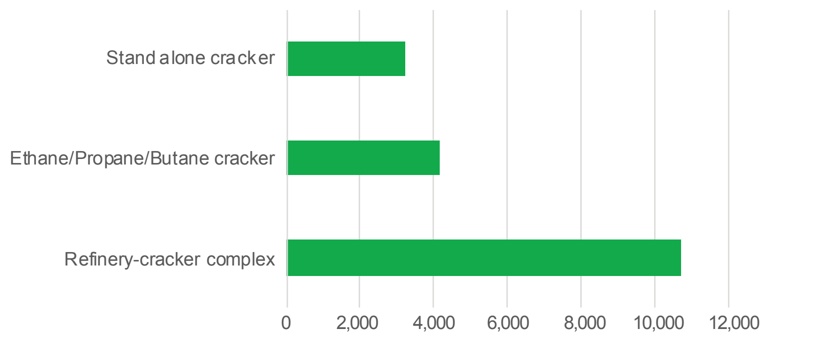
The cost of construction is an advantage that can offset some of the negatives of higher feedstock costs. With its large labor pool, improving capabilities in technology, and large mining resources, China has continued to increase the local content of parts in large petrochemical facilities. This advantage, combined with rapid progress on the learning curve, is driving the China construction process to near half the total cost of a similar plant on the US Gulf of Mexico coast. This is a tremendous build plus for China.

On top of this cost advantage, China is experiencing the build-out of many complementary industries , creating scale not available in many parts of the world. As shown in Table 1, China is building on a mix of feeds, with the largest portion of new builds coming with integrated refining and petrochemical sites.

But, China is not the only region with capacity potential. Table 2 shows the relative advantage of other regions on the four variables:

With these regional considerations in mind, countries and companies in each of these regions will work to weigh the plusses and minuses of these drivers to make their build decisions. IHS Markit's global analysis of ethylene covers many of these points. Count on us to assess the capacity additions and investment decisions needed to meet the growing global appetite for ethylene.

Table 1: 2018-2027 Ethylend cracker capacity additions



Source: IHS Markit.

Table 2: Regional advantage for new ethylene builds

	India	North America	South America	Middle East	Africa
Feed	–	+++	+	+++	+
Demand	+++	–	+	–	++
Cost of construction	=	=	+/–	+/–	+/–
Legal, political, and social	+	+	–	=	+/–

Source: IHS Markit.

Developing focused strategies for managing and curbing plastic usage, disposal, and recycling

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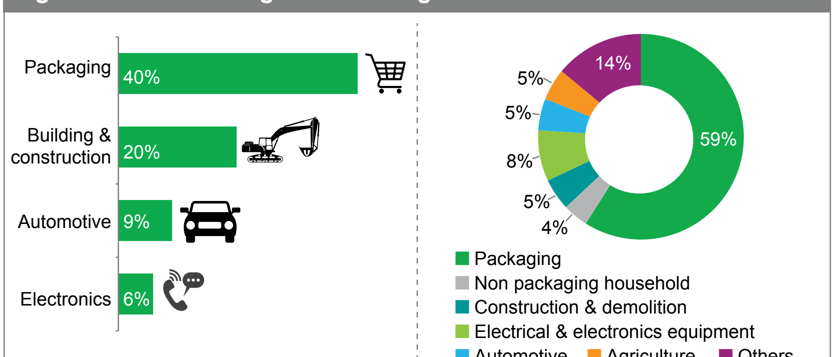
Plastic brings tremendous value to modern life and gives a significant boost to the economy. It is lightweight, multifunctional, easy to process, and user friendly. Its high performance-to-weight ratio helps trim CO2 emissions, and superior insulation properties help cut energy bills. Plastics packaging also helps ensure food safety and limits food waste.

However, its benefits and user-friendliness have made plastics a victim of its own success. Due to excessive littering and lack of proper post-use management, major environmental issues have developed. The millions of tons of plastic litter that end up in the oceans every year are one of the most visible and alarming signs of these problems, escalating public concern and the dismay of authorities. Between 150,000 and 500,000 tons of plastic waste enters the oceans of European Union countries each year.

Apart from marine litter, microplastics – which are fragments of plastic below 5mm in size – accumulate in the sea, where they are easily ingested by marine life. Recent studies have also found microplastics in the air, drinking water, and foods such as salt and honey, with yet unknown impacts on human health. It is estimated that between 75,000 to 300,000 tons of microplastics are released into the environment every year in the EU. At the same time, landfill and incineration rates of plastic waste remain high, at 31% and 39% respectively. While landfill has decreased over the past decade, incineration has grown.

Lack of proper disposal has also led to suboptimal value capture. According to estimates, 95% of the value of plastic packaging material is lost to the economy annually after a very short first-use cycle. Demand for recycled plastics today accounts for only around 6% of plastics demand in Europe. This low demand may be due to the fact that much of the collected plastic waste was, until recently exported to countries such as China.

Figure 1. Plastics usage and waste generation



Source: IHS Markit.

Plastics Recycling Strategies in the EU

Increasing the recyclability of plastics requires a focus on plastics packaging. Today packaging accounts for about 60% of post-consumer plastic waste in the EU (see Figure 1). Better product design is one of the keys to improving recycling levels. Experts calculate that design improvements could halve the cost of recycling plastic packaging waste. Recently the European Commission announced a series of measures to curb and manage use and disposal of plastics. Four primary objectives are behind the EC move:

1. Make the recycling business profitable
2. Curb plastic waste and stop littering at sea
3. Drive investment and innovation
4. Spur change across the world

In a recent strategy paper, the European Commission proposed that at least 50% of all plastics packaging in the EU should be recycled by 2025. The number rises to 55% by 2030. The paper also urged member states to reduce consumption of plastic bags to 90 per person annually by 2019 and 40 bags per person by 2026. The paper also focuses on improving product design to makes plastics more durable, easier to repair, and easier to recycle. In addition, the EU urges member states to monitor and reduce their marine litter. The paper holds producers responsible for contributing to the awareness, clean-up, collection, and waste treatment of plastic packets and wrappers. It also identifies the following items as the most polluting single-use plastic products:

- Drink bottles, caps, and lids
- Snack packets and wrappers
- Sanitary applications
- Plastic bags
- Cutlery, straws, and stirrers
- Drink cups and lids
- Balloons and balloon sticks
- Food containers, including fast-food packaging

The European Commission is also discussing a plastic tax with the twin objectives of bridging the revenue gap post-Brexit and discouraging plastic consumption.

Although this tax is currently in the discussion stage and details are sketchy, such narratives show how authorities are working to cap the use of plastic by fiscal and non-fiscal means.

The EU authorities acknowledge the importance and value of plastics in the economy and society. However, they want to promote a responsible, managed use of the product and generate optimum value through recycling and repairing. Given the resolve of these authorities, it is clear that the proposed regulations and legislation are irreversible. Executives in the plastic industry are wise to collaborate with the various stakeholders to support the initiative and work towards meeting the target. The European Commission is also introducing the concept of new extended producers responsibility (EPR), which will require plastics producers and intermediaries to manage and enact the targets set by the Commission.

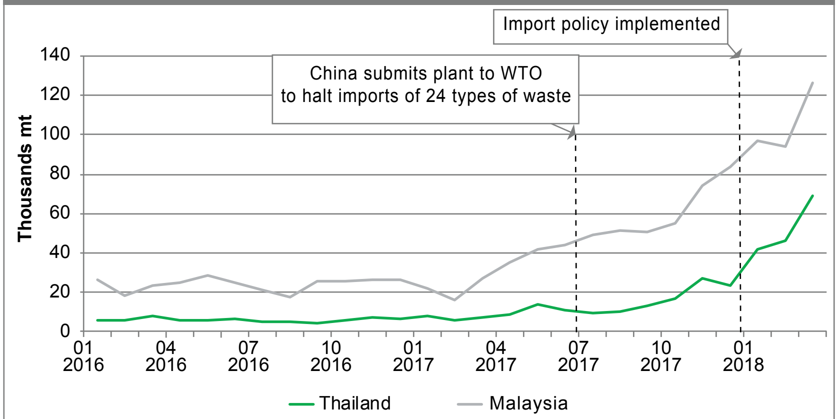
Although the short-term outcome of the regulation is likely to be detrimental to plastics demand, the authorities are playing the role of facilitator — not inhibitor – by containing long-term fallout and promoting design and innovation. By addressing environmental and consumer concerns, the EU is taking a leadership position that may become a template for other regions. Therefore, the plastics industry should adopt a holistic global approach to long-term scenario planning for the impact of EU regulation and not desist from managing their responses to these new regulations.

Plastics Recycling Challenges in Asia

For almost a decade, a seemingly ideal business model addressed recycling in Asia: China produced goods and took back the packaging. This model balanced the trade deficit and utilized empty containers through reverse haulage. Global plastic waste fueled dynamic demand in China, and thousands of recycling companies provided competitive raw materials. Imports of plastic scrap peaked in 2016 at roughly 8 million tons, representing almost half of the global traded recyclable plastic. Under this model, advanced countries such as the U.S., Japan, and almost all of Europe relied on China to take their waste.

Increasing environmental issues forced China´s authorities to close the doors. On January 1, 2018, China stopped the import of 24 kinds of solid waste, including plastics waste. Under the new standard, China will only accept recycled plastics that are less than 0.5% contaminated. This program, named "National Sword," will heavily impact market players along the chain. Chinese recyclers will lose the access to high-quality scrap from the developed world. Instead, China will need to focus on local plastic scrap, which is considered low quality. What's more, official inspections will take place; in case of violations of environmental rules, recyclers will lose their licenses.

Figure 2. Imports of waste plastics by Malaysia and Thailand



Source: IHS Markit. © 2018 IHS Markit

There is also a ripple effect that affects Southeast Asia's emerging countries. Plastic recycling is a billion-dollar business, providing enormous margin opportunities if crude oil prices pushes virgin materials above $1,200 per metric ton. To keep their businesses running, Chinese recyclers began making investments in various countries, such as Vietnam, Malaysia, and Thailand. These countries are competitive in their cost positions, and they provide significant profit opportunities to the Chinese plastics community. Consequently, there is a massive ramp up in plastic exports towards these countries (see Figure 2).

In March 2018, Malaysia and Thailand imported almost 200,000 tons of plastic scrap, the same volume imported in all of 2016. But these countries were unprepared to receive such a huge wave of waste. There are serious limits to their port facilities, logistics, and qualified disposal plants. Recycling companies were constructed in shortest possible time, and many more are planned. Thailand received requests to license more than 1,000 additional recycling facilities, almost all of them from Chinese companies. It is estimated that already more than 500 Chinese recyclers have moved their operations to South Asian countries.

But these importing countries are turning increasingly defensive. Thailand has put licensing on hold and Vietnam is expected to stop plastic scrap imports for a few months to attempt to gain control of the imports. Thousands of containers are stored in Thailand's harbor areas, uninspected and without any clear ownership. As governments assert control, they will begin inspecting shipments and fighting against scrap smuggling. Restrictions will be imposed and the first import licenses may be revoked. To avoid China's pollution problems, these Southeast Asian countries may quickly take steps to stop uncontrolled growth of recycling activities. For these newcomers to plastics recycling, the war on illegal rubbish and toxic scrap is just beginning.

Plastics packaging for the food and beverage industries: A case study in changing attitudes

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History of packaging

Traditionally the food and beverage packaging industry was dominated by glass. Many properties of glass make it an ideal packaging material: it is odorless and chemically inert, impermeable to gasses and vapor, insulating, and transparent. Glass can be shaped and coloured, and it is reusable and recyclable. By comparison, plastic packaging such as polyethylene terephthalate (PET) can have variable permeability to light and vapors, and its reuse and recyclability are currently not comparable with glass. For example the typical shelf life of beer in glass containers is significantly longer than that of beer in PET bottles. However, the concerns of both consumers and producers of food and beverages extend beyond the material's ability to maintain product freshness. In the modern globalized marketplace, cost and affordability play an ever-more-significant role.

Since its introduction as a viable packaging material, plastics such as PET have continued to grow in popularity. PET packaging is generally much lighter than glass, reducing the cost and CO2 footprint of product transportation and improving affordability. The costs of raw materials and production processes for PET packaging manufacture are also lower than glass, on a per unit basis, giving it a further cost advantage. PET can also be combined with other plastics in packaging materials to endow it with different properties. In some instances, these blended plastics lower the overall packaging weight.

Figures 1 and 2, which use data from Packaging World magazine, illustrate the influence exerted by plastic and PET packaging, specifically in the North American beverage market.

Thanks to preferred use of plastic as a packaging material over glass, packaging represents 26% of the world's plastic output. The main niche retained by glass packaging over PET is the alcoholic beverage sector. Glass offers lower permeability to O2 and CO2 than plastic, which means alcohol can be stored longer in glass. In the soft drinks sector, this is less of an issue. With the obvious cost advantage, PET has become the dominant packaging material in that sector.

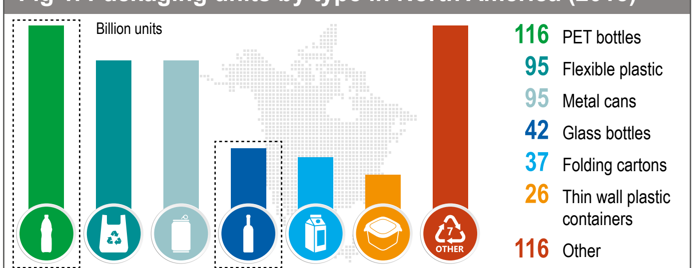
Despite the apparent advantages of plastic packaging materials over traditional glass materials, there is a growing awareness of the environmental impact of using plastics. With this in mind, will the demand for plastic packaging in the future be affected by environmental concerns?

Recycling Issues

It is difficult to directly compare the environmental impact of PET versus glass. Studies often fail to capture the effect of the full life cycle of a product on the environment – especially what happens to packaging at the end of its life cycle. Even when recycling meets ISO standards, studies of the environmental impacts of materials vary. These life cycle assessments often fail to account for the real life, practical issues of waste disposal and recycling – such as waste collection infrastructure and waste sorting – which leave much of the world's plastic waste in landfill or in oceans.

One source of plastic waste that finds its way into the wider environment originates from the PET packaging industry. In 2017 total global demand for PET was 21.5 million mt of which 75 to 80% was used to make PET bottles. However, around 7.3 million mt

Fig 1. Packaging units by type in North America (2015)



Source: IHSMarkit, Packaging World

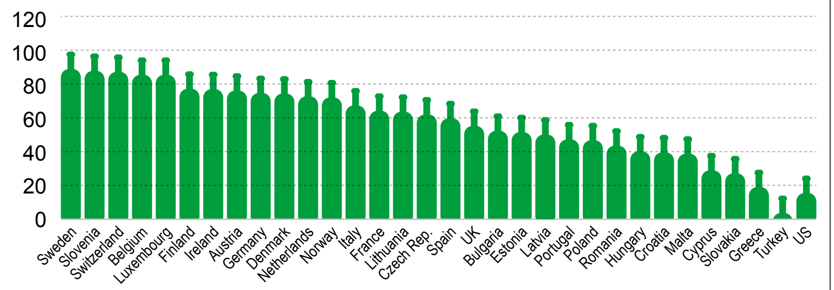
Fig 2. Beverage packaging units by type in North America (2015)

Source: IHSMarkit, Packaging World

of PET was recycled in 2017, equating to around 34% of all the PET production. Currently all recycled PET comes from PET bottles. 6 million mt of this recycled material goes into other plastics streams and only 1.3 million mt goes into making new plastic bottles.

Glass, on the other hand, can be infinitely recycled back into glass packaging without any loss of quality. Therefore, glass recycling has a much more direct impact on demand for new packaging material. According to FEVE, the European Container Glass Federation, the use of one ton of cullet or recycled glass reduces CO2 generation by 580kg in the glass industry, and it saves 1.2 tons of virgin raw materials. Thanks in part to the greater suitability of glass packaging for recycling, in many regions the infrastructure surrounding glass bottle collection and cullet use is much more developed compared than that of plastic collection. For example, in the EU 74% of all glass bottles are collected and recycled (see Figure 3).

Figure 3. Glass recycling rates by country



Source: FEVE, EPA, GPA

Reuse Opportunities

A further issue is that PET is not, at least in the public's perception, infinitely re-useable – although a debate still exists over the impact of reusing plastic bottles multiple times. There are currently numerous examples, particularly in developing regions where glass bottles are cleaned and reused, that show a reduced demand for new packaging material.

One specific example is the company HCCBPL, the Indian bottling arm of Coca-Cola. The company offers a program in which reusable glass bottles can be returned to the shop in which they were purchased and sent back to the plant for re-use. A similar initiative is being carried out by Diageo in India, which is the country's largest spirits producer. Since 2017, Diageo has been collaborating with its glass suppliers to use returnable glass bottles across a number of its most popular brands. The adoption of these initiatives on a wider scale will further demonstrate the environmental advantage of glass as a packaging material compared to plastic.

Public Perception of Plastics for Packaging

A recent study by Plymouth University found that a third of the fish and shellfish consumed by humans contained plastic. In addition, researchers have found that 267 species of birds and 61% of turtles tested also had plastic in their digestive tracts. With growing awareness of these and similar impacts of the use of plastic packaging and the mismanagement of waste plastic packaging, public perceptions towards packaging are beginning to change. With it, consumer trends are also shifting. Recent surveys by the market research group Mintel found that 79% of consumers in the UK think that plastic recycling should be incentivized, suggesting that a vast majority of consumers are concerned about plastic waste.

Other studies suggest a consumer preference for glass over plastic as packaging material. In a survey of European consumers, FEVE found that 85% of respondents preferred glass as a packaging material and that 73% thought it was a safer material for drink packaging.

It appears as though this overwhelming shift in public perception is beginning to have an impact on the behavior of businesses and legislators. For example, the EU is planning to place a ban on plastic straws, stirrers, and cutlery with the aim of ensuring that 55% of all plastics are recycled by 2030. In the UK, all major supermarkets have agreed to eradicate all unnecessary single-use plastics by 2025, while the UK government has proposed its own plan to eliminate all avoidable plastic waste by 2042. In India, Prime Minister Modi has pledged to abolish all single-use plastics by 2022.

Conclusions

Although PET has a number of advantages as a food packaging material over glass, including cost and weight, the impact of using plastics as a packaging material on the environment is becoming a much more visible issue. The debate over what is the most appropriate food and beverage packaging material, glass, PET or other alternative materials such as aluminium is set to intensify in the coming years. As attitudes shift and the pressure intensifies on governments to address the issue of plastic waste, we could see a reversal of the trends observed the last few decades with consumers and producers opting for glass or other alternatives such as aluminium over plastics.

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