North American Downstream Market Outlook and Insights 2019

- Engineering & Construction
- Reliability & Maintenance
- Shutdowns & Turnarounds
- Process Engineering / Technology









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INTRODUCTION

The US economic expansion is nearing the longest in history. In fact, at 10 years old, this is the second longest expansion since 1900. Meanwhile, 2018 represents the sixth year of an extended upcycle in global chemical markets. The extended period of profitability has caused another surge in investment not only in North America, but also in the Middle East and Asia.



Figure 1. Image: ICIS. Data through September 2018. US = ISM, Eurozone = IHS Markit, China = Caixin

A burgeoning oil and gas industry have transitioned the US in just a few years from scarcity of supply to indefinite abundance, changing the dynamics of the global marketplace.



Figure 2. Image: American Chemistry Council





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The US is now expected to add 27.9 million tonnes of new natural-gas derived

petrochemical production capacity between 2011 to 2020 to meet this new global demand.

New petrochemical capacity growth in the US is expected to outpace the Middle East for now, which will add 21.1 million tonnes of new petrochemical capacity between 2011 to 2020, according to IHS Markit estimates. At the same time, risks are developing that could challenge global growth in the coming years.

Key issues the Americas downstream industry is focused on include unstable crude oil prices, government policies and currency fluctuations, global tensions, trade disputes and growing investment in the Middle East and Asia.

Petrochemical Update spoke with the experts to get insights on the key trends shaping the petrochemical, refining and liquified natural gas construction sectors.

Owners and operators, Engineering, Procurement and Construction (EPC) firms, project managers, service providers, technology experts, consultants and experts were interviewed to discuss how the industry is handling investment decisions, shutdowns, turnarounds, capital project management, reliability, maintenance, digitalization, technology and staffing during these evolving times in order to stay competitive.

The key trends Petrochemical Update and the Downstream Conference Advisory Team are focusing on include:

Building the next wave differently. The first wave of petrochemical investment in the US was rushed and owners and EPC firms are taking learnings from the first round as they embark on another set of investments. Most importantly, executives are striving to leverage global execution, technology and data.

Design for reliability. Maintenance and reliability professionals need to be able to clearly articulate how reliability and maintainability can be linked to business profits. While companies talk about the importance of reliability, few understand that reliability is a design attribute. Meaning that the maximum level of reliability a plant can achieve is set by its design.

Creating a Culture of Improvement. The economy is booming, but the industry still has a skills gap, and there are concerns the sector will not be able to attract craft or high-tech jobs in the short or long-term future. An industry-wide adoption of better technology and reputation improvement is critical.

Refinery/petrochemical integration: A decline in the growth of transportation fuels is causing more refiners to rethink their petrochemical strategy and the industry will see a higher conversion ratio of crude oil into chemicals.

Changes in China's energy markets. The top three destinations for US product are Canada, Mexico and China. The China energy industry is evolving. Key considerations are changes to China's environmental laws, outside investment, and the ongoing trade war.

Growth in the Middle East. As demand for transportation fuels wanes, the crude oil to chemicals facilities increase. The Middle East will not sit by and let the US take more market share in chemicals with shale gas. The Middle East will usher in a wave of new capacity through massive investments by 2025. The crude oil to chemicals facilities will produce a ratio much higher than the ethane-based chemicals produced in the US.

As the global industry prepares to enter a new decade of the 2020s, investors, owners, and service providers will have to be well prepared as decisions are made.

The Downstream 2019 Exhibition and Conference in Houston on June 11 and 12, 2019 is the place to tackle core challenges with world-class experts, hear about the latest disruptive technology, and to meet and form partnerships with new and existing suppliers.





US DOWNSTREAM CONSTRUCTION MARKET

Planned capital and maintenance project spending is showing a 7.4% decline for the next 12 months out to third-quarter 2019.

The pipeline of planned infrastructure spending across the twelve industries researched stands at \$593 billion from fourth-quarter 2018 to third-quarter 2019, according to analysis by Industrial Information Resources (Industrial Info).

However, the volume of projects has increased almost 2% for projects with a planned kickoff date in the next 12 months and stands at almost 6,500 capital projects and a further 6,400 maintenance projects and turnarounds.



Figure 3. Image: Industrial Info

"This is a trend that has been continuing for some time as we see some sectors such as upstream crude and mining continue to retrench and hold back on committing dollars into some of those large grassroot and expansion projects," Shaheen Chohan, Industrial Info's vice president of global analytics and author of the quarterly market outlook report, said. "This comes from favoring the channeling of investment toward smaller in-plant capital projects, which are more geared toward process optimization and efficiency upgrades."

The current 12-month outlook still shows a 3% year-over-year improvement in infrastructure spending and is up \$17 billion compared to the same 12-month period reported last year.

Despite flat long-term electricity demand growth expected in US power generation, project spending is up \$32.5 billion compared to the same 12-month period last year. This is driven in part by the continued decarbonization of the fuel mix and a wave of additional battery storage projects.

On the oil and gas side, planned pipeline spending is up \$24.4 billion year-over-year and reflects the continued demand growth for additional crude, gas and natural gas liquids (NGL) takeaway capacity.

Year-over-year comparative spending in upstream oil and gas production is mixed.

Overall, North American production spending for the forthcoming 12-month period is lower by almost 19% compared to last year.

"Considerable headwinds will likely persist for any new grassroot Canadian oil sands projects, as investment has continued to shift away from these and move into US shale plays," Industrial Info said.

US shale plays have continued to produce more crude, but with only a limited uptick in capital spending due to greater levels of advancement in drilling and production techniques.

Overall, US gas production is expected to hit 79 billion cubic feet per day (Bcf/d) in 2018 and grow to 93 Bcf/d in 2020. A similar theme to crude is occurring with shale players achieving more gas production volumes without the need for a huge rise in additional drilling rigs. This has been achieved by efficiency gains, and the knock-on effect is less wells. However, there is a big increase in new NGL processing capacity currently under development.







All in all, across all 12 industries that make up the report, both capital and maintenance spending across the US is looking decent and is trending in line with expectations.

There are some headwinds that the market still needs to contend with, namely the ongoing trade dispute with China. "If this extends deep into 2019 and isn't resolved, it will have some impact on lowering global trade flows, and this will have a knock-on effect across both energy and industrial manufacturing supply chains and may put a little more uncertainty into the minds of some current projects owners," Chohan said.

"However, uncertainty is the daily fabric of what today's decision-makers need to factor into their planning and for those equipped with the right data and insights, then they can help turn some of these headwinds into opportunities," Chohan added.

US PETROCHEMICAL / CHEMICAL CONSTRUCTION MARKET

More than 300 projects valued at just over \$200 billion have been announced since 2010. Of these, more than \$100 billion have been completed or are under construction, according to the American Chemistry Council.



Figure 4. Image: American Chemistry Council





71% of chemical investment from shale gas is bulk petrochemicals and plastic resins. Of that, 52% of total investment (around \$105 billion) is petrochemicals and 19% of total investment (around \$37.5 billion) is plastic resins.



Figure 5. Image: American Chemistry Council

US petrochemical investment has largely focused on agricultural chemicals, methanol, ethylene and ethylene derivatives, especially polyethylene.

Nearly 20 facilities, or crackers, are being built or expanded in the US to convert NGLs such as ethane and propane into ethylene. Ethylene is the most used petrochemical globally currently and the main ingredient in polyethylene plastic.

Nine of these crackers are expected to come online in the US by 2020, representing 10.7 million tonnes/year of new ethylene capacity. 9.2 million tonnes of that will be online by the end of 2019 in the US Gulf.

An additional 1.4 million tonnes of ethylene is coming online because of cracker expansions for a total of 9.2 million tonnes of additional ethylene capacity in the US Gulf or 35% of existing US capacity by 2019, according to ICIS.





NEW US CRACKER COMPLETE, UNDER CONSTRUCTION, FID MADE

COMPANY	C2 CAPACITY (KT/YEAR)	DOWNSTREAM (KT/YEAR)	LOCATION	START-UP	
OxyChem/ Mexichem	544	Feed existing VCM plant of 1,050	Ingleside, Texas	Q1 2017	
Dow Chemical	1,500	ELITE PE (400); LDPE (350) - Plaquemine, Louisiana; EPDM (200); elastomers(320)	Freeport, Texas	Q3 2017, LDPE and EPDM Q1 2018, elastomers late 2018	
ExxonMobil Chemical	1,500	mLLDPE plus LLDPE (650x2) at Mont Belvieu	Baytown, Texas	Q2 2018	
Chevron Phillips Chemical	1,500	Bimodal HDPE (500), mLLDPE (500) both at Old Ocean	Cedar Bayou, Texas	Q1 2018	
Formosa Plastics	1,200	HDPE (400), LDPE (400), EG (800)	Point Comfort, Texas	Q4 2018	
Sasol	1,500	LDPE (450), LLDPE (450), EO/EG (300), ethoxylates, detergent alcohols (300)	Lake Charles, Louisiana	Q4 20-18, LDPE early 2019, qlcohols H2 2019	
Shintech	500	VCM (300), PVC (300), caustic soda (200)	Plaquemine, Louisiana	2018	
Westlake/Lotte	1,000	MEG (760) by Lotte, feed into existing PVC for Westlake	St Charles, Louisiana	Early 2019	
Shell	1,500	HDPE/LLDPE (550x2), HDPE (500)	Monaca, Pennsylvania	Early 2020s	
9 new crackers = 10.7m tonnes/year Through 2019 = 9.2m tonnes/year					

Figure 6. Image: ICIS

EXPANSIONS OF EXISTING US CRACKERS, PLUS 1 RESTART

COMPANY	C2 CAPACITY (KT/YEAR)	LOCATION	STATUS/START-UP	
LyondallBasell	363	Corpus Christi, Texas	Fully started up Q2 2017	
Westlake Chemical	32	Calvert City, Kentucky	Started up Apr 2017	
Indorama (restart)	440	Lake Charles, Louisiana	Q4 2018	
Dow Chemical	91	Orange, Texas	Early 2019	
Dow Chemical	500	Freeport, Texas	End 2019	
INEOS	270	Chocolate Bayou, texas	FID H2 2018, start-up 2020	
LyondallBasell	250	Channelview, Texas	Evaluating for 2020s	
Expansions about 1.4m tonnes/vear + new crackers 9.2m = 10.6m, or 35% of existing US capacity by 2019				

Figure 7. Image: ICIS



2ND WAVE OF NEW US CRACKER PROJECTS

COMPANY	C2 CAPACITY (KT/YEAR)	DOWNSTREAM (KT/YEAR)	LOCATION	START-UP	STATUS
Total/Borealis/ NOVA	1,000	Borstar PE (625) + existing PE (400)	Port Arthur, Texas	End 2020	Cracker under construction, FID made in Sep for PE
Shell	1,500	HDPE/LLPE (2x 550), HDPE (500)	Monaca, Pennsylvania	Early 2020s	Under construction
SABIC/ ExxonMobil	1,800	PE (2 units(, MEG	Corpus Christi, Texas	H2 2022	Under construction
PTTGC/Daelim	1,000	HDPE (700)., MEG (500), EO (100)	Belmont County, Ohio	2021	Evaluation
Formosa Petrochemicals	1,200	LLDPE (400), HDPE (400), EG (900)	St. James Parish, Louyisiana	2022	Permitting, Evaluation

Figure 8. Image: ICIS

Most of the crackers being built include a polyethylene plant.

The US will add 6.5 million tonnes/year of polyethylene capacity through 2019 or roughly 39% of US capacity, based on ICIS data.

That number nearly doubles by 2022 with 12.1 million tonnes of capacity added assuming all announced plants are built. This is 74% of total US capacity, according to ICIS.

Total polyethylene capacity could increase by another 5 million tonnes by 2022 as second wave plants begin operations.

The US polyethylene market is now dependent on exports.

NORTH AMERICA PE EXPANSIONS

COMPANY	C2 CAPACITY (KT/YEAR)	GRADE, BREAKDOWN	LOCATION	START-UP
Dow Chemical	400	ELITE PE	Freeport, Texas	Q3 2017
Dow Chemical	350	LDPE	Plaquemine, Louisiana	Q4 2017
Chevron Phillips Chemical	1,000	Bimodal HDPE (500), mLLDPE (500)	Old Ocean, Texas	Q3 2017
ExxonMopbil Chemical	1,300	mLLDPE plus LLDPE (2x 650)	Mont Belbieu, texas	End 2017
INEOS/Sasol	470	HDPE	La Porte, texas	Q4 2017
Formosa Plastics	800	HDPE (400), LDPE (400)	Point Comfort, texas	H2 2018
Dow Chemical	125	Bimodal HDPE	St Charles, Louisiana	Q4 2018
Sasol	890	LLDPE (470), LDPE (420)	Lake Charles, Louisiana	H2 2018 (LLDPE), 219 (LDPE)
LyondellBasell	500	HDPE	La Porte, Texas	Mid-2019
ExxonMopbil Chemical	650	PE (unspecified)	Beamont, Texas	2019
Total/Borealis/NOVA	625	Borstar PE	Bayport, Texas	2021
Shell	1,600	HDPE/LLDPE (2x 550), HDPE (500)	Monaca, Pennsylvania	Early 2020s





NORTH AMERICA PE EXPANSIONS

COMPANY	C2 CAPACITY (KT/YEAR)	GRADE, BREAKDOWN	LOCATION	START-UP
PTT Global Chemicals*	700	HDPE (2x 350)	Belmont County, Ohio	2021
NOVA Chemicals	430	LLDPE	Sarnia, Canada	Late 2021/ Early 2022
SABIC/ExxonMobil*	NA	PE unspec (2 units)	Corpus Christi, Texas	H2 2022
Dow Chemical*	600	PE (unspec)	US Gulf Coast	2020s
Dow Chemical*	350	PE (unspec)	Various debottlenecks	2020s
Through 2019 = 6.5m tonnes/year (+39% US capacity) Through 2022 = 12.1m tonnes/year** (+74% US capacity)				

*No FID yet | ** Assuming 1,300kt PE for SABIC/ExxonMobil

Figure 8. Image: ICIS

In addition to the \$100 billion in petrochemicals investments, there are nearly 750 plastics processor projects, valued at nearly \$20 billion. One-third is new construction and two-thirds is expansions.



Figure 10. Image: American Chemistry Council

Fertilizers are another major target of chemical capital investment. More than 20 US plants are being built or expanded to convert gas into ammonia, a key ingredient. Since 2014, more than \$31 million of capital investments has gone into expanding existing nitrogen plants or building new ones, according to The Fertilizer Institute (TFI).





PROJECT SPENDING NEAR TERM

The North American Industrial Project Spending Index, which measures the value of active projects in the pipeline for the year, was up more than 12% in September 2018 compared with the measurement reported a year earlier, with eight of the twelve tracked industries showing increases.

The index, by Industrial Info, provides spending details by industry and market region, including monthly updates that measure the rate of activity from this year to last year during the same month.

The Index for September totaled \$334.12 billion, up by \$36.63 billion from September 2017.

Industrial Manufacturing registered the largest gain in September, with an increase of \$26.14 billion, or 36.4%, over the value of project activity in September 2017. Total manufacturing index activity amounted to \$97.97 billion in September this year.

Petroleum Refining, Metals and Minerals, Pulp, Paper and Wood, also grew significantly.

Chemical Processing registered a drop of 8.9% from September 2017. In fact, Chemical Processing has registered a drop-in year-over-year spending for the past four months.

The Chemical Processing spending index for September amounted to \$19.11 billion, compared with \$20.98 billion in September 2017.

"The slight decline in petrochemical spending this year has really been the result of fewer mega projects beginning construction in 2018 compared to the past several years," Trey Hamblet, Industrial Info Vice President of Chemical Processing Industry research said.

"By mega projects I'm referring to those projects with individual values of \$500 million or more. If we take mega projects out of the equation entirely, there has been a slight increase in overall chemical industry spend this year, with another slight increase expected in 2019. There are still an impressive number of mega projects planned and proposed for 2019 and beyond, just not at the same level we have witnessed since 2014," Hamblet added.

Globally, petrochemicals are set to account for more than a third of the growth in world oil demand to 2030, and nearly half the growth to 2050, adding nearly 7 million barrels of oil a day by then.

Petrochemicals are also poised to consume an additional 56 billion cubic meters of natural gas by 2030, and 83 billion cubic meters by 2050, according to the IEA.

According to the Hydrocarbon Processing Construction Boxscore Database, more than 320 new downstream capital projects have been announced over the past year globally. This total represents a 43% increase in new project announcements year over year.

Most of these new projects are within the gas processing/LNG and petrochemical industries. A breakdown of each sector includes: 41% in the gas processing/LNG sector, 39% in petrochemicals and 20% in refining.

The Asia-Pacific region continues to lead in new project announcements. The US follows the Asia-Pacific region with a 26% market share in new project announcements, according to Hydrocarbon Processing.

Developers have been on a manufacturing project binge this year, with year-over-year, double-digit increases seen in each month this year so far.

According to the National Association of Manufacturers' latest outlook survey, released on October 5, 2018 optimism among manufacturers remains very high at 92.5%, following enactment of federal tax and regulatory reform, and is on pace for the highest yearly reading in the survey's 20-year history.

Attracting a qualified workforce seems to be one of the biggest challenges that the industry faces these days, according to the survey.





MAJOR US GULF CHEMICAL PROJECTS RIGHT NOW

Several petrochemical producers have multi-billion-dollar projects in the US right now.

A resurgence in US petrochemicals manufacturing has attracted another round of investments as companies seek to capitalize on the shale boom in West Texas.

Hydraulic fracturing there has unleashed a steady supply of crude oil and natural gas for use in feedstocks to make base chemicals for plastics and other applications.

SASOL

The largest complex to date is an \$11.13 billion complex being built near Lake Charles, Louisiana by South Africa's Sasol.

At the heart of the project is an ethane cracker that will produce 1.5 million tonnes of chemicals produced in the facility to be used in six downstream plants on-site to produce a range of high-value derivatives including ethylene oxide, mono-ethylene glycol, ethoxylates, low density and linear low-density polyethylene, and alcohols.

EXXONMOBIL

One of the more substantial North American chemical projects now under construction is Exxon Mobil's 1.4 billion pound/year low density polyethylene unit addition in Beaumont, Texas.

Mitsubishi Corporation, Jacobs Engineering Group and Zachry Construction are working on the project, which is expected to reach completion in early 2019.

ExxonMobil in September 2018 finished and started up its new unit that will produce another 45,000 barrels/day of ultra-low sulfur gasoline and diesel fuels to meet rising federal standards.

Exxon Mobil just finished a plastics expansion at its Mont Belvieu plant near Houston to churn out 1.3 million tonnes of polyethylene a year, and Exxon Mobil is considering another plastics expansion at its nearby Baytown campus.

SABIC/EXXONMOBIL

SABIC and ExxonMobil have created a new joint venture to advance development of the Gulf Coast Growth Ventures project, a 1.8 million tonne ethane cracker currently planned for construction in San Patricio County, Texas.

The facility will also include a monoethylene glycol unit and two polyethylene units.

SABIC is the operating partner for two long-standing joint ventures with ExxonMobil in the Kingdom of Saudi Arabia, Kemya in Jubail and Yanpet in Yanbu.

Creation of the joint venture represents a key milestone that allows the two companies to continue advancing the project, which is expected to create 600 new, permanent jobs, about 3,500 indirect and induced jobs during operations, as well as 6,000 construction jobs during the peak of construction.

Construction of the project, announced in 2016, is pending completion of the environmental permitting process. The plant is expected to be operational in the 2021-2022 timeframe.

The cost of the project is estimated at about \$7.3 billion. EPC contracts have been signed with Chiyoda Kiewit Joint Venture and CTCI McDermott.





METHANEX

KBR was awarded a reimbursable EPC contract from Methanex Corporation to provide front-end engineering design (FEED) services for its new Geismar 3 methanol unit in Geismar, Louisiana.

The 1.8 million tonne/year facility will be located next to two of Methanex's existing methanol units. A bidding war between Canada and Geismar, Louisiana began earlier this year for Methanex's new North American methanol plant.

The Canada-based producer announced in April 2018 the company had acquired land for a third methanol plant in Geismar, adjacent to its two existing methanol plants there.

Methanex is still probably a year away from making a final investment decision (FID).

DOWDUPONT

DowDuPont is wrapping up Dow's multi-year \$6 billion Gulf Coast buildout program that began before the massive merger between Dow Chemical and DuPont.

Dow is expanding it's recently commissioned 1.5 million tonne/year ethylene cracker by another 500,000 tonnes in Freeport,-Texas.

Dow is also building a 650,000 tonne/year polyethylene unit.

As of November 2018, the Plant B low-density polyethylene (LDPE) unit addition at Dow's complex in Freeport, Texas is undergoing final commissioning. Fluor is the mechanical contractor for the project.

In St. Charles, Louisiana, Dow is putting the finishing touches on a high-density polyethylene (HDPE) unit debottleneck that will increase its capacity by 125,000 tonnes/year.

Planned DowDuPont project completions for 2019 include a 1.1 million pound/year unit expansion in Freeport, Texas; a 200,000 pound/year ethylene unit expansion in Orange, Texas, and a polyolefins catalyst production unit addition in Seadrift, Texas.

LOOKING AHEAD AT DOW'S PLANS

Dow no longer expects to build a new cracker in its "Wave 2" of planned expansions, in line with its renewed focus on capital discipline, the company's chief executive said.

"Wave 2 will not have a new cracker. We will be adding capacity at existing sites, including debottlenecking ethylene," said Jim Fitterling, CEO of Dow, at Dow's investor day in New York in November.

Wave 2, which will take place from 2021-2023 in Dow's packaging & specialty plastics segment, will add around 1.4m tonnes/year of capacity and involve many products, including swing polyethylene (PE) units in the US and Europe, as well as higher alpha olefins and elastomers in the US.

At the November earnings Day, the company said the new Dow investment plan will aim for projects with an internal rate of return (IRR) of over 13%, with a faster payback.

These types of projects tend to be incremental growth investments rather than mega projects which have had lower IRRs of 10-13% in the past.







Braskem and The Linde Group, the lead EPC contractor for Braskem's new world-scale North American polypropylene (PP) production line, announced that Bilfinger Westcon has been selected as the lead mechanical subcontractor.

Braskem has committed up to \$675 million towards the design and construction of the new PP production line named Delta which is being constructed next to Braskem's existing production facilities in La Porte, Texas.

With the initial steel erection phase now underway, the final phase of main construction remains on track and targeted for the first quarter of 2020.

The new plant will have a production capacity of 450 kilotons (kt), or the equivalent of approximately 1 billion pounds/year.

BOREALIS/TOTAL/NOVA

The joint venture between Borealis, Total and Nova aims to build a \$1.7 billion steam cracker on the US Gulf Coast. The facility is scheduled to start up in 2020. The JV will also build and own a 625,000 tonne/year polyethylene plant at Total's petrochemical production site in Bayport, Texas.

LYONDELLBASELL

LyondellBasell began construction in August 2018 on its priciest project to date, a \$2.4 billion plant in Texas. The plant will be the largest propylene oxide (PO) and tertiary butyl alcohol (TBA) plant ever built. Startup is planned for 2021.

The project will create more than 2,200 construction jobs at the peak of construction and 160 permanent positions, the company said.

The two facilities will be constructed on existing manufacturing sites. The 140-acre PO/TBA plant will be built at the Lyondell-Basell Channelview Complex located in Channelview, Texas while an associated 34-acre ethers unit, which will convert TBA to oxyfuels, will be built at the company's Bayport Complex in Pasadena, Texas.

COVESTRO

Covestro plans to invest \$1.7 billion in its Baytown, Texas plant to boost production of a key chemical for polyurethane foams. The new unit, expected to begin operations in 2024, will have the annual capacity to produce 1.1 billion tons of methylene diphenyl diisocyanate, a base chemical for polyurethanes.

The company already employs about 1,000 people at the site and expects to add another 25 to support the expanded operations after closing a smaller production unit there.

NORTHEAST PETROCHEMICAL CONSTRUCTION MARKET

COMPANY/LOCATION	ETHYLENE CAPACITY, KTA	DERIVATIVE UNITS	FID	START-UP
Shell Beaver County, PA	1500	Polyethylene	Taken	2022
PTT Global Chemicals Belmont County, OH	1000	Polyethylene, Monoethylene Glycol	Evaluating	2022
Braskem Wood County, WV	1050	Polyethylene	On Hold	







Shell completed a substantial step in the construction of its Pennsylvania Petrochemicals Complex in fall 2018, bringing the Northeast chemicals hub dream another step closer to reality.



Figure 12. The heavy lift of the quench tower, undertaken October 7, 2018, marked an important milestone in the Shell Pennsylvania Petrochemicals Project. Image: Shell

Shell said in October 2018 it had successfully installed the project's largest piece of equipment: a 285-foot cooling and condensation tower for gas and other hydrocarbons.

At approximately 2,000 tonnes, the tower spent more than three and a half weeks in transit up the Mississippi and Ohio rivers and required one of the world's largest cranes to lift it into place.

Upon arrival in Pennsylvania, it was unloaded onto a dock and transported down a newly-created road – both specially-designed to handle the large quench tower.

The heavy lift of the quench tower, undertaken October 7, 2018 marked an important milestone in the project.

SHELL NORTHEAST TIMELINE

In May 2018, Shell introduced its Shell Polymers line of business to customers.

Shell took the final investment decision (FID) on the Pennsylvania Petrochemicals Complex in June 2016.

The site preparation program ended in November 2017, with Shell announcing the start of main construction. Commercial production is expected to begin early next decade.

Since the start of main construction in November 2017, Shell has also safely erected two of three reactors associated with the





planned polyethylene units and laid around 15 miles of underground pipe for the cooling, firewater and drainage systems.

The project is bringing economic growth and jobs to the region, with some 3,000 workers on site. That number will likely increase to 6,000 by the end of 2019 through its construction phase, according to Shell.

Shell expects around 600 onsite jobs when the complex is completed.

SHELL NORTHEAST DETAILS

The petrochemicals complex will use ethane from shale-gas producers in the Marcellus and Utica basins to produce 1.6 million tonnes of polyethylene per year.

The complex will include four processing units – an ethane cracker and three polyethylene units. Two polyethylene units will manufacture high-density polyethylene (HDPE) grades of pellets and a third unit will produce linear low-density polyethylene (LLDPE) pellets.

Shell is also constructing a 900-foot (274-metre) cooling tower, rail and truck loading facilities, a water treatment plant, an office building and a laboratory.

NORTHEAST CONDITIONS

The Shell petrochemical complex in Pennsylvania will be the first major US project of its type to be built outside the Gulf Coast in 20 years, but many say Shell is paving the way for a major Appalachia petrochemical industry.

The Northeast region has lagged the US Gulf Coast in petrochemical developments since the Shale Renaissance building boom began despite ample supplies of natural gas from the Marcellus and Utica shale formations which span Pennsylvania, Ohio and New York.

There is enough ethane being produced in the Northeast US now to provide the chemical industry enough feedstock without any additional drilling or exploitation, industry analysts said.



Figure 13. Ethane supply from Marcellus and Utica Shales. EIA, ACC





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"There is more than enough ethane in the Northeast region now for another two to three world scale crackers," US Energy Information Administration Industry Economist Warren Wilczewski said while speaking at Petrochemical Update's Northeast US Petrochemical Construction Conference in 2017.

A report by IHS Markit in 2018 later stated that a rise in the production of ethane in the Northeast could be enough to supply an additional four crackers to generate ethylene for plastics manufacturing.

Surging supply of ethane is expected to come from the Marcellus and Utica shales over the next several years. By 2020, a quarter of US ethane will be produced in Appalachia, according to the US Energy Information Administration (EIA).

NORTHEAST REQUIREMENTS

Pipelines, infrastructure and storage are still necessary for the northeast petrochemicals hub to become a reality, players caution.

According to analysts, a storage solution is a crucial next step in transforming the Appalachian Basin and its natural gas assets into a petrochemical production center.

A proposed multibillion-dollar regional storage complex for natural gas liquids sourced from the Marcellus, Utica and Rogersville shale plays moved one step closer to reality in August when Parsons was named the EPC partner for the buildout of the Appalachia Storage and Trading Hub (ASTH).



Figure 14 Appalachia Storage Hub. Image: Matric





Parsons will initially focus on the pre-front end engineering design (FEED) and FEED stages including project management and execution planning. Subsequent phases would include constructing the \$3.4 billion project and its long-term operation.

The American Chemistry Council (ACC) has estimated that the ethane storage hub would act as a catalyst for more than \$36 billion in follow-on petrochemicals investments and the creation of more than 100,000 long-term jobs.

MORE NORTHEAST PROJECTS

There are more than \$90 billion in planned projects and development for the region.

Besides Shell, two more key projects dominate the spotlight, in addition to the development of an underground storage system that could attract additional investment.

PTT



Figure 15. The site selection will be in Mead Township (outlined in red) in the Dilles Bottom area on the west side of the Ohio River. Image: PTTGC America

While an FID is not yet on the table for the US subsidiary of PTT Global Chemical's (PTTGC America) planned Belmont County world scale petrochemical complex in Ohio, recent company announcements have been positive signs for this project.

PTT officials have publicly cited that a decision will be made on its \$7-10 billion investment before year end. Initially, the estimated cost of the cracker to be built along the Ohio River was \$5.7 billion.

South Korea's Daelim Chemical is now a partner on the ethane cracker project.

Ohio Governor John Kasich said the international energy firms now control about 500 acres of property needed to build the cracker.

PTT previously bought a 168-acre parcel overlooking the Ohio River in Dillies Bottom, an unincorporated area in Belmont County, Ohio across the Ohio River from Wheeling, West Virginia. The land was purchased from FirstEnergy Corp for \$13.8 million.

Contracts have been signed by Fluor Corporation and Bechtel Enterprises Holding, two EPC firms that will separately conduct their respective front-end engineering design work.





CHINA MOU

China Energy Investment Corporation Limited's plans to invest \$83.7 billion in shale gas development and chemical manufacturing projects in West Virginia, the West Virginia Department of Commerce said.

West Virginia Secretary of Commerce H. Wood Thrasher and China Energy President Ling Wen signed a Memorandum of Understanding (MOU) in November 2018 between China Energy and the state of West Virginia as part of the US-China Business Exchange trade mission to enhance relations between the two countries.

Planning for the projects is underway and will proceed in phases over the course of 20 years. The projects will focus on power generation, chemical manufacturing, and underground storage of natural gas liquids and derivatives.

"Expanding Appalachia's energy infrastructure, including developing a regional storage hub and market for natural gas liquids, will have a transformative effect on our economy, our security, and our future. From driving growth and creating jobs to maximizing America's energy potential, the benefits for West Virginia and the country from this new investment will be significant and long-lasting," Senator Shelley Moore Capitol said in a statement.

China Energy is the creation of a merger between China's state-owned coal mining company Shenhua Group and energy producer Guodian Group. The merger positions China Energy as the world's largest power company with more than 200,000 employees.

NORTHEAST CHEMICAL HUB BENEFITS

Projects in the northeast will be located close to ethane supplies and gas processing infrastructure in the heart of the "wet" Marcellus/Utica natural gas liquids production region, which will provide a significant feedstock transport cost advantage versus Gulf Coast crackers, even if ethane prices rise in the next few years.

The proximity to the end user market is another advantage. More than 70% of North American plastics customers are within a 700-mile radius of Pittsburgh.

According to the EIA, northeast region natural gas production at 20 billion cubic feet (BCF) per day in 2017 is expected to double in the next 35 years, accounting for 40% of total US natural gas production.

US LNG CONSTRUCTION MARKET

Liquified natural gas (LNG) capital projects are gaining momentum in the Americas again because of both the recovery in oil prices, and increased demand from growing economies including India, China and Japan.



Figure 16. Construction continues at the nearly \$2 billion Elba Liquefaction Project in Georgia with a total of six liquefaction units on site. Image: Kinder Morgan





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The collapses in energy prices in 2014 and concern that the US would be oversupplied slowed projects for a while.

Stable oil prices and strong demand from growing economies such as China and India are changing sentiment again. There are currently two operational LNG export terminals in the US. Cheniere's Sabine Pass plant in Louisiana and the Dominion's Cove Point in Maryland are now operating in the US.

More than \$88 billion in LNG projects are currently planned, being built or in operation across the US, according to Industrial Information Resources (Industrial Info).

Canada hasn't added any new projects since shale gas burst onto the scene.

However, up to \$138 billion in LNG projects have been proposed in Canada, according to data calculated from Natural Resources Canada.

"Canadian projects require developing greenfield plants and pipelines, as well as getting regulatory approvals from the indigenous First Nations communities," said Ruth Liao, LNG Editor Americas for ICIS.

"When global crude oil prices plunged in 2015, the Canadian greenfield projects did not look as favorable compared with other projects globally, and some of the development efforts stalled or were cancelled," Liao said.

DEMAND

The US started to export LNG in February 2016, when Cheniere brought online its 1.4 Bcf/d Sabine Pass export facility in Louisiana.

A major change in the LNG demand outlook happened soon after as China began importing more LNG to reduce coal burn in its fight against pollution.

US LNG deliveries to China surged as low prices encouraged buyers to switch from coal, according to the U.S.-China Economic and Security Review.

China has been the third-biggest importer of US LNG so far in 2018, behind South Korea and Mexico, according to January-July figures from LNG Edge.

The US stands to become the world's third-largest LNG exporter by 2020, when it's expected to ship about 8.3 billion cubic feet a day of capacity, or 14% of the world's share, according to London-based consultant Energy Aspects. Meanwhile, projects such as LNG Canada envision a Pacific LNG port, potentially giving that project an advantage over its US competitors for the major East Asian demand growth areas.

The retaliatory trade announcements by the US and China may have an interesting side effect on Canada and some of the other countries developing further LNG exports, such as Mozambique and expansion efforts in Papua New Guinea, Liao said. "The latest announcement by China's finance ministry to impose a 25% tariff on US LNG was the latest blow to US LNG expansion efforts given that China is a key growing market for new demand in global LNG," Liao said.





LNG PROJECTS US

CURRENT US LNG PROJECTS

PROJECT	DEVELOPERS	LOCATION	STATUS
Cheniere LNG/Sabine Pass	Cheniere Energy	Louisiana	Operating
Cove Point LNG, MD	Dominion	Maryland	Operating
Cameron LNG	Sempra-Cameron	Louisiana	2019
Port Arthur LNG	Sempra	Texas	2019
Elba Island LNG Trains 1-5	Kinder Morgan-Southern LNG	Georgia	2019
Corpus Christi Trains 1-2	Cheniere Energy	Texas	2019
Freeport LNG	Freeport LNG	Texas	2019

Figure 17 Current US LNG Projects

Sempra Energy and Total S.A. in November 2018 announced that they have entered a Memorandum of Understanding (MOU) that provides the framework for cooperation in the development of North American LNG export projects.

The scope of the MOU covers continuing the development of the Cameron LNG liquefaction-export project in Louisiana and the Energía Costa Azul (ECA) liquefaction-export project in Baja California, Mexico.

The MOU between Sempra Energy and Total contemplates Total potentially contracting for approximately up to 9 million tonnes per annum (Mtpa) of LNG offtake across Sempra Energy's LNG export development projects on the US Gulf Coast and West Coast of North America, specifically Cameron LNG Phase 2 and Energia Costa Azul (ECA) LNG.

Total, which is already a partner of the Cameron LNG joint venture with a 16.6% stake, also may acquire an equity interest in ECA LNG.

"The US is increasing its global leadership position in the production of oil and natural gas", Jeffrey W. Martin, CEO of Sempra Energy, said a company statement.

"In large measure, the next step in fulfilling our country's energy potential is the development of critical export infrastructure for LNG," Martin said. "Sempra Energy has a long-term goal of developing more than 45 Mtpa of LNG export capacity in North America."

"That is why our relationship with Total is so important. We plan to leverage the competitive strengths of both companies to accelerate development of North American LNG exports to global markets," Martin added.

The \$10 billion Phase 1 of the Cameron LNG joint-venture liquefaction-export project includes three liquefaction trains with approximately 14 Mtpa of export capacity under construction in Louisiana.

Commissioning of the first train is now under way and all three trains are expected to be producing LNG in 2019. Phase 2 of the Cameron LNG project, previously authorized by FERC and being developed jointly by the Cameron LNG co-owners, encompasses up to two additional liquefaction trains and up to two additional LNG storage tanks with approximately 9 Mtpa of capacity.

ECA Phase 1 is a one-train facility with an expected total export capacity of 2.5 Mtpa, utilizing the existing LNG receipt terminal's tanks, loading arms and berth. ECA Phase 2 is expected to have additional export capacity of 12 Mtpa of LNG. The ECA project is in Baja California, Mexico and will be supplied with natural gas from the US.

Development of the LNG export facilities is subject to several risks and uncertainties, including obtaining binding customer commitments, required regulatory approvals and permits, securing financing, completing the required commercial agreements and other factors, as well as reaching a final investment decision. The ultimate participation by Total remains subject to finalization of definitive agreements, among other factors, the company said.





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In addition to the Cameron LNG project and ECA Phase 1 and 2, Sempra Energy is also developing the Port Arthur LNG liquefaction-export project in Texas, a facility with two liquefaction trains capable of producing 11 Mpta of LNG.

Additional US plants could come online in the next two years including Kinder Morgan's Elba Island LNG in Georgia, Cheniere's second project, Corpus Christi LNG in south Texas, Freeport LNG in Texas and Cameron LNG in Louisiana.

NORTH AMERICAN LNG EXPORT TERMINALS PROPOSED

PROPOSED TO FERC PENDING APPLICATIONS:	PROJECTS IN PRE-FILING:
Pascagoula, MS: 1.5 Bcfd (Gulf LNG Liquefaction) (CP15-521)	PF1. Cameron Parish, LA: 1.18 Bcfd (Commonwealth, LNG) (PF17-8)
Cameron Parish, LA: 1.41 Bcfd (Venture Global Calcasieu Pass) (CP15-550)	PF2. LaFourche Parish, LA: 0.65 Bcfd (Port Fourchon LNG) (PF17-9)
Brownsville, TX: 0.55 Bcfd (Texas LNG Brownsville) (CP16-116)	PF3. Sabine Pass, LA: NA Bcfd (Sabine Pass Liquefaction) (PF18-3)
Brownsville, TX: 3.6 Bcfd (Rio Grande LNG – NextDecade) (CP16-454)	PF4. Galveston Bay, TX: 1.2 Bcfd (Galveston Bay LNG) (PF18-7)
Brownsville, TX: 0.9 Bcfd (Annova LNG Brownsville) (CP16-480)	PF5. Plaquemines Parish, LA: 0.9 Bcfd (Pointe LNG) (PF18-8)
Port Arthur, TX: 1.86 Bcfd (Port Arthur LNG) (CP17-20)	
Jacksonville, FL: 0.132 Bcf/d (Eagle LNG Partners) (CP17-41)	
Plaquemines Parish, LA: 3.40 Bcfd (Venture Global LNG) (CP17-66)	
Calcasieu Parish, LA: 4.0 Bcfd (Driftwood LNG) (CP17-117)	
Nikiski, AK: 2.63 Bcfd (Alaska Gasline) (CP17-178)	
Freeport, TX: 0.72 Bcfd (Freeport LNG Dev) (CP17-470)	
Coos Bay, OR: 1.08 Bcfd (Jordan Cove) (CP17-494)	
Corpus Christi, TX: 1.86 Bcfd (Cheniere – Corpus Christi LNG) (CP18-512)	

Figre 18. North American LNG Import/Export Terminals Approved as of October 23, 2018. Image: FERC

Start-up delays of Cameron LNG, Freeport LNG and Elba Island now make Dominion Energy's Cove Point LNG Liquefaction the sole facility to reach commercial operations in the US in 2018.

Kinder Morgan, which had previously halted construction at Elba Island in advance of the arrival of Hurricane Florence in September 2018, recently revised the start-up of train 1 to the first-quarter of 2019.

Construction on the 2.5 billion tonne/year Elba project, which will add liquefaction and export capabilities to an existing LNG export terminal, began on November 1, 2016. Kinder Morgan expects all 10 of the project's trains to come on line in 2019.

REFINING CONSTRUCTION MARKET

The North American Construction Starts Index, which measures the amount of project activity that has been funded and started construction this year, for September 2018 totaled \$214.58 billion, up 13.7% from a year earlier.

Petroleum Refining construction start activity rose 62.2% to \$5.02 billion from \$3.1 billion a year earlier.

Meridian Energy Group begun construction on the \$600 million Davis Refinery near Belfield, North Dakota, which would process 27,500 barrels/day of Bakken crude to produce gasoline, diesel and naphtha.

SEH Design|Build Incorporated is contracted for the civil construction of the Davis Refinery, which is expected to reach completion in mid-2020.

The US Mid-Continent region will face a heavier-than-usual maintenance slate during the fourth quarter of 2018, according to Oil & Gas Journal.





ExxonMobil's is considering an expansion of its Beaumont Refinery. The project would kick off in 2020 and take about two years to complete. The expansion would involve increasing the refinery's 344,000-barrel-per-day (BBL/d) capacity to 700,000-850,000 BBL/d by adding a third crude unit.

Industrial Info is forecasting \$170 million in refining maintenance projects across four US market regions that are planned for the fourth quarter of 2018.

REFINING PROJECTS

US refiners processed a record volume of crude during the summer months, according to the Energy Information Administration, and refineries across the country are expanding capacities and upgrading equipment to accommodate new products and growing demand.

There are \$1.38 billion in active capital projects in the US Petroleum Refining Industry that are scheduled to begin or finish construction in the fourth quarter 2018, according to Industrial Information Resources.



Figure 19. The top 10 US states for capital refining projects. Image: Industrial Information Resources.

ExxonMobil's nearly \$500 million gasoline hydrotreater addition at its refinery in Beaumont, Texas, began in the second half of 2016 and is set to wrap up by the end of 2018. The 40,000-barrel-per-day (BBL/d) unit, for which Bechtel Group is providing engineering and construction services, is intended to comply with the US government's Tier 3 gasoline requirements, which mandate the sulfur content of gasoline to be reduced from 30 parts per million (ppm) to 10 ppm.

In West Texas, MMEX Resources Corporation expects to finish construction on a \$50 million crude oil refinery in Fort Stockton before the end of 2018. The project, which is the first phase of a planned, \$1 billion refinery complex, features a 10,000-BBL/d crude distillation unit. Jack Hanks, the chief executive officer of MMEX, told The Fort Stockton Pioneer that the facility will produce non-transportation fuels like off-road diesel, naphtha and residual fuel oil in the first phase, and thereafter would make transportation fuels like gasoline and jet fuel.

Flint Hills Resources Limited Partnership, a subsidiary of Koch Industries Incorporated is at work on a pair of upgrades at its Pine Bend Refinery in Rosemount, Minnesota, both of which are expected to wrap up toward the end of 2018: a \$50 million upgrade to Hydrogen Unit 4, which will reduce emissions and increase hydrogen production, and a multi-million-dollar upgrade to Distillate Hydrocracker Unit 29, so it can accept a gas-oil feed from a heavy gas-oil fractionation column, also under construction.







Husky Energy Incorporated's Lima Refinery in Lima, Ohio, has two projects that are set to wrap up by the end of 2018: the \$100 million addition of a sulfur recovery unit, with a capacity of 195 tons per day, and the \$25 million upgrade of a delayed coker unit, which will modify its main fractionation column and replace a pair of coke drums.

Flint Hills and Husky also have several projects set to begin construction at major refineries. At its refinery's East site in Corpus Christi, Texas, Flint Hills is preparing for a pair of projects that are set to begin and end in the fourth quarter for a total spend of \$25 million, which includes an upgrade of its FCCU 2 Unit, which processes 45,000 BBL/d, and upgrade of its crude and vacuum units, which process 60,000 BBL/d and 36,000 BBL/d, respectively.

Husky is preparing for a \$27 million upgrade to its refinery in Superior, Wisconsin, in which it will rebuild the 38,000-BBL/d crude and vacuum unit and 11,000-BBL/d fluid catalytic cracking unit (FCCU). The same refinery was damaged by a tank explosion earlier this year that injured 11, after Husky purchased it last year for \$435 million.

Flint Hills and Husky are among the refiners with more than \$170 million in maintenance projects that are planned for the fourth quarter of 2018, including several at Flint Hills' East site in Corpus Christi and Husky's Lima Refinery.

The record production from refineries resulted in record gasoline stocks at the end of the summer driving season. But John Kemp of Reuters says this likely means less production soon: "The now-plentiful supply of gasoline and, to a lesser extent, distillate implies refiners will have to cut processing more sharply than usual over the next couple of months to avoid creating a glut of refined products."

CANADA DOWNSTREAM CONSTRUCTION MARKET

COMPANY	PROJECT	LOCATION	соѕт	STATUS
Interpipeline	Propane Dehydration and Polypropylene Facility	Redwater, Alberta	\$3.5 billion	Construction has begun
Nova Chemicals	Corunna Expansion and Polyethylene Facility	Sarnia - Lambton	\$2 billion	Construction has begun
Canada Kuwait Petrochemical Company	Propane De-Hydrogentation Facility	Sturgeon County, Alberta	\$3.8 - \$4.2 billion	Waiting on FID
Projectbecancour.ag	Methanol-Urea Plant	Becancour, Quebec	Cost Undisclosed	Waiting on FID
Nautical Energy	Methanol Facility	Grande Prairie, Alberta	\$2 billion	Waiting on FID
LNG Canada	LNG Export	Kiitmat, BC	\$40 billion	Approved

CANADA DOWNSTREAM CONSTRUCTION PROJECTS

Figure 20 Canada Downstream Construction Projects

Canada is becoming an increasingly-attractive area in North America for chemical-related investments. A highly skilled and educated workforce, proximity to export to Asia, a competitive tax system and government subsidies for chemical investments, and cheap and plentiful feedstocks top the list of reasons why investors are considering Canada.





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Figure 21. Alberta Energy Minister Margaret McCuaig-Boyd announces support for energy diversification, making Alberta more competitive for major private investments in the petrochemicals sector. Date: March 12, 2018. Image Credit: Government of Alberta

While news headlines for the petrochemical construction boom have mainly been focused on the US, another boom is beginning in Canada.

There are nearly 100 projects being proposed and researched for Canada, valued at more than \$12 billion, according to the Chemistry Industry Association of Canada (CIAC). While some are facing stiff competition from US jurisdictions, Canada is quick to offer tax incentives to grow this industry.

PETROCHEMICAL DIVERSIFICATION PROGRAM

In Alberta, the province is committing up to \$1 billion to grow its petrochemical industry. The Honorable Margaret McCuaig-Boyd, Minister of Energy for Alberta, told Petrochemical Update the money will be used for loan guarantees, grants and royalty credits to spur more private investments in the sector.

There will be \$500 million in royalty credits for a second round of the Petrochemicals Diversification Program, spread over four years starting in 2020-21.

Another \$500 million is for loan guarantees and grants for a petrochemical feedstock program starting in 2021. "We are encouraging construction of new extraction facilities with \$500 million in loan guarantees and grants through a Petrochemical Feedstock Infrastructure Program which was announced on March 12, 2018," McCuaig-Boyd said.

"This new feedstock program is intended to encourage natural gas midstream projects to support liquids extraction, focusing on ethane recovery, such as building a straddle plant along a pipeline," she added.

Inter Pipeline's \$3.5 billion propane dehydrogenation and polypropylene facility, received \$200 million in funding through the first round of Alberta's Petrochemicals Diversification Program.





INTER PIPELINE



Figure 22. Image: Inter Pipeline has begun detailed construction of its \$3.5 billion Heartland Petrochemical Complex in Strathcona County, near Edmonton. Image Credit: Inter Pipeline

Inter Pipeline has begun construction on Canada's first integrated propane dehydrogenation (PDH) and polypropylene (PP) complex.

The \$3.5 billion Heartland Petrochemical Complex will be in Strathcona County and, once operational in late 2021, will convert Alberta's abundant supply of propane into high value, easy to transport, and recyclable PP.

The Heartland Petrochemical Complex will be designed to convert 22,000 barrels/day of locally sourced, low-cost propane into 525,000 tonnes/year of PP.

The facility design has \$400 million invested to date in engineering, procurement and early civil works, and the company expects to invest \$650 million more by the end of 2018.

"I believe the Canadian energy industry is evolving. In Canada, we have long been very good at extraction and export of oil and gas," said David Chappell, Senior Vice President, Petrochemical Development of Inter Pipeline.

"The next step is for the Canadian industry to move along the energy value chain and produce valuable products that the world wants and needs. Polypropylene is one great example, but there are more derivatives with great potential," Chappell said.

A big advantage for Inter Pipeline is the propane feedstock advantage. Over the long-term the Canadian propane market is expected to be oversupplied. Supply is expected to continue to grow as producers drill for liquids rich gas.

Alberta propane trades at a discount to the Mont Belvieu (Texas) hub price, creating a feedstock cost advantage for Alberta-based propane derivatives.

OTHER MAJOR PETROCHEMICAL INVESTMENTS

Industrial chemical capital expenditures in Canada grew by 7% to just under \$1 billion in Canada, according to the CIAC, but there is room for more growth.





NOVA

NOVA Chemicals plans to spend \$2 billion building a new polyethylene plant near Sarnia and expanding production at the Corunna plant where it makes ethylene. The province is providing a \$100 million grant for the project.

Work is already underway preparing the plant site and construction is expected to take four years to complete. The plant is expected to go into production in late 2021.

NOVA HIGHLIGHTS: PROJECT SCHEDULES

COMPANY/LOCATION	DERIVATIVE UNITS
Genesis Pipeline Extension	Completed 2013
Corunna Revamp	Completed 2014
Corunna All-Ethane Conversion	Completion targeted for 2018
Corunna Second Feed System Connectivity	2018
Moore Emissions Reductions Completion	targeted for 2019
Moore Rail Yard Expansion Completion	targeted for 2018
Rokeby Polyethylene Facility Completion	targeted for 2021

Three other projects have been announced but have not yet made a Final Investment Decision

CANADA KUWAIT PETROCHEMICAL

Canada Kuwait Petrochemical Corp. (CKPC), a joint venture of Pembina Pipeline Corp., Calgary, and Petrochemical Industries Co. KSC (PIC) of Kuwait, has let a contract to Jacobs Engineering Group to provide front-end engineering design services for a proposed 1.2 billion pound/year grassroots, integrated propane dehydrogenation and polypropylene (PP) complex in Sturgeon Count near Edmonton.

This latest contract for CKPC's planned complex follows the JV's previous contract award for the project to Honeywell UOP LLC to license its proprietary C3 Oleflex technology for production of 550,000 tonnes/year of polymer-grade propylene based on a feedstock of 22,000 barrels/day of Alberta-produced propane from Pembina's Redwater fractionation complex and other regional facilities.

First announced in May 2017, the proposed polypropylene complex has a preliminary price tag of \$3.8-4.2 billion.

PROJETBÉCANCOUR.AG

Développement Nauticol Québec Ltée and Entreprise IFFCO Canada Ltée have created ProjetBécancour.ag Limited Partnership for the development of a construction project for a urea and methanol production plant in Bécancour, in the Centre-du-Québec region.

On December 1, 2017, ProjetBécancour.ag submitted a notice of project to the Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques.

If the project is brought to completion, it will be built in the Bécancour Waterfront Industrial Park and could create up to 200 direct jobs within a few years, once the plant begins production.

NAUTICOL ENERGY

Nauticol has announced its intention to build a \$2 billion methanol facility near Grande Prairie.

The project will produce up to 3 million tonnes of methanol per year. Commercial operation for Phase I of this facility is expected in 2021, with Phases II and III set for 2022. The project will create an estimated 1,000 construction jobs.





The facility will use 300 million cubic feet of natural gas per day. The single largest market for methanol is China. Nauticol Energy expects to export much of its product.

LIQUIFIED NATURAL GAS PROJECTS UPDATE -CANADA



Figure 23. LNG Canada is the country's largest private sector investment to date. Image: LNG Canada

After several LNG projects failed to materialize in recent years, Royal Dutch Shell managed to push forward a long-delayed LNG export project in British Columbia, putting Canada on track to see a major construction and export boom.

Royal Dutch Shell gave the green light to the LNG Canada facility on October 2, 2018 pushing it closer to becoming Canada's first LNG export terminal.

LNG Canada is the first large greenfield LNG plant approved in five years and the largest since 2013.

Overall investment for the whole project wasn't disclosed in the Final Investment Decision statements, but was previously put at about \$40 billion.

LNG Canada is a joint venture company comprised of four global energy companies– Shell, PetroChina, KOGAS and Mitsubishi Corporation.

The LNG Canada joint venture is building an LNG export facility in Kitimat, British Columbia, which will initially consist of two LNG trains. The first LNG train is expected before the middle of the next decade.

This project will also see the construction of a natural gas pipeline from northeast B.C. to Kitimat, where a new terminal will process and ship LNG to Asian markets.

LNG Canada is advantaged by access to abundant, low-cost natural gas from British Columbia's vast reserves and the relatively short shipping distance to North Asia, which is about 50% shorter than from the US Gulf of Mexico and avoids the Panama Canal.







Figure 24. Image: Canadian Association of Petroleum Producers

The LNG Plant will be constructed on a large, partially-developed industrial site with existing deep-water port, roads, rail and power supplies.

TransCanada Corporation will build, own and operate the 670-km Coastal GasLink (CGL) pipeline that will connect natural gas from northeastern British Columbia to the export plant in Kitimat.

The joint venture of JGC-Fluor Corporation will be the EPC contractor for LNG Canada and will construct the project on a lump sum basis.

The LNG plant and CGL pipeline will together employ approximately 10,000 people at peak construction with up to 900 people at the plant during the operations of the first phase.

EXPORT

Shell's decision to move forward on the massive LNG Canada project signals confidence that global demand will rise quickly enough to keep up with growing supplies of LNG and opens the region up to a massive export market.

It also opens a new competitive front for the US terminal developers who have raced to invest in LNG export facilities.

The terminal will compete directly for Asian business with a wave of new and planned US LNG terminals.

"Western Canada is seen as an attractive location to develop LNG exports because of its closer proximity to east Asia in shipping distance," Liao said. "LNG exported from Canada also would not have to be subject to the Panama Canal, which has seen some bottlenecks in transits of LNG vessels due to the canal's current reservation booking system."

LONG TERM SUPPLY

Looking ahead, Shell is convinced that there could be a 275 million tonne supply shortage beginning in 2020. "As much as \$200 billion in new investments will be needed to build liquefaction plants around the world as demand "has continued to defy expectations," according to Shell.







While the US has been adding one LNG platform after another, Canada hasn't added any new projects since shale gas burst onto the scene largely because of a long, complicated regulatory process, cost, and needed supply chain developments. Twenty LNG export facilities have been proposed in Canada. 14 in British Columbia, three in Quebec and three in Nova Scotia representing a total proposed export capacity of 257 million tonnes/year of LNG. Since 2011, 24 LNG projects have been issued long-term export licenses, according to Natural Resources Canada.

"The Final Investment Decision taken by our joint venture participants shows that British Columbia and Canada, working with First Nations and local communities, can deliver competitive energy projects," said Andy Calitz, CEO of LNG Canada in a statement.

"This decision showcases how industrial development can co-exist with environmental stewardship and Indigenous interests."

PARTNERS

Each joint venture participant will be responsible to provide its own natural gas supply and will individually offtake and market its share of LNG.

Shell has been a pioneer in LNG for more than 50 years and is involved in every stage of the LNG value chain: from finding the fields, extracting the gas and liquefying it; to shipping LNG and turning it back into gas; to distributing it to customers. Shell has LNG supply projects around the world, as well as interests in and long-term capacity access to regasification plants. Shell Canada Energy is a wholly owned subsidiary of Royal Dutch Shell plc.

PETRONAS is a fully integrated energy company with extensive experience in LNG. Through its wholly owned upstream energy company, Progress Energy Canada Ltd and its partners, PETRONAS is one of the largest natural gas reserves owner in Canada – with most of these reserves in the North Montney natural gas formation in northeast British Columbia. The North Montney LNG Limited Partnership is a wholly-owned entity of PETRONAS.

Mitsubishi Corporation is a global integrated business enterprise with more than 50% share of LNG imported into Japan. Mitsubishi has been investing in LNG since 1969 and has an interest in 11 LNG export projects globally.

PetroChina Company Limited (PetroChina) is China's largest oil and gas producer and distributor, playing a dominant role in the oil and gas industry in China. PetroChina is one of the largest oil companies in the world, and among the Chinese companies with the highest sales revenue in China.

PetroChina's wholly owned and Canada-based subsidiary is PetroChina Canada Ltd., headquartered in Calgary, Alberta. KOGAS is one of the world's largest LNG importers and South Korea's principal LNG provider, operating four LNG import terminals and a nationwide pipeline network. KOGAS has taken a new path of seeking opportunities to participate in the development of international upstream projects, as well as downstream businesses.

Canada's only operational LNG terminal so far is Canaport LNG's regasification import terminal located in Saint John, New Brunswick.

Twenty LNG export facilities have been proposed in Canada. 14 in British Columbia, three in Quebec and three in Nova Scotia representing a total proposed export capacity of 257 million tonnes/year of LNG. Since 2011, 24 LNG projects have been issued long-term export licenses, according to Natural Resources Canada.





GLOBAL DOWNSTREAM CONSTRUCTION MARKET

Demand continues to ride an upswing across the globe with India showing the highest annual growth in the mid-7% range, and Japan the lowest at 1.0% and below, American Chemistry Council Economist Kevin Swift pointed out. Once lower-class

economies are becoming middle class. The US is not the only region with expansion plans to meet this demand.

MIDDLE EAST

The rise of big national oil is coming in the Middle East in 2025 as well, Chang said.

"The oil companies recognize that demand for oil for fuel will likely decline with the rise of electric cars, so they are looking to invest in using their crude for petrochemicals," Chang said.

"They are not going to sit by and let the US take more market share in chemicals with shale gas. The Middle East will usher in a wave of new capacity through massive investments by 2025."

ADNOC has a \$45B investment plan to create a new mixed feed cracker which would triple its petrochemical capacity to 14.4 million tonnes/year by 2025. The investment would also add new downstream chains including construction chemicals, surfactants, detergents, and oil and gas chemicals.

Saudi Aramco has several investments including: a 9 million tonne/year crude oil to chemical complex with SABIC; a \$9 billion cracker and downstream JV with Total; and a JV with ADNOC and Ratnagiri to build a \$44 million refining and petrochemical complex, which will produce 18 million tonnes/year of petrochemical capacity.



Figure 25. The rise of big national oil in the Middle East. Image: ICIS





CHINA

At the same time the added capacity floods the US markets, China will have limited new capacity come online before 2020.

CHINA - NEW CRACKERS

NAPHTHA CRACKING, THE MOST ATTRACTIVE WAY OF ADDING NEW OLEFIN CAPACITY

COMPANY NAME	STATE	FEEDSTOCK	ETHYLENE (KTA)	START TIME
CNOOC AND SHELL PC	HUIZHOU	NAPHTHA	1200	May,2018
ZHEJIANG PETROCHEMICAL	ZHOUSHAN	NAPHTHA	1400	H1, 2019
SHANDONG YUHUANG CHEMICAL	HEZE	NAPHTHA, DIESEL OIL	360	2019
WANHUA CHEMICAL	YANTAI	LPG	1000	2020
SINOPEC ZHONGKE REF. & PC.	ZHANJIANG	NAPHTHA	800	2020
SHENGHONG REFINING & CEMICAL	LIANYUNGANG	NAPHTHA	1100	2020
SINOCHEM QUANZHOU PETROCHEMICAL	QUANZHOU	NAPHTHA	1000	2020
HENGLI PC	DALIAN	NAPHTHA	1500	2020
SINOPEC SABIC TIANJIN PC	TIANJIN	NAPHTHA, ETHANE	300*	2020
SP CHEMICALS	TAIXING	ETHANE	780	2019
LIAONING BORA PETROCHEMICAL	PANJIN	NAPHTHA	1000	2020
SINOPEC-SK WUHAN PC	WUHAN	NAPHTHA	300*	2020
NINGBO HUATAI WEALTHY POLYMER MAT	NINGBO	ETHANE, REFINERY GAS	600	2020
ZHEJIANG SATELL. PC	LIANYUNGANG	ETHANE	1250	2021
FUJIAN GULEI PETROCHEMICAL	ZHANGZHOU	NAPHTHA	800	2021
NORTH HUAJIN CHEMICAL IND.	PANJIN	NAPHTHA	1000	2022

"For many years, many in the industry had a fear that China would flood the market with cheap capacity. This is not as likely anymore due to China's crackdown on pollution. The pollution changes are a game changer for the industry," Chang said.

"China's coal to olefins (CTO) and methanol to olefins (MTO) polyethylene capacity are not as big a factor as previously feared because of the environmental factors and high investment costs," Chang added.

In April 2017, China began air pollution inspections in Beijing, Tianjin and 26 other cities in the Northeast, a result of their '2+26 Plan.'

Stringent environmental regulations have shut down chemical plants – many permanently.

Chemical markets have tightened. Only larger, well-funded players can compete. As a result, it is now unlikely there will be a flood of cheap capacity in China.



CHINA CTO / MTO PE CAPACITY - NOT MUCH THROUGH 2020

COMPANY, LOCATIONS	PE CAPACITY (KT/YEAR)	START-UP	
Yan'an Energy and Petrochemical, Shaanxi	CTO HDPE: 450	2018	
Zhong'an Lianhe Coal Chemical, Anhui	CTO HDPE/LLDPE: 350	Q2 2019	1,7M
Qinghai Damei Coal Industry, Qinghai	CTO HDPE/LLDPE: 300	2019	TONNES/YEAR
Niongxia Baofeng Energy	CTO LLDPE: 320	2019	2010-2020
Shanxi Coking, Shanxi	CTO: HDPE/LLDPE: 300	2020	
Sinopec Guizhou, Guizhou	CTO LLDPE: 300	2021	
Shaanxi Yanchang Coal Yulin, Shaanxi	CTO LDPE: 300	2021	
Jiutai Energy, Inner Mongolia	CTO HDPE/LLDPE:250	2022	2 414
China Power Investment Corp, Inner Mongolia	CTO HDPE/LLDPE:300	2022	Z. TM TONNES/YEAR
Huahong Hongjin Coal Chemical, Gansu	CTO HDPE/LLDPE:200	2022	2021-2024
Shenhua Ningxia/SABIC	CTO LDPE 210, UHMWPE 35	2022	
Shenhua Baotao, Inner Mongolia	CTO LLDPE: 220	2022	
Sinopec, Henan	CTO PE:300	2024	

Figure 26. China CTO/MTO PE capacity near term. Image: ICIS

Just 1.7 m tonnes of new polyethylene capacity is expected between 2018 and 2020, plus 2.5 m tonnes from naphtha crackers through 2020 in China, according to ICIS.

China may see another 2.1 m tonnes of PE capacity from CTO or MTO come online between 2021 and 2024, but the next big wave will be from naphtha crackers through around 2025, according to Chang from ICIS.

Some of that new capacity coming on in China later in the 2020s could be from foreign owned companies as the tariff war pressures new laws into place.

INDIA RISING

OIL

Reliance Industries is considering a plan to boost its oil-refining capacity by about half, Bloomberg reported in November. The refiner is expected to make the final investment decision soon with an aim to start work in 2020.

The proposed plant, to come up at the world's biggest refining complex in Jamnagar, would be able to process as much as 30 million tons of crude a year.

Reliance previously considered expanding its refining capacity in 2013-2014 and sought environment approval but did not move ahead with the plan as it focused on increasing downstream chemicals capacities.

Billionaire Mukesh Ambani, owner of Reliance Industries and Asia's richest man seeks to cement Reliance's dominance in the world's fastest-growing major oil consuming nation as rivals including Saudi Aramco, Abu Dhabi National Oil Co., and Russia's Rosneft PJSC acquire plants in India.

Total SA and Royal Dutch Shell are also expanding into fuel retailing in India.

The International Energy Agency expects India's energy demand to more than double by 2040, making it the single largest source of global growth.

Rosneft and partners acquired the country's second-largest private oil processor.

Plans to build the largest single location refinery complex in the world are already underway with Saudi Aramco and the Abu





Dhabi National Oil Company (Adnoc) owning a 50% stake in the project. The remaining 50 % will be owned by the Indian Consortium.

Capable of processing 1.2 million barrels of crude oil per day (60 million tonnes/year), the project will produce a range of refined petroleum products, including gasoline and diesel, automotive and aviation fuels and a range of petrochemical products.

Shell has restarted retailing gasoline and diesel in the country, while Total partnered the Adani Group to set up LNG import terminals and fuel retailing business. Last year, BP Plc expanded its partnership with Reliance to retail auto fuels.

Demand for fuel in India and the Middle East will make the two regions bigger oil consumers than the European Union by 2030, driven mainly by diesel for trucks and petrochemicals feedstock, according to the IEA.

PETROCHEMICALS

In 2018, Reliance Industries' ramped up its massive Jamnagar petrochemical complex anchored around a 1.5m tonne/year refinery offgas cracker, according to ICIS.

Downstream capacities are 550,000 tonnes/year of linear low density PE (LLDPE), 400,000 tonnes/year of low density PE (LDPE) and 800,000 tonnes/year of monoethylene glycol.

Reliance is nearing full operations at three of its crackers on the West coast of India using imported U.S. ethane – at Dahej, Nagothane and Hazira, according to ICIS. The Hazira cracker was using 100% naphtha, but has been converted to a mixed feed cracker.

Other India PE additions in India have been brought online in the past several months.

ONGC Petro additions Limited (OPaL) started up its 1.1 million tonne/year mixed feed cracker in Dahej in November 2016 and downstream PE lines consisting of a 360,000 tonne/year HDPE/LLDPE swing plant, and a standalone 340,000 tonne/year high density PE (HDPE) plant in the following months. Earlier in 2016, GAIL ramped up its 400,000 tonne/year HDPE/LLDPE swing plant in Pata, Uttar Pradesh, according to ICIS.

As of press time, the India government wants state-run Gail to exit its petrochemical business and focus on its core area that is pipeline.

India economic growth is accelerating with a renewed focus on infrastructure and affordable housing investment by the Modi government, and the full implementation of the Goods and Services Tax (GST), a system that unifies the disparate tax codes of India's 28 states into one federal tax.

This would create huge efficiencies, or rather eliminate huge inefficiencies, in doing business in India and open new regional markets.

MAJOR PETROCHEMICAL INVESTMENTS IN INDIA					
Reliance Industries	Jamnagar petrochemical complex	1.5 million tonne/year offgas cracker	550,000 tonnes/year LLDPE, 400,000 tonnes/ year LDPE and 800,000 tonnes/year of monoethylene glycol.		
Reliance Industries	Dahej	U.S. ethane cracker			
Reliance Industries	Nagothane	U.S. ethane cracker			
Reliance Industries	Hazira	Mixed feed cracker			
ONGC Petro	Dajej	1.1 million tonne/year mixed feed cracker	60,000 tonne/year HDPE/LLDPE swing plant, and a standalone 340,000 tonne/year high density PE (HDPE) plan		
GAIL	Pata, Uttar Pradesh	1.1 million tonne/year mixed feed cracker	400,000 tonne/year HDPE/LLDPE swing plant		





ASIA PAC

The Asia Pacific region accounts for more than 55% of the current \$1.1 trillion global active pipeline of Chemical Processing investments under development, according to Industrial Information estimates.

Among the largest projects in the region is Petroliam Nasional Berhad's (PETRONAS) Refinery and Petrochemical Integrated Development (RAPID) project in Malaysia, which is set to be completed in 2019.

In addition to refining, the project will produce 7.7 million tonnes/year of chemical products. The project includes construction of a steam cracker to produce 1.1 million tonnes/year of ethylene. Construction on the ethylene unit began in 2016 and is scheduled for completion in the middle of 2019.

TRADE WAR / TARIFFS

J.P. Morgan now expects the US will proceed with tariffs on all Chinese goods by the end of 2019, the company said in October 2018. If the prediction is correct, it could spell trouble for the global economy and US investment.

The global economy began to grow in 2016 and has largely maintained that into the beginning of 2018.

The September 2018 global manufacturing PMI (Purchasing Manager's Index) data shows that the major global economies are still in expansion mode except for China. When the manufacturing PMI is above 50, there is expansion.

However, momentum began to decline starting in the summer months for all regions. The global economic upswing is becoming less synchronized, with Europe slowing slightly and China slowing more.

"Emerging markets such as Turkey, Argentina, Brazil and South Africa are being pressured by US interest rate hikes and a stronger US dollar," Chang said.

"The China slowdown, due to tariff and trade concerns, is troubling and bears watching."

"The U.S. chemical industry is nearly dependent on trade. Most U.S. exports go to Canada, Mexico and China. And Mexico is almost 2/3 of the entire U.S. chemical trade surplus." "(US) Growth accelerated meaningfully in 2018 on the back of fiscal stimulus and an improving trade deficit," Dr. David Kelly, Chief Global Strategist for J.P. Morgan said in the 2018 fourth quarter Asset Management Market and Economic Update.

"Moving forward, however, growth should slow as trade numbers worsen, the effects of fiscal stimulus fade, and structural limitations become a drag," Kelly said.

As the US opens trade battles on multiple fronts including China, Europe, Turkey and Japan; business confidence and financial markets will be impacted, analysts warn.

"NEW NAFTA" RELIEF

"At the same time, prospects for the newly agreed upon "new NAFTA" are positive for the US, because Canada and Mexico are the number one and two destinations for US exports," Chang said.

Bringing Canada into an agreement already embraced by Mexico and the US in late August, negotiators agreed on the New NAFTA on September 30, 2018.

The new trade deal is called the United States-Mexico-Canada Agreement (USMCA), refreshing the original agreement in place since 1994.

The American Chemistry Council (ACC) commended the negotiators from the US and Canada, and Mexico for agreeing to update a trade pact that has historically leveraged chemical manufacturing and the highly-integrated, North American supply chain to reduce costs, boost US exports, and inject new growth and job-creation throughout the region.




"The pact appears to include several enhancements long sought-after by the US chemical sector," the ACC said in a statement.

The US chemical sector has capitalized on duty-free trade under NAFTA ever since its inception, more than tripling US chemicals exports to Canada and Mexico – from \$13 billion in 1994, to \$44 billion in 2018. Chemical exports are projected to grow to \$59 billion by 2025, the ACC said.

US CHEMICAL	TRADE 2017							
Sm, excluding	pharmaceuti	cals		Mexico	-			-
	Exports	Imports	Trade Balance	Belgium	-	Marie	a le almost 7/7	of the option
Canada	21.970	18,017	3,959			Lifesha	o is almost 275	of the entire
Mexico	21,068	5,323	15,745	ill rate i		Usche	emical trade sui	pius
China	11,536	15,463	-3,927	- Country				
Belgium	6,882	3,644	5,238	Lamina				
Brapil	6,563	1,991	4,570	south care	-			
Japan	5,843	8,411	-2,570	Popular interior c.a				
South Korea	5,100	5,528	1,852	Netherlands	-			
Netherlands	4.361	2,162	2,199					
Germany	3,261	7,748	-4,467	Singapore				
Singapone	3,126	2,090	1,035		-			
				a di secondo di s				
BY REGION								
Latin America	38,486	10,555	27,931	5-040				
Asia	36,554	37,916	-1,362	and shall be a little				
EU 28	23,307	28,649	-5,342	Contraction of the local division of the loc				
World	130.042	105,314	24,728	- 5670		and at	10000	15000

Figure 27. Image: ICIS, Data: American Chemistry Council

"If NAFTA broke apart, we would see further tariff developments," Chang said. "The new NAFTA provides relief that this healthy trade will continue with America's partners."

IMPACT OF TARIFFS AND TRADE WAR

With the third round of US-China tariffs now in effect, China finished plastics products and US exports of commodity chemicals are beginning to see impacts. The tariff rate goes even higher in January when the 10% US tariffs on \$200 billion in China imports rises to 25%.

	US Tariffs	China retaliation
1st round	25% tariffs on \$34 bn in China imports (no chemicals) – July 5, 2018	25% tariffs on \$34 bn in US imports (no chemicals) – July 5, 2018
2nd round	25% tariffs on \$16 bn in China imports – August 23, 2018	25% tariffs on \$16 bn in US imports – August 23, 2018
3rd round	10% tariffs on \$200 bn in China imports – Sep 24; Rises to 25% on Jan 1, 2019	5-10% tariffs on \$60 bn in US imports
4th round	(Threatened) – tariffs on additional \$267 bn in China imports	



The first round of 25% tariffs on \$34 billion in China imports did not include any chemicals. The second round of 25% tariffs on \$16 billion in China imports, which many trade associations did not think would go through, impacted \$2 billion in US chemicals and plastics exports, according to the ACC.





The third round, 10% tariffs on \$200 billion in China imports, impacted another \$8.8 billion in US exports of these products, the ACC said.

"The big impact will be on China with its finished plastics exports to the US – products such as vinyl flooring, pipes, plastic bags, films and containers," Chang said.

As China finished plastics exports to the US take a hit, it will likely reduce overall Chinese demand for polymer resins to create those finished goods, Chang explained.

SO MUCH POLYETHYLENE

US exports to China of high-density polyethylene (HDPE) and linear low-density polyethylene (LLDPE) were around 500,000 tonnes, or less than 5% of total production in 2017, but US PE exports to China were estimated to hit nearly 2 million tonnes by 2020 pre tariffs, Chang said.

"Looking at 2017 numbers, the percent of total US bulk chemical production actually impacted by China tariffs remains less than 7% for many chemicals. However, China has put tariffs on major grades of US polyethylene just when major capacity is starting up," Chang said.



Figure 29. Tariff impact on US and China chemicals. Image: ICIS

Nearly 7 million tonnes of additional polyethylene capacity are expected in North America from 2016 to 2019 as first wave plants start up. Total polyethylene capacity could increase by another 5 million tonnes by 2022 as second wave plants begin operations.

Nine new crackers are expected to come online in the US by 2020 representing 10.7 million tonnes/year of new ethylene capacity.

An additional 1.4 million tonnes of ethylene is coming online because of cracker expansions for a total of 9.2 million tonnes of additional ethylene capacity in the US Gulf or 35% of existing US capacity by 2019, according to ICIS.

Most of the crackers being built include a polyethylene plant.

"Of the new plants coming online, polyethylene is mostly for export. The US polyethylene market is well supplied, and the market is only growing at US GDP levels," Chang said. "With tariffs in place, we may see companies thinking twice about these large investments."

Less capacity additions elsewhere in China and the Middle East through 2020 will help the US scenario for a little while. But a big wave of new investment in China, the Middle East and India comes around 2025, Chang said.





CHINA THREAT

FOREIGN BUSINESS IN CHINA

The Chinese government has been facing increased pressure over the demands it makes on foreign firms seeking to gain access to the Chinese market. The Trump administration is pointing to unfair practices by Beijing as some of the reasons for the tariffs.

One consequence of the tariffs could be that China attracts more foreign investment.

An example is with auto maker Tesla. China has put an import tariff of 40% on Tesla vehicles compared with an import tariff of 15% for other types of vehicles.

Tesla said it costs 55% to 60% more to make its vehicles than the exact same car made by Chinese producers. The market in China is by far the largest in the world for electric vehicles, Tesla said.

Tesla said it is responding to the heightening tensions and increasing costs by accelerating construction of its Shanghai factory, which the company announced in July 2018.

That announcement came days after Tesla said it was raising prices on its vehicles by 20% in China to respond to the first round of tariffs.

The Shanghai factory is roughly two years from producing vehicles and about five years from pumping out around 500,000 vehicles per year, Tesla said.

GREATER ACCESS TO CHEMICAL INVESTMENT

China is now allowing greater access to its chemicals market to feed plastics, coatings and adhesives as witnessed by two massive investment announcements by companies not based in China.

ExxonMobil Corp signed a deal in September to build a petrochemical complex and liquefied natural gas (LNG) terminal in southern China.

investment -	- ExxonMobil
Integrated cracker complex in Guangdong province - proposal 1.2m tonne/year flexible feed cracker 2 performance PE lines 2 performance PP lines 5 tart-up targeted for 2023 1 would address in the complexity of the start-up targeted for 2023	Chemical capacity growth MTA 35

Figure 30. ExxonMobil investment in China. Image: ICIS

The deal would include an integrated cracker complex in Guangdong province, a 1.2 million tonne/year flexible feed cracker, two performance polyerhylene lines, two performance polypropylene lines. Start-up is targeted for 2023.





Exxon would be one of only a few international oil majors to invest in LNG infrastructure in China.

Exxon's plan comes after a similar agreement announced in July by BASF to build a \$10 billion plant, also in Guangdong. BASF intends to build a world-class Verbund site in South China to serve fast-growing customer industries in the region.

BASF i	ntends to build a world-class	Verbund site in South China
to serv	e fast-growing customer ind	ustries in the region
Steam cracker (planed capwity -1 relition fore p.a of athylene	Limme Ethylene Ethylene gycol noide Sarlactanes Annum. Sarlactanes Annum. SAP Acrylic acid Arylanes Dispersions Oxo-C4 Dispersions Polyola HPPO Hermonication Hermonication Dispersions Polyola Hermonication Dispersions Dispersions Polyola	 100% BASF-oximed and operated Potential investment of up to USS10 billion until around 2000 Investment to evolve in phases Startup of first plants in 2020 all the latest Most advanced Verbund site with smart manufacturing concept Environment, health and safety concept according to BASF's global standards and local laws and regulations Next step: Pre-feasibility study

Figure 31. BASF investment in China. Image: ICIS

The parameters are that it is 100% BASF owned and operated. A potential investment of up to \$10 billion until around 2030 with the investment to evolve in phases.

Startup of first plants would be by 2026 at the latest. The plant would be the most advanced Verbund site with smart manufacturing, environment, health and safety concept according to BASF's global standards.

Local laws and regulations would be applied. The next step for BASF is a pre-feasibility study.







CONSTRUCTION COSTS ANALYSIS

CRACKER CONSTRUCTION COSTS ANALYSIS

Pathfinder LLC provided observations and recommendations for estimating Ethylene Projects in the upcoming 5-year timeframe by evaluating some industry available information. The following is Pathfinder's analysis:

Over the past five years, US Ethylene projects have ridden a wave of new construction spurred on by US shale gas production and cheap ethane and propane which are ethylene production feedstocks. Most of the additional capacity is produced for export to Asia (China and India) to cover plastic (polyethylene) demand.

In support of this demand, there has been a dramatic increase in capital project execution over this same time period. *The number of petrochemical projects constructed simultaneously had significant impact in the marketplace. "Time to market" was the primary driver for these projects as everyone wanted to capture the early market opportunity. This resulted in a fast track planning and construction driven project environment.*

This strategy caused many plants to be built with higher cost and schedule delays. Specific impacts resulted from:

- 01. Labor shortages
- 02. Raw material shortage (steel, alloys)
- 03. Immature design (Weak FEL) with implications in EPC scope and change orders
- 04. Poor planning during construction which impacted labor productivity
- 05. Competitive labor market to hire skilled workers

During the first two years of the wave, the US petrochemical industry maintained an advantage with its shale gas price. Plants in Asia and Europe mostly use naphtha as feedstock which is a derivative of crude oil. With the decline of crude oil prices in 2014 - 2015, some projects were delayed or canceled with the changing economics of naphtha vs shale gas.

Stability of crude oil pricing coupled with a forecast increase in demand is motivating a new wave of ethylene and propylene derivatives. Petrochemical producers are confident that the availability of cheap gas is a long-term event. Even though, potential return from new ethylene plants is not as high as previous periods, there are still market opportunities that can be covered from new US projects. Even with the above described improved outlook, producers must be aware that factors which impacted previous project cost are still there and must be considered in planning new projects.

The construction Industry consistently struggles with an upward trend in cost. The trend results from multiple contributing factors including those listed above. The trend has driven many Owner organizations to defer, suspend, or cancel capital projects.

In other down periods, reduced activity has stimulated a "buyers' market" wherein Suppliers and Contractors react to reduced activity with competitively priced proposals and willingness to share risk/reward. This does not appear to be the case during the recent extended period when rather than reducing prices, contractors have cutback staffing and capabilities to reduce losses until the long-term effect of changing economics becomes more predictable.

In any event, cost impacts can be confusing. Reduced activity in some areas, is being replaced by new projects associated with the shift toward other more profitable energy sources and emerging new opportunities related to the availability of reasonably priced sources of oil and gas. New projects include multiple business sectors.

It now appears that the power and energy and petrochemical industries are poised to take advantage of currently attractive natural gas prices with a flurry of new plant construction. While new projects would seemingly be good news for the industry, the current increase is having the immediate impact of adding to the labor shortage which in turn adds to project cost and schedule delay.





In 2017, the cost of labor and material escalated both due to short term events, and continuing longer term impacts like declining or varied capital investment. These impacts have caused craft labor to seek alternative industries, reducing the labor pool associated with the hydrocarbon industries, necessitating owners and contractors to offer attraction and retention premiums to secure the levels required to support large to mega-scale capital projects.

In addition, while wage rates have remained reasonably stable, there has been a notable decrease in productivity leading to the need to spend more hours on both direct and indirect activities.

Foreseeable marketplace and feedstock cost conditions have stimulated particular interest in sponsorship, investment and construction of large to mega-scale petrochemical facilities such as ethylene plants.

Given the level of interest, these cost estimate(s) were prepared to provide a point of reference for participants in ethylene projects. The data was prepared by normalizing six recent estimates and should provide insight into how cost has been impacted by 2017 events and how current trends may impact the future.

This research focuses on evaluating the anticipated cost of constructing a 1.5 million tonne/year year ethylene facility in either the Gulf Coast or in the northeast region of the US.

This type of analysis is challenging in that available reference information is subject to variations in plant size, process design, ultimately selected site conditions, technical standards and other considerations such as tax abatement incentives, proximity to feedstock supply, customer base/consumers, logistics, etc.

The team collected relevant data associated with recent ethylene projects, to represent the best estimating experience and data of the organizations involved in the reference projects. The data has been normalized to align construction timing and plant size to establish a representative base case for a hypothetical 1.5 million tonne/year facility based on current market conditions and cost trends.

The above-mentioned variations in plant scope and conditions makes it impossible to produce a highly accurate single point estimate without pinpointing a particular plant configuration. However, using estimates for clear scope variances and "most common" design information, the team was able to establish a minimum / maximum cost range for the 1.5 million tonne/-year facility and subsequently able to condition the cost to fit two distinct geographic locations in the US.

The following table presents a representative base case for constructing a mega-scale ethylene production facility on the Gulf Coast of the US in 2017 dollars.

1.50 Million Ton per year USA Gulf Coast Ethylene Facility 1/1/2017 to 12/31/2017

Cost Categories	Qty	UoM	Material	M-H's	M-H Rate	Labor Cost	Minimum Total	Material	M-H's	M-H Rate	Labor Cost	Maximum Total
Major Equipment (M.E.)												
Columns c/w trays	70	EA	292,388,671	31,850	31.40	1,000,090	293,388,761	380,105,272	41,405	40.82	1,690,152	381,795,424
Drums / Vessels	67	EA	16,536,026	26,850	31.40	843,090	17,379,116	21,496,833	34,905	40.82	1,424,822	22,921,655
Pumps	98	EA	14,586,472	13,800	31.40	433,320	15,019,792	18,962,413	17,940	40.82	732,311	19,694,724
Compressors / Fans / Blowers	25	EA	79,711,416	100,600	31.40	3,158,840	82,870,256	103,624,840	130,780	40.82	5,338,440	108,963,280
Heat Exchangers	91	EA	17,386,317	12,750	31.40	400,350	17,786,667	22,602,212	16,575	40.82	676,592	23,278,803
Tanks	7	EA	12,123,821	2,850	31.40	89,490	12,213,311	15,760,967	3,705	40.82	151,238	15,912,205
Material Handling	4	EA	13,595,999	3,600	31.40	113,040	13,709,039	17,674,799	4,680	40.82	191,038	17,865,836
Water Treatment	10	EA	4,189,213	1,900	31.40	59,660	4,248,873	5,445,977	2,470	40.82	100,825	5,546,802
Miscellaneous Equipment	19	EA	46,584,699	15,350	31.40	481,990	47,066,689	60,560,109	19,955	40.82	814,563	61,374,672
Electrical Equipment	29	EA	12,556,814	5,750	31.40	180,550	12,737,364	16,323,859	7,475	40.82	305,130	16,628,988
Instrumentation Devices (Tagged)	5,400	EA	14,725,360	129,000	31.40	4,050,600	18,775,960	19,142,968	167,700	40.82	6,845,514	25,988,482
Freight		ALLOW	16,003,650				16,003,650	20,804,745				20,804,745
Vendor Assistance		ALLOW	1,287,140				1,287,140	1,673,282				1,673,282
Total Major Equipment (M.E.)			541,675,597	344,300		10,811,020	552,486,617	704,178,276	447,590		18,270,624	722,448,900
Removals / Demolition		ALLOW	6,524,716	60,000	29.63	1,777,800	8,302,516	8,482,130	78,000	38.52	3,004,482	11,486,612
Site Earthmoving / Improvements	1,200,000	СҮ	25,629,032	600,000	29.63	17,778,000	43,407,032	33,317,742	780,000	38.52	30,044,820	63,362,562
Piling	6,000	LF	6,446,014	120,000	29.63	3,555,600	10,001,614	8,379,818	156,000	38.52	6,008,964	14,388,782
Buildings	60,000	SF	6,446,014	180,000	29.63	5,333,400	11,779,414	8,379,818	234,000	38.52	9,013,446	17,393,264
Concrete	84,000	СҮ	34,486,785	140,000	29.63	4,148,200	38,634,985	44,832,820	182,000	38.52	7,010,458	51,843,278
Refractory / Fireproofing		ALLOW	4,680,291	6,000	29.63	177,780	4,858,071	6,084,379	7,800	38.52	300,448	6,384,827
Structural Steel / Platforms	9,000	TON	28,019,649	240,000	29.63	7,111,200	35,130,849	36,425,543	312,000	38.52	12,017,928	48,443,471
Piping systems	780,000	LF	160,018,669	3,000,000	29.63	88,890,000	248,908,669	208,024,270	3,900,000	38.52	150,224,100	358,248,370
Insulation		ALLOW	38,776,998	48,000	29.63	1,422,240	40,199,238	50,410,097	62,400	38.52	2,403,586	52,813,683
Electrical / Instrumentation	4,200,000	LF	10,079,971	1,200,000	29.63	35,556,000	45,635,971	13,103,963	1,560,000	38.52	60,089,640	73,193,603
Painting / Coatings		ALLOW	2,583,365	72,000	29.63	2,133,360	4,716,725	3,358,375	93,600	38.52	3,605,378	6,963,753
Other Miscl Costs		ALLOW	13,418,642	120,000	29.63	3,555,600	16,974,242	17,444,234	156,000	38.52	6,008,964	23,453,198
Bulk Material Costs			337,110,145	5,786,000		171,439,180	508,549,325	438,243,188	7,521,800		289,732,214	727,975,402
Fringe Benefits / Payroll Burdens						50,817,185	50,817,185				66,062,341	66,062,341
Consumables / Small Tools						19,448,880	19,448,880				25,283,544	25,283,544
Field Supervision & Expenses				1,215,000	37.81	45,939,150	45,939,150		1,579,500	49.15	59,720,895	59,720,895
Field Establish't (Trailers, Toilets)			7,768,910	240,000	29.16	6,998,400	14,767,310	10,099,583	312,000	37.91	11,827,296	21,926,879
Support Labor (logistics / clean up)			1,293,045	600,000	30.24	18,145,620	19,438,665	1,680,959	780,000	39.32	30,666,098	32,347,056
Fuel			77,795,525	175,000	30.24	5,292,473	83,087,998	101,134,183	227,500	39.32	8,944,279	110,078,461
Heavy Lift Cranes			6,491,830	6,000	30.24	181,456	6,673,287	8,439,380	7,800	39.32	306,661	8,746,040
Scattolding			649,185	300,000	29.16	8,746,980	9,396,165	843,941	390,000	37.90	14,782,396	15,626,337
lemporary field utilities						6,491,830	6,491,830				8,439,380	8,439,380
laxes on Plant Hire consumables				120.000	01.00	6,491,830	6,491,830		156.000	105 22	8,439,380	8,439,380
H O Construction Support				120,000	81.02	9,722,400	9,722,400		156,000	105.33	12,639,120	12,639,120
Contractor Fee						64,652,235	64,652,235				84,047,906	84,047,906
Overtime - Shiftwork						12,930,445	12,930,445				16,809,579	16,809,579
BAR Insurance & Performance Bonds						19,422,275	19,422,275				25,248,957	25,248,957
Other Costs						6,491,830	6,491,830				8,439,379	8,439,379
Freight (Bulk Materials)						9,045,990	9,045,990				11,759,787	11,759,787
Contingency						128,405,630	128,405,630				166,927,319	166,927,319
Indirect Costs			93,998,495	2,656,000		419,224,611	513,223,106	122,198,044	3,452,800		560,344,316	682,542,360
Total Construction Cost			972,784,237	8,786,300		601,474,811	1,574,259,048	1,264,619,508	11,422,190		868,347,154	2,132,966,662
Detail Design / Engineering		M-H's		1,200,000		195,432,850	195,432,850		1,560,000		254,062,705	254,062,705
Project Management & Controls Procurement - Subcontracts &		M-H's M-H's		100,000		19,543,285	19,543,285		130,000		25,406,270	25,406,270
P.O.'s EPC Warranty						12,921,180	12,921,180				16,797,534	16,797,534
EP Fee						65,144,285	65,144,285				84,687,570	84,687,570
S/T				1,400,000		312,584,885	312,584,886		1,820,000		406,360,349	406,360,349
Total Project Cost			972,784,237	10,186,300		914,059,695	1,886,843,933	1,264,619,508	13,242,190		1,274,707,503	2,539,327,011
EPC Cost per Ton							\$1,258					\$1,693
Cost per Major Equipment 420 Items							\$4,492,486					\$6,046,017
Cost per Major Equipment 5,820 Tagged Items (includes Instrumentation Devices).							\$324,200					\$436,310

Etimate Basis & Remarks:

Exclusions & Qualifications

Owner Costs (Engineering, Oversight & 3rd party Inspection) Spare Parts Initial Start Up Materials Soil Testing Based on 45 hour workweek Above costs reflect 4th Q 2017 values







This cost model assumes that the plant is being built on the Gulf Coast of the US using nonunion labor. Industry experience demonstrates that building the same facility at other locations will impact the cost, and differences must be evaluated on a case by case basis.

For example, building the plant in the northeast US using union labor will result in higher wage rates, and additional work hours associated with work rules, variations in craft productivity, etc. But with the poorer productivity now being experienced in the Gulf Coast these tend to even themselves out.

The selection of the US Gulf Coast for the base case is consistent with industry trends. Typically, the Gulf Coast is used for this type of modeling with the intent of applying variations in craft productivity, wage rates and other factors associated with large scale construction. This practice/trend is based on the assumption that the Gulf Coast offers good weather conditions, ability to attract a qualified work force and an adequate level of Construction support and logistical access. In simple terms, the Gulf Coast offers a standard case that can be contrasted with other locations to identify the impact of less desirable conditions.

The following tables that can be used to tailor an estimate to a particular location, work force makeup and projected productivity based on a composite of industries, including heavy and light industrial, pharmaceutical, commercial buildings.

STATE / CITY	OPEN SHOP / NON-UNION WORKERS	UNION WORKERS
Louisiana	1.00	1.10 – 1.15
Ohio (Cleveland)	1.05 – 1.10	1.15 – 1.20
Ohio	1.05	1.10 - 1.15
Pennsylvania (Philadelphia / Pittsburgh)	1.10 - 1.15	1.20 - 1.30
Pennsylvania	1.05 - 1.10	1.10 - 1.20
Texas (Dallas / Houston)	1.05 - 1.10	1.10 - 1.20
Texas (Gulf Coast) - Base Case this includes Gulfport, Baton Rouge, New Iberia, Lake Charles, Beaumont, Port Arthur, Baytown, Texas City and Victoria: (Note: in certain cases i.e. large projects with a lot of repeat / similar work activities: productivity could be 0.90 – 1.00 say an average of 0.95)	1.00	1.10 – 1.15 (typically all work is completed on open shop basis)
West Virginia	1.00 - 1.05	1.00 - 1.15

Average Open Shop Wage Rates US Gulf Coast): 3rd Q 2017:

Abbreviations FB/H = Fringe Benefits - Holidays WCI = Workers Compensation Insurance Average F&S / FICA = Federal & State Unemployment / FICA ST&C = Small Tools & Consumables

SS = Safety Supplies ST = Sub Total HO & S & P = Home Office Support & Profit THR (W/O per Diem)* = Total Hourly Rate without per diem per Diem)







Average Union Wage Rates (Pennsylvania): 3rd Q 2017:

Abbreviations

FB/H = Fringe Benefits - Holidays
WCI = Workers Compensation Insurance Average
F&S / FICA = Federal & State Unemployment / FICA
ST&C = Small Tools & Consumables
SS = Safety Supplies
ST = Sub Total
HO & S & P = Home Office Support & Profit

THR (W/O per Diem)* = Total Hourly Rate without per diem per Diem)

	Trade / Skill	Base Hourly Rate	FB/HWP Average 3.25%	WCI Average 16.50%	F&S / FICA Average 15%	ST&C \$3.85	SS 2.5%	ST	HOS & P 15%	THR (W/O)* per diem)
1	Carpenter (Journeyman)	28.82	0.94	4.76	4.32	3.85	0.72	43.41	6.51	49.92
2	Mason / Bricklayer (Journeyman)	28.66	0.93	4.73	4.30	3.85	0.72	43.19	6.48	49.66
3	Concrete Finisher	21.90	0.71	3.61	3.29	3.85	0.55	33.91	5.09	38.99
4	Equipment Operator (Heavy Crawlers / Cranes)	29.19	0.95	4.82	4.38	3.85	0.73	43.91	6.59	50.50
5	Electrician (Journeyman))	32.12	1.04	5.30	4.82	3.85	0.80	47.93	7.19	55.12
6	Instrumentation Installer (Journeyman)	32.12	1.04	5.30	4.82		0.80	44.08	6.61	50.70
7	Insulator (Journeyman)	27.39	0.89	4.52	4.11	3.85	0.68	41.44	6.22	47.66
8	lronworker (Journeyman)	29.14	0.95	4.81	4.37	3.85	0.73	43.84	6.58	50.42
9	Laborer	19.57	0.64	3.23	2.94	3.85	0.49	30.71	4.61	35.32
10	Millwright (Journeyman)	31.33	1.02	5.17	4.70	3.85	0.78	46.85	7.03	53.88
11	Oiler / Mechanic (Journeyman)	29.40	0.96	4.85	4.41	3.85	0.74	44.20	6.63	50.83
12	Pipefitter (Journeyman)	31.37	1.02	5.18	4.71	3.85	0.78	46.91	7.04	53.94
13	Painter	24.37	0.79	4.02	3.66	3.85	0.61	37.30	5.59	42.89
14	Refractory (Journeyman)	28.90	0.94	4.77	4.34	3.85	0.72	43.52	6.53	50.04
15	Rebar Installer	28.53	0.93	4.71	4.28	3.85	0.71	43.01	6.45	49.46
16	Scaffolder	24.03	0.78	3.96	3.60	3.85	0.60	36.83	5.52	42.36
17	Truck Driver / JLG Lift	21.83	0.71	3.60	3.27	3.85	0.55	33.81	5.07	38.88
18	Welder (Journeyman)	31.42	1.02	5.18	4.71	3.85	0.79	46.97	7.05	54.02







Abbreviations

FB/H = Fringe Benefits - Holidays
WCI = Workers Compensation Insurance Average
EA = Each
LF = Lineal Feet
F&S / FICA = Federal & State Unemployment / FICA
M-H = Man Hours
ST&C = Small Tools & Consumables
SS = Safety Supplies
ST = Sub Total
HO & S & P = Home Office Support & Profit
**THPR (W/O per Diam) = Total Hourly Rate without per second s

****THR (W/O per Diem) =** Total Hourly Rate without per diem per Diem)

	Trade / Skill	Base Hourly Rate	FB/HWP Average 4.25%	WCI Average 16.50%	F&S / FICA Average 15%	ST&C \$4.35	SS 2.5%	ST	HOS & P 15%	THR (W/O)** per diem)
1	Carpenter (Journeyman)	35.30	1.50	5.83	5.30	4.35	0.88	53.16	7.97	61.13
2	Mason / Bricklayer (Journeyman)	35.15	1.49	5.80	5.27	4.35	0.88	52.94	7.94	60.88
3	Concrete Finisher	26.83	1.14	4.43	4.02	4.35	0.67	41.44	6.22	47.65
4	Equipment Operator (Heavy Crawlers / Cranes)	35.76	1.52	5.90	5.36	4.35	0.89	53.79	8.07	61.85
5	Electrician (Journeyman))	39.35	1.67	6.49	5.90	4.35	0.98	58.75	8.81	67.56
6	Instrumentation Installer (Journeyman)	39.35	1.67	6.49	5.90	4.35	0.98	58.75	8.81	67.56
7	Insulator (Journeyman)	33.45	1.42	5.52	5.02	4.35	0.84	50.60	7.59	58.19
8	lronworker (Journeyman)	35.80	1.52	5.91	5.37	4.35	0.89	53.84	8.08	61.91
9	Laborer	23.99	1.02	3.96	3.60	4.35	0.60	37.52	5.63	43.15
10	Millwright (Journeyman)	38.44	1.63	6.34	5.77	4.35	0.96	57.49	8.62	66.12
11	Oiler / Mechanic (Journeyman)	36.06	1.53	5.95	5.41	4.35	0.90	54.20	8.13	62.33
12	Pipefitter (Journeyman)	38.43	1.63	6.34	5.76	4.35	0.96	57.48	8.62	66.10
13	Painter	29.85	1.27	4.93	4.48	4.35	0.75	45.62	6.84	52.47
14	Refractory (Journeyman)	35.40	1.50	5.84	5.31	4.35	0.89	53.29	7.99	61.29
15	Rebar Installer	34.95	1.49	5.77	5.24	4.35	0.87	52.67	7.90	60.57
16	Scaffolder	29.48	1.25	4.86	4.42	4.35	0.74	45.10	6.77	51.87
17	Truck Driver / JLG Lift	26.94	1.15	4.45	4.04	4.35	0.67	41.60	6.24	47.84
18	Welder (Journeyman)	38.47	1.63	6.35	5.77	4.35	0.96	57.53	8.63	66.16







CLICK

* Application of the appropriate location specific factors, provides a reasonable assessment of how costs will differ. In reviewing the resultant estimate, it is important to note that achieving a reasonable level of estimate accuracy will require not only consideration of high-level adjustments, such as wage rates and estimated productivity, but also consideration of review of project specific conditions that can significantly impact cost. Perhaps the most significant factor to be considered is the availability of a qualified work force. In 2017, resource availability was a point of discussion for virtually any new project. Locating a new plant in an area already identifying labor shortages creates a multifaceted risk of cost increase including per diem cost, bonus wages, lost productivity, excess overtime, etc. This should all reflected in the Project Execution Plan (PEP) which is also an integral aspect of the estimate. The scope of work and supporting data outlined above provides the "what" will be built, but the PEP provides the "how" and in today's marketplace it is equally as important as the "what".

As a first step, Compass completed a detailed assessment of both labor and material escalation that occurred in 2017. A subset of this information is provided below.

As the team analyzed the 2017 data, it was clear that a notable impact, (particularly on the Gulf Coast), is recent extreme weather resulting in both a shortage of qualified labor and an increased level of construction activity associated with repair work.

While this impact can be viewed as temporary, a recent report estimates that the impact over the next six months will range from 5% to 10% for construction support equipment and other indirect costs, and 3.5% to 6.5% increase for craft labor.

While the northeast US is not expected to see this level of increased labor cost, it is clear that there will be impact relative to bulk materials resulting from increased repair activity on a national basis. This impact is expected to range from 2.5 % to 5% for all projects, including those in the northeast.

Based on the above considerations and a variety of other potential events, the team established a look ahead escalation table that can be used to model potential escalation for calendar years 2018, 2019, and 2020.

	1st Q 2018	2nd Q 2018	3rd Q 2018	4th Q 2018	Total for 2018	1st Q 2019	2nd Q 2019	3rd Q 2019	4th Q 2019	Total for 2019	1st Q 2020	2nd Q 2020	3rd Q 2020	4th Q 2020	Total for 2020
US Gulf Coast															
Materials	1.50	1.50	1.25	1.00	5.25	1.00	1.00	1.00	1.00	4.00	0.90	0.90	0.90	0.80	3.50
Labor	1.50	1.50	1.25	1.25	5.50	1.25	1.00	1.00	1.00	4.25	0.90	0.90	0.90	0.80	3.50
US North East															
Materials	1.25	1.00	1.00	1.00	4.25	1.00	1.00	1.00	1.00	4.00	0.80	0.80	0.80	0.80	3.20
Labor	1.25	1.00	1.00	1.00	4.25	1.00	1.00	1.00	1.00	4.00	0.80	0.80	0.80	0.80	3.20

2018, 2019 & 2020 Escalation Forecast

While the level for the Gulf Coast is slightly higher than that in the northeast, reflecting the more direct impact of weather events (hurricanes, flooding), both geographic locations reflect a level of increase that represents further challenges for the industry.

It is clear that that the seemingly endless escalation of construction costs is not limited to a single event or short-term impacts but also includes potentially more significant circumstances such as a diminishing pool of experienced/qualified work force, the industry's failure to anticipate and accommodate cyclical marketplace conditions and a failure to apply innovation and technology in an effective manner.

These topics have a negative influence on industry participants that manifests itself as a continual deterioration in construction productivity, performance and associated cost effects. While the overall prognosis is somewhat disconcerting, given decades of deteriorating, or, at best unchanged performance, it is becoming clear to industry leadership that focus on improvement and innovative solutions is appropriate.

are starting to show results. Unfortunately, long term solutions such as technology advancement and revised construction processes, will take time and are unlikely to have any material impact on the current generation of ethylene projects.





A look at current conditions leads to the conclusion that the rate of escalation will slow or at least stabilize as the impact of recent weather events is fully absorbed and the three-year outlook is expected to be as presented in exhibit 7.

In any event, while the analysis presented in this article may be utilized as a basis/input to development of ethylene project cost estimates, there is no substitute for thorough marketplace and labor availability assessments, realistic consideration of project specific risk factors and effective application of risk analyses, such as Monte Carlo Simulation based techniques to arrive at a reasonable level of cost estimate accuracy and predictability upon which alternatives can be analyzed and informed business decisions can be made.

LABOR MARKET IMPACT

2020 will be a peak year for utilized labor man-hours in the US, surpassing the previous peak of 2015.

New labor "hot spots" are emerging, as old ones continue to accelerate labor demand. Among these areas are Lake Charles, Louisiana, and Corpus Christi, Texas, according to analysis by Industrial Info.

Over the past few years, Lake Charles and Corpus Christi have had challenging labor situations, with limited local labor supply because of population and demographic challenges.

More than \$32.5 billion in projects are planned to kick off in the greater Lake Charles area between the end of 2019 and the end of 2020, according to Industrial Info.

Among these are several planned LNG production plants, including Lake Charles LNG Export LLC's plan to construct a plant beginning in 2019. The facility initially would have a total inlet capacity of 2.6 billion cubic feet per year to produce 5 million tons per year of LNG. In addition, construction of two additional production trains could occur, with construction of the second kicking off in 2020.

Also, on the books is Lake Charles Methanol LLC's planned coke-to-methanol facility. The plant would process petroleum coke into 1 million tonnes/year of methanol, along with 400,000 tons/year of sulfuric acid. Construction is planned to kick off in the first half of 2019 and last into 2021. Fluor Corporation is the EPC.

LNG projects also are affecting Corpus Christi's labor market. Cheniere Energy has begun construction on Train 3 of its Corpus Christi liquefaction terminal, which is expected to last through 2022.

Also in the Corpus Christi area, Exxon Mobil Corporation and Saudi Basic Industries Corporation are planning to construct a grassroot petrochemicals complex.

The facility would produce an estimated 3.96 billion pounds/year of ethylene, along with monoethylene glycol (MEG), high-density polyethylene (HDPE), and linear low-density polyethylene (LLDPE). The project could kick off construction in the second half of 2019 and last through 2022.

Because of the increased amount of project activity caused by these and other projects in the Corpus Christi area, Industrial Info predicts dramatic labor shortages and strong competition for travelers.

Industrial Info also is seeing strong project activity in the Brownsville and Beaumont areas along the Texas Gulf Coast during this time. With the amount of project activity in Beaumont, Industrial Info predicts the area will require more man hours than at any time in history.

Among the project activity in the area is ExxonMobil's possible expansion of its Beaumont Refinery. The project would kick off in 2020 and take about two years to complete. The expansion would involve increasing the refinery's 344,000-bar-rel-per-day (BBL/d) capacity to 700,000-850,000 BBL/d by adding a third crude unit.

In Port Arthur, Texas, in the same market zone, Motiva Enterprises is considering constructing a grassroot petrochemicals complex, which could kick off construction in 2020, taking up to four years to complete.

Several large maintenance turnarounds are also on the books for the area 2020. Among these is Huntsman Corporation's





first-quarter turnaround of its propylene oxide (PO) and methyl tert-butyl ether (MTBE) unit in Port Neches. In total, Industrial Info is tracking more than \$600 million in maintenance projects planned to kick off in 2019 and 2020 in the Beaumont-Port Arthur area.

In certain areas, Industrial Info expects to see full employment and shortages in many crafts in the coming years and has a Labor Market Analysis tool that can provide guidance on ongoing wage rates for this and other regions.

In areas where the labor shortage is high and there is an increased need for travelers, recruitment, estimating, sourcing and category managers can use Industrial Info's 90th-percentile wage bracket, or in extreme cases HSW, Highest Surveyed Wage which is the highest surveyed wage gathered in the past 90 days and expect to pay the highest per-diems as quantified in Industrial Info's Labor Forecast.

In those with local utilization rates of 75% or greater, employers should expect to pay the 75th percentile and the average per-diem, with expected staff shortfalls. In the metropolitan areas with ample labor supply, employers should expect to pay the 25th or 50% percentile wages without per-diem.

"We have seen contractors using base wage rates between the 10% and the 25% percentiles to 'get the job' however they are losing employees at an alarming rate and have poor employee retention that causes project delays and poor productivity," said Tony Salemme Industrial Info's Vice President of Western U.S. Labor Risk Assessment, Association, Government Markets. "Owners must remember that the 25% percentile base wage rate means that 75% of the contractors are paying more for their journeymen and therefore 'travelers' and journeymen will jump to a higher paying project."

ARE CALIFORNIA'S CONTRACTOR REGULATION CHANGES A SIGNAL OF LABOR COST CHANGES TO COME?

The California Supreme Court made it harder for employers to classify their workers as independent contractors. Instead, it would force companies to classify these independent contractors as employees.

The Supreme Court of California established new rules on April 30, 2018 for determining whether a worker is an independent contractor or an employee for purposes of California's Industrial Welfare Commission (IWC) Wage Orders.

The Wage Orders set forth California's requirements for minimum wage, overtime pay, record keeping, and meal and rest periods, among other wage and hour obligations.

In Dynamex Ops. West, Inc. v. Superior Ct., the California Supreme Court held that a worker will be considered an employee of the "hiring entity" for purposes of the Wage Orders unless the "hiring entity" can establish all three of the following factors:

The worker is free from the control and direction of the hiring entity in connection with the performance of the work, both under the contract for the performance of the work and in fact

The worker performs work that is outside the usual course of the hiring entity's business

The worker is customarily engaged in an independently established trade, occupation, or business

The "hiring entity's" failure to prove any one of these three prerequisites will be enough to establish that the worker is an employee for purposes of the Wage Orders.

Many construction hauling trucks are operated by independent contractors.

Worker classification is the core issue in recent labor disputes between unions and trucking firms serving the Los Angeles and Long Beach ports.

Reclassification will derail the plans of roughly 79% of independent contractors in California who prefer it over traditional employment, according to the U.S. Bureau of Labor Statistics.

The ruling also dramatically impacts established businesses throughout California.





"Reclassifying a worker as a traditional employee triggers a deluge of regulatory requirements, liability and taxes and fees that are placed on the employer, including payroll taxes and contributions to Social Security and workers' compensation," explains journalist Gene Wunderlich in California newspaper "The Press Enterprise.

US MAINTENANCE & RELIABILITY MARKET

MORE THAN \$1 BILLION WORTH OF MAINTENANCE TURNAROUND-RELATED PROJECTS IN THE US CHEMICAL PROCESSING INDUSTRY ARE SCHEDULED TO KICK OFF BETWEEN FOURTH-QUARTER 2018 AND THE END OF FIRST-QUARTER 2019.

More than 75% of that amount comes from the US Southwest region, where the Gulf Coast is witnessing a boom in chemical-related projects, according to Industrial Info.



Figure 32. Image: The top 10 U.S. states for maintenance-related chemical projects that are set to kick off before the end of March 2019. Industrial Info

These projects are subject to sudden changes, and plenty of factors could alter their content or delay their start dates.

These projects include an estimated \$785 million in projects in Texas and Louisiana, such as Chevron Phillips ethylene unit turnaround at its olefins and aromatics plant and BASF SE's ethylene unit turnaround at its petrochemical plant, both in Port Arthur, Texas.

Chevron's project kicked off in September and BASF's project is expected to kick off in January. The units produce roughly 1.8 billion and 2.4 billion pounds per year of ethylene, respectively; the BASF unit also produces 694 million pounds per year of propylene.

Also, on the Texas Gulf Coast, INVISTA, a subsidiary of Koch Industries, kicked off a September turnaround on three adipic acid units at a resins plant in Victoria, which produces a combined 838 million pounds/year. The 30-day turnaround, which includes 15 days of mechanical work, kicked off in September.

Shintech Louisiana, a subsidiary of Shin-Etsu Chemical Company Limited, has three six-week maintenance turnarounds that kicked off in October at its vinyls production plant in Plaquemine, Louisiana: VCM Unit 1 and EDC Unit 1, which produce about 2.25 billion pounds/year of vinyl chloride monomer (VCM) and 2.69 million pounds/year ethylene dichloride (EDC); Chlor-Alka-li Unit 1, which produces 642,000 tons/year of chlorine and 702,000 tons/year of sodium hydroxide (caustic soda); and the utilities area, which includes major electrical equipment and boilers.





Figure 33. US Chemical Maintenance Projects by Sector. Image: Industrial Info

The plastics and rubbers sector's \$212.6 million in maintenance projects is far behind the petrochemical sector's \$501 million, but it includes two of the larger projects outside Texas and Louisiana: Saudi Basic Industries Corporation's (SABIC) turnaround at its resins plant in Mount Vernon, Indiana, and LyondellBasell Industries NV's spring maintenance on a polymerization unit at its ethylene and plastic pellets plant in Clinton, Iowa.

The SABIC project will handle individual units on an as-needed basis, while the LyondellBasell unit features four reactors that produce about 487 million pounds/year of low-density polyethylene (LDPE) and 450 million pounds/year of high-density polyethylene (HDPE).

US SHUTDOWNS & TURNAROUNDS MARKET

The US Energy Information Administration's (EIA's) latest analysis of planned refinery outages for the fourth quarter of 2018 finds that planned outages in the US are not likely to cause a shortfall in the supply of petroleum products—including gasoline, jet fuel, and distillate fuel—relative to expected demand, either nationally or within any US region. EIA has reached this conclusion despite the current high level of US gasoline demand, which so far in 2018 has been close to the record high seen in 2017.

Planned refinery maintenance in the East Coast will be moderate in the fourth quarter of 2018, except for outages as a result of maintenance on hydrocracking capacities in October, which will exceed 50% of regional capacity. In October, planned maintenance for crude distillation capacity will reach a peak average of 243,000 barrels per day (b/d), or 19% of regional capacity. Production losses associated with planned maintenance could be offset by movements from other regions, by imports, and by drawing down inventories.

Planned outages in the Midwest in the fourth quarter of 2018 will be moderate, except for crude distillation and coking capacities in October and reforming capacity in October and November, which are close to or exceed the previous 10-year maximum. Nevertheless, EIA expects supply of petroleum products to be adequate to meet domestic demand in the Midwest during the fourth quarter. Production losses from planned outages in October and November will average 235,000 b/d and 107,000 b/d in gasoline, 49,000 b/d and 24,000 b/d in jet fuel, and 164,000 b/d and 48,000 b/d in distillate fuel, respectively.

Planned outages in the Gulf Coast in the fourth quarter will be light, and regional inventories appear to be enough to offset lost production from those planned outages. More than half of the refining capacity in the United States is in the Gulf Coast region1, and as a result, the region produces far more petroleum products than it consumes. The Gulf Coast's surplus production supplies other US regions, mainly the East Coast and the Midwest, as well as international markets.





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Planned refinery maintenance for the Rocky Mountain will be light in the fourth quarter. Because oil consumption in the Rocky Mountain region is low compared with other parts of the country and inventories of petroleum products are close to the 10-year average, the planned maintenance should not affect product availability.

Planned outages in the West Coast in the fourth quarter will be moderate, no higher than 10% of regional capacity, except for coking capacity in October, with outages of 11% of regional capacity. The production losses from planned maintenance in October will average 86,000 b/d in gasoline, 24,000 b/d in jet fuel, and 52,000 b/d in distillate fuel, respectively.

EXECUTIVE INSIGHTS, TECHNOLOGY BREAKTHROUGHS & BEST PRACTICE SHARING

ENGINEERING & CONSTRUCTION | DOW CASE STUDY

DOWDUPONT PROJECT MANAGERS SHARE SUCCESS BEHIND \$6 BILLION US GULF COAST INVESTMENT



Figure 34. Dow's PDH unit in Freeport, Texas. Image: Dow

Dow Chemical has delivered a successful US Gulf Coast investment program and will take lessons learned in efficient construction, capital effectiveness, costs and quality as the company looks to invest further, company executives said.

Three Dow Chemical leaders who oversaw the company's \$6 billion US Gulf Coast Investment program spoke about the fundamental's that led to the success of the six-year massive buildout to utilize low-cost and advantaged US shale gas feedstock.

They discussed the challenges and strategies that made the program successful at the 2018 Downstream Engineering, Construction and Maintenance conference and exhibition in Galveston, Texas.







Dow had 15 project teams that were set up across eight geographic sites, working with different EPC firms and construction contractors and using a variety of execution models with overlapping schedules on a multi-year timeline, William Newton, the commissioning and startup leader said.

"The investments involved roughly 4,000 pieces of equipment, 32,000 instruments and analyzers, and more than 3 million feet of pipe that had to be installed, tested, commissioned and started up and that was done successfully with no major issues for the gulf stream program," Newton said.

INVESTMENT PROGRAM

Dow started up the crown jewel of the program, the ethylene and plastics complex in Freeport, Texas at the end of 2017, making it the first to debut a major ethylene project along the Texas Gulf Coast.

The cracker will produce some 1.5 million tonnes/year ethylene, and the company has also begun the expansion phase to increase that capacity to 2 million tonnes/year, making it the world's largest ethylene production plant.

The Gulf Coast Investment Program began more than five years ago with a series of comprehensive investments in projects designed to take advantage of low-cost shale gas feedstock.

"We looked at how we could be more effective as a company delivering products to our consumers," said Ron Huijsmans, US Gulf Coast Program Director said. "One of the areas was clearly the cost avoidance error. For us, this means switching from getting ethylene and propylene at market to getting ethylene and propylene at cost."

"We use a lot of propylene and as the industry moves to cracking lighter feeds, the propylene pricing and availability became much more volatile so that was our motivation to build this PDH plant," Huijsmans said.

DETAILS

The Gulf Coast Investment Program began with Dow restarting and recommissioning its ethylene cracker in St. Charles, Louisiana in 2012. The cracker was previously idled in 2009.

Next, was the PDH project in 2015 to get on-purpose propylene from the propane facility to reduce costs. In 2016, Dow took advantage of the shale gas opportunity by retrofitting an olefins unit in Plaquemine, Louisiana.

"We had been working on our feed slate. We want to be flexible in the feed that we take in to our crackers to get the best pricing at the end of our supply chain," Huijsmans said.

"One of the things we did there was retrofitting an olefins unit in Plaquemine, Louisiana to be able to crack more ethane and to also increase its capacity," he added.

At the start of 2017, Dow completed a Gas Phase Poly Retrofit in Seadrift, Texas.

At the end of 2017 and start of 2018, Dow completed its world scale cracker, which included three high performance derivative assets and a gas phase retrofit.

Currently, Dow is on track to complete another Gas Phase Poly Retrofit, this time in Saint Charles, Louisiana and to add additional flexibility, a specialty elastomers unit in Texas. Both projects are expected to be complete by the end of 2018.

A tremendous amount of utilities and infrastructure went along side each project.

STRATEGY

Program Director Scot Scherwitz, who oversaw the Freeport project, said setting up an "A Team" of leaders to be involved through all project phases, plus development of a perfect front-end engineering design (FEED) that required no changes played a big role in the project's success.





Engineering firms TechnipFMC and Fluor worked on the Freeport project.

"You need to set the vision and define what success looks like for each one of your project teams, develop those detailed plans and execute against them," Scherwitz said.

"You have to begin with the end in mind and really start early with defining what your strategy is going to be, where do the teams have flexibility to do what makes sense locally and what are those critical deliverables that have to be part of your program," he added.



OVERALL PERFORMANCE

Overall safety performance was successful, Huijsmans said, with a total recordable incident rate (TRIR) of 0.13, beating out the previous Dow average of 0.15.

"We did that over a six-year time frame where we expended about 55 million working hours...And I think we were very efficient in our manhour spending," Huijsmans said.

Costs were somewhat higher than expected, but not at the level of overrun reported in industry surveys, Huijsmans said.

"Construction costs escalation is a real thing. There is an opportunity to optimize costs, and an opportunity to be more capital effective on the Gulf Coast," he said.

LABOR DROUGHT

The new cracker created 500 jobs but having enough craft to complete all the construction tasks proved to be a challenge for many projects on the Gulf Coast. Dow dealt with a U.S. Gulf labor shortage by using modules and global sourcing.

There was a total of 59 modules built in Mexico, and 1/3 of pipe and steel was moved on site. They also sourced an automation team in Thailand.

Schedules were within anticipated windows even with aggressive targets, Huijsmans said.

Dow's strategy is to be driven by costs and sensitive to the schedules, but overall construction driven on the projects.





"We have to make sure that all projects will be construction driven," Huijsmans said. "That is really key in high risk areas like the Gulf Coast, but also in other countries like Europe, Canada and even Latin America to some extent."

NEXT TIME

Dow plans to focus on efficient construction techniques to be more capital effective on future projects.

"You can go to China and build for 60% of the Gulf Coast cost and export the ethane over there," Huijsmans said. "Those are options that are really on the edge of being attractive, so we need to be more cost competitive here on the Gulf Coast."

DIGITALIZATION, CULTURE AND DISRUPTION INSIGHTS FROM DECIE AUTIN OF EXXONMOBIL

Employees need new skills focused on innovation, change and creativity along with the new technologies themselves, such as artificial intelligence (AI) and the Internet of Things (IoT).

The US' ability to meet the world's demand for energy and chemicals relies heavily on the industry's ability to make transformational changes – not incremental ones – to capture value and grow profitably, said Decie Autin, Vice President Project Management at ExxonMobil.

"The industry must transform how it develops and executes major capital projects," Autin said.

Autin delivered a presentation on transformation in the energy industry at the Downstream 2018 conference and exhibition in Galveston, Texas.

Nearly 12 million tonnes of ethylene capacity will enter the US market before the end of 2021.

Derivative units, Methanol plants and LNG export facilities also top the list of major capital projects for The Second Wave.

From changing regulatory issues, supply chain challenges, and rapid technology improvements, to a developing trade war and its impact on feedstocks and derivatives, petrochemical companies are bombarded with change.

In such a dynamic environment, the need to master not just efficient delivery of capital projects but make the right decisions about what project to build and when, and how has never been more important.

"Going forward, our companies must seek to disrupt the way we work ...we must be on the lookout for opportunities to transform our approach and create new models that allow us to achieve maximum profitability and sustainability in a changing world (e.g., digital)," Autin said.

DISRUPTION

The term disruption has been used a lot more often in the petrochemical industry recently.

"Digital disruption is an effect that changes the fundamental expectations and behaviors in a culture, market, industry or process that is caused by, or expressed through, digital capabilities, channels or assets", according to the Gartner IT Glossary

In the downstream industry, companies see evidence of that disruption, as technology enables greater efficiency, speed and innovation in everything from construction and manufacturing to the supply chain and marketing.

CULTURE

As organizations continue to embrace digital transformation, they are finding that it is not as simple as buying the latest technology. Instead, it requires big changes to culture and systems.

"The reality is that digital business demands different skills, working practices, organizational models and even cultures," according to a Gartner report published June 20, 2018 titled: Six Barriers to Becoming a Digital Business, and What You Can Do About Them.







In addition, the report notes, "To change an organization designed for a structured, ordered, process-oriented world to one designed for ecosystems, adaptation, learning and experimentation is hard. Some organizations will navigate that change, and others that can't change will become outdated and be replaced."

Digital innovation can be successful only in a culture of collaboration, the executives explained.

"We must drive innovation within our organizations, we must demand exceptional project execution, we must provide transformational leadership and we must challenge ourselves and our peers to develop and nurture a "one-team" collaborative culture," Autin said.

"Success with digital innovation requires a culture of collaboration that encourages people to work across boundaries and explore new ideas. Many organizations are stuck in a culture of silos and hierarchies that resist change," according to Gartner.

The Gartner report continues, "Culture is organizational 'dark matter' — you can't see it, but its effects are obvious. The challenge is that many organizations have evolved with a clear hierarchy. This groups people clearly and creates boundaries between areas of responsibility."

"Processes and governance then attempt to define how these groups work together, with work handed over between groups... But digital innovation requires highly collaborative cross-functional teams, and outcomes are uncertain, so these teams need to be adaptive and creative," according to Gartner.

Companies must change their risk tolerance as they can never achieve breakthroughs if employees are fearful of failure, or resistant to trying something new, Autin said.

"Improving our work environments to encourage and support those who challenge the status quo or who identify opportunities for change is a major step in the right direction," Autin said.

Changes begin at the personnel level with developing innovative leaders and teams, Autin said.

LEADERS

Employees need new skills focused on innovation, change and creativity along with the new technologies themselves, such as artificial intelligence (AI) and the Internet of Things (IoT).

As with any change, the behavioral aspects will be the most challenging. The industry will need leaders who model the right behaviors, encourage others to do the same and help shape the actions and beliefs of their teams.

"The industry needs transformational leaders. Leaders should promote a culture of empowerment, where highly skilled employees have the knowledge and resources to integrate seamlessly with technology to make decisions and carry out both daily tasks and long-term strategies," Autin said.

"We need people who are visionary, inspiring, daring. We need risk-takers and thoughtful thinkers," she added.

INSIGHTS FROM FIRST WAVE OF DOWNSTREAM PROJECTS CASE STUDY AND INTERVIEW WITH KEITH ACKLEY, JACOBS

Many of the petrochemical projects from the first wave construction boom began operations in 2017 and 2018. Learnings from the first wave on key items such as technology, data and managing the workforce are spurring strategic decisions as the US begins a second wave petrochemical construction boom.

The first wave of construction projects was unprecedented in terms of growth, and the race to build so many ethylene crackers quickly and simultaneously led to implications for the industry.

Labor and raw material shortages resulted in higher costs during the first wave of construction, as companies largely did design, procurement and construction at the same time and had to compete for both materials and labor.





The rush to build led to engineering challenges as well. Other general challenges included poor communication and planning such as language barrier issues between foreman and craftsman and making basic poor timing choices such as pouring concrete on the US Gulf Coast on a hot summer day when temperatures might soar to 100 degrees Fahrenheit or higher.

Petrochemical Update spoke with Keith Ackley, Jacobs Engineering Vice President and General Manager of Energy and Chemicals for Houston and Major Projects, about how companies can learn from the past and leverage technology, data, the workforce and global execution to their advantage during the next big petrochemical construction boom.

01. What do you think are the key lessons the industry should take from the first wave and apply to future projects?

As the industry places more demanding requirements on its capital projects, the complexity of the definition and execution phases is growing exponentially.

Whether it is the normal drive for cheaper, or faster, or the quest for capital efficiency, the demands we are placing on our project teams are ever-increasing.

In the interest of becoming more cost efficient ourselves, we have reduced the capacity and experience levels of our execution teams. This contraction is not a new response to the business cycle, but how we react during the inevitable upswing.

The difference in the situation from the past is the order of magnitude, greater access to technology solutions and the availability of a global resource pool that technology facilitates.

The solutions may be better, faster access to information which facilitates more robust decision making from a less experienced workforce; analytics to provide better analysis and drive the right decisions; automation, or the use of remote construction techniques to move the work to where the qualified, cost effective workforce is located.

Regardless of the solution, leverage of technology, information, automation and global execution should all play a part in moving our industry forward, not repeating the boom and bust cycle as we have done in the past.

02. What is an emerging strategy or technology now that may become standard five years from now? Can you provide any examples at Jacobs or on your projects?

I feel that we are further along in development of the analysis and information than we are in gathering the fundamental information that drives the analytics.

The next evolution is how we automate or build in the raw data capturing into our facilities.

This appears to be the current bottleneck. The challenge we face is the cost and complexity of gathering consistent, quality information is far greater than developing the analytic process to transform it.

Jacobs has invested heavily in the infrastructure to capture information at our construction job sites and once the foundation of the data infrastructure is in place, not only do we want more information to analyze, we seem to find nearly endless uses for the information to further drive our understanding, our efficiency, and our workforce safety.

Getting to an Internet of Things (IOT) is the hard part; it appears once you have it, the uses of the data stretch our imaginations.

Of course, then our imagination drives the need for more information than originally envisioned.

03. You specifically mentioned leveraging global execution in your discussions at the 2018 Downstream Convention. How can the US make the best use of global partners for future projects?

In the past decade we have witnessed a step change in the capability and capacity of our global execution partners.





Whether in professional services, equipment and materials fabrication, or even nearly complete facilities fabrication in modules, the capability and capacity of service and material suppliers in Asia, and Middle East have now caught up with traditional suppliers in North America and Europe.

This new capability, if coupled with new execution models like true Globally Integrated Design, mega modularization, and fabrication yard commissioning, is and will continue to drive the next opportunity in capital efficiency.

TECHNOLOGY BREAKTHROUGHS

Technology has moved at lightning speed over the last couple of years and moving even faster as the world gets closer to 2020. The rate of adoption and disruption has been almost too fast for the petrochemical industry, an industry immersed in traditional habits and values.



The idea that some technologies are moving too fast does not mean, however, that those technologies won't become the next big thing. The technologies are moving quickly because the demand is so strong, an analyst told Petrochemical Update.

Inevitably, the disruptive technologies of today will become the next day to-day big thing, just as the world went from telegraphs to land lines to mobile phones to smart phones, only at a faster pace than ever before seen in history.

Long-term, which key technologies will change the way the downstream petrochemical engineering, construction and maintenance sectors operate and become day-to-day functions?

Petrochemical Update spoke to Dr Carl T. Haas Department Chair, Professor, Canada Research Chair at the University of Waterloo & President International Association for Automation and Robotics in Construction.

By adopting and taking advantage of technologies and concepts that already exist such as artificial intelligence, drones, 3D scanning and printing, Radio Frequency Identification Technology (RFID), modularization, autonomous equipment and advanced building materials; companies can boost productivity, streamline project management, ultimately reduce costs, and enhance quality and safety.





ARTIFICIAL INTELLIGENCE

Artificial Intelligence (AI) will play a central role here, as it is being used already to gain new insights into how craft work safely and productively.

Al is giving researchers at the University of Waterloo new insights to help reduce wear-and-tear injuries and boost the productivity of skilled construction workers.

Masonry and construction are demanding fields, requiring constant and repetitive motions that can lead to fatigue, wear and tear, and musculoskeletal injury.

As part of their work, the researchers are now developing a system that uses sensor suits to give trainees immediate feedback so they can modify their movements to reduce stress on their bodies.



Figure 35. AI experiment at University of Waterloo. Image: University of Waterloo, Canada

"There is an unseen problem with craft workers who are just wearing out their bodies," he said. "It's not humane and it's not good for our economy for skilled trades people to be done when they're 50."

ROBOTICS

Although it may not be obvious from the outside at first, robotic technology is already in use on the job site.

For now, routine applications are minimal and highly specific, such as scanning and grade control. But that is expected to change.

"Robotics tried to emerge in the 80s and 90s and didn't meet people's expectations, but I think now we are getting some pretty good stuff around robotics like welding, exoskeletons, and support for the more difficult craft jobs. All of this will impact productivity on site," Haas said.





Construction robots can be used in the industry for fabrication, building construction machinery, arc welding metal components, applying adhesives, and assembling doors and windows.

Construction robots are also used in the handling and manipulation of bricks and other heavy blocks. Robotic systems can also be utilized to dispense concrete on the job site.

According to RobotWorx, Welding time on Japanese construction sites has dropped dramatically since the implementation of robotic welding systems.

One firm developed a system that uses two six-axis robots to weld structural steel for buildings. The I-beams are cut and welded prior to being delivered to the construction site, resulting in little welding needing to be done onsite.

Prior to delivery, holes for plumbing and electrical systems are cut into the beams. These cuts must be made with exceptional accuracy, usually within 0.16 mm. After the cuts are made, the robots attach a unique part number to each beam to ensure that each beam gets used for the right job.

The efficiency of this robotics system has decreased the time it takes to put up steel in a building, allowing more time to develop other projects.

EXOSKELETON

One technology that Haas is certain will be a regular part of future construction sites is the exoskeleton. Naval shipyard workers are already using exoskeletons. These workers lift heavy hand-held tools and supplies, work in awkward postures, and work at various heights as in construction.

A U.S. government study of the industrial human augmentation system (iHAS), an integrated system composed of two different exoskeletons found that use of the iHAS was associated with a 10% increase in productivity, a reduction in vibration of the hands, and improved quality of work.

Exoskeletons have the potential to enhance worker productivity, provide assistance to aging workers, and decrease the risk of musculoskeletal disorders.

COLLABORATIVE DESIGN

Complex projects with numerous stake-holders experience substantial risks related to the interfaces among stakeholders. This is particularly true during project definition and design, where despite discrete deliverables across the interfaces, decisions require some repetition.

Interface management is a way of agreeing on deliverables between project stakeholders and managing the flow of those deliverables using automated work systems in a set up.

Managing interfaces has become feasible with the advent of internet and electronic product and process-management systems to the extent that full-time interface-management (IM) positions exist in practice.

Collaborative design makes this possible as it allows for more than one stakeholder to access the 3D models and all the aspects of the product information.

Contracting strategies such as Integrated Project Delivery (IPD) are making this possible.

"It is an interesting thing where the contracting strategies that balance the risk and create trust and partnerships are combining with the technology that is allowing us to communicate remotely and communicate effectively finally and then the management of workflow best practices like Interface management coming to fruition," Haas said. "That combination is really coming together to improve execution."





MATERIALS TRACKING

Haas also believes future project construction sites will include more materials tracking using GPS and RFID tags. The future sites will use more 3D imaging and 3D modeling in combination to improve productivity and quality control.

Haas has used 3D imaging and other automated sensing algorithms to create digital twins of constructed facilities such as buildings. Construction companies use the tool to automate their progress tracking and locate where each object has been placed during construction of a new building.

Haas also developed RFID tags and algorithms to locate items on the construction site quickly and easily.

ADVANCED WORK PACKAGING

Since the first wave of construction projects, the Advanced Work Packaging process has grown in popularity in North America as a way for owners and contractors to handle the construction boom environment in which schedules, budgets and labor are increasingly tighter. So much so, that some owners won't even hire contractors unless they will offer it.

Olfa Hamdi of The Advanced Work Packaging Institute has been documenting through case studies and expert interviews AWP benefits as part of her academic research work and thesis published at University of Texas Austin entitled "Advanced Work Packaging (AWP): from project definition through site execution."

"The most notable benefit from AWP implementation is field execution acceleration and accuracy which translates in schedule savings," Hamdi said. "Cost savings have been observed but they do depend on the level of maturity of AWP implementation."

"There is an initial front-end cost to it, but savings achieved down the road are worth it," she added.

Indirect benefits observed and documented by the AWP Institute are improved front end alignment and more predictability to the overall project value.

The Institute has documented up to 25% savings of total installed costs and up to 15% field productivity increase. ExxonMobil, Dow and Shell are some of the owners using AWP for mega projects.

START WITH THE END IN MIND

AWP originated in Canada in 2013 about the same time the North American construction industry was booming in the petrochemical sector.

This newly discovered solution was a result of a joint study via the Construction Owners Association of Alberta and the University of Texas at Austin.

Improvements in field productivity using AWP have reached 37% increase in tool time. Evidence of AWP implementation benefits also include over 25% savings in chemical project construction and engineering costs, according to the AWP Institute. Using AWP for front-end planning, owners can increase productivity and increase profitability, industry participants said.







Figure 36. Image source: The Advanced Work Packaging Institute

AWP is a work process framework based on thinking with the end in mind. It is designed to allow engineering planning to be driven by construction sequencing.

The best way to implement a successful AWP program is to start at the owner level, William Lewis, Senior Manager and Projects Coordinator at SABIC said while speaking at the Downstream 2017 conference.

Owner involvement is more important to change than many realize, Lewis said.

"If you think back a couple decades, when we went into the safety venture, it took the owner driving safety to actually make a difference," he said.

"If you want to improve productivity, the owner has to play a major role in it. The owner will have to mandate it and encourage it to make that change."

SCOPE DEFINITION

The most common thing owners fail to do early in the project cycle is sufficiently define the project to support a successful FEED, according to a Petrochemical Update Poll conducted at the Conference.

"Productivity is a piece of capital efficiency and takes a number of steps. I don't think there is any one thing that is the answer, but there are a couple of important things that can be done," said Jim Collins, President of Business Development for Global Refining, Chemical, Petrochemical and Midstream at AMEC Foster Wheeler.

Collins was speaking in a Panel at the Conference.

"I want to focus very much on the front end, get the definition of scope right, get the plans right, get the right input from the owner side, and put the right construction planning in place at the front end," Collins said. "Change really drives a lot of inefficiencies. It's not just a cost impact, it is a productivity impact."

Assessing all the potential alternatives and identifying and planning for major risks were also listed high on everyone's list as common things owners fail to do early in the project life cycle.





"One of the things for the owners to look at is contractor involvement very early in the planning of how the project will be, and construction and put that in the feed and build up from it," Collins said. "In the field, there are many activities really complemented by AWP, but that's only good as scope allows."

MAN-HOURS AND AWP

Many owners and EPC firms have initiated skills training and recruiting programs to get craft labor up to speed, but it will take some time before the crafts are experienced.

"With all the projects ongoing and the ones, we are seeing on the pipeline, this challenge is not something that is going to change real quick," Lewis said. "A lot of people are making investments in training and education, which is something that we definitely need to do, but it is not going to happen overnight."

In the interim, Lewis suggests moving man hours off site, coming up with an offsite fabrication or modularization plan and working that into the AWP programs.

"We need to look at the module yards, fabrication facilities, pipe shops, steel shops and make sure they have a good process for completing the work, scheduling and planning it and getting it out on time, and keeping that schedule on time and in compliance," Lewis said.

MAINTENANCE & RELIABILITY INSIGHTS

CREATING A CULTURE OF CONTINUOUS IMPROVEMENT -CASE STUDY AND BEST PRAC-TICE SHARING

Downstream operators are using the latest technology to accelerate execution of turnarounds, maintenance and major projects, but many projects are often missing the communication aspect, according to analysts.



Figure 37. Advanced sustainment and lean operation methods, which focus on reduced waste and greater communication, are used by owners like Suncor, Shell, and ExxonMobil to get through turnarounds and projects. Image: Cecilie Arcurs







Technology is moving faster than ever before, and downstream operators are focusing on new, innovative ways to handle turnarounds, maintenance and major projects using the latest, greatest technology trends and racing to finish first; but experts warn projects and teams may be overlooking the communication aspect.

As the first wave of petrochemical construction projects begin to start up along the US Gulf, the realization is that the rush to build so many major petrochemical complexes quickly and simultaneously did not come without problems.

First wave labor and raw material shortages resulted in higher costs as companies largely did design, procurement and construction at the same time and had to compete for both materials and labor. The rush to build quickly led to engineering challenges as well.

The first wave of petrochemical projects drained resources, thus pushing operators to turn to new solutions for efficiency as the second wave begins.

More owners are now turning to advanced sustainment and lean operations for managing major projects including shutdowns and turnarounds.

LEAN OPERATIONS

Advanced sustainment and lean operation methods, which focus on reduced waste and greater communication, are used by owners like Suncor, Shell, and ExxonMobil to get through turnarounds and projects.

Documented improvements have been seen in schedule accuracy and attainment by more than 15%, work order quality by more than 20%, and reducing contractor needs by more than 15%, according to Argo Consulting. Advanced sustainment methods focus on building people skills and interactions, while the lean operations focus is on improving the process, Argo said.

By improving communications and using components like visual boards, visual management tools and leader standard work, operators can channel high-level work programs down to a pragmatic real-time and flexible communication approach. In doing this, employees are interconnected at the right points for maximum project success and are better able to react to unforeseen events.

Visual management boards are used to communicate the status of safety, quality, cost, and delivery on a real-time basis and are also used to update manually a metric(s) that means something to a craft team, such as work orders completed per shift, materials returned to warehouse or repeat work.

"Visual management techniques, if implemented properly, represent the targets and the status in real time. If the right people are in the room at the time and at the right frequency, collaboration, accountability and problem-solving happen naturally, because everyone is looking at the same data," Jorge Mastellari of Argo said.

VISUAL MANAGEMENT

Various visual management and status meeting techniques will work effectively depending on the complexity of the turnaround or project, the amount of contractors, the length of the event and the particular site.

Chris Vaughn, currently a Plant Manager at Addivant, has used visual management in turnarounds, shutdowns and projects.

Vaughn's management process for many turnarounds would typically involve two 30-minute status update meetings each week and keeping a recap visual board updated daily for all participants to see.

The status meetings typically take place twice a week, on Monday mornings to check in and establish the week's priorities, performance measurement, resources needed and any potential roadblock or barriers. Then, a check out meeting on Thursday afternoon is held to provide status updates and discuss performance and improvement goals for the following week.





DAILY RECAP VISUAL MANAGEMENT AGENDA ITEMS

SAFETY	OPERATIONS	MINOR CAPITAL PROJECTS	MI&QA INSPECTIONS	STATUS
Daily safety theme Safety KPI's Audit behaviour & trends	Status of decommissioining, prep, commissioning & start-up activities	List of all capital projects status with RYG indicators	List of equip,ment inspected during the day Use of equipment that can be returned to service	Overall Critical paths Units
SAFETY	OPERATIONS	MAJOR CAPITAL PROJECTS	MI&QA INSPECTIONS	STATUS
Simple and impactful Broadly communicated to site and contractors through TAR update status email	List of work activities completed per schedule List of all activities that did not get worked or completed per schedule	List of all capital projects with RVG indicators	Status of outstanding repairs to be completed before service	Track action items with responsible personnel and timing

Figure 38. Daily Recap Visual Management Agenda. Image: Chris Vaughn

"Smaller projects and standard turnarounds with less contractors might do ok with weekly status updates," Vaughn said. "A more complex turnaround or project with multiple contractors and day-to-day activities would necessitate daily status updates."

The supervisor leads the conversation around a clear target to win and allows craft to adjust schedules according to priorities and potential issues, Mastellari said.

"The supervisor has a finger on the pulse of every team and demands explanation for misses every time a craft team does not meet its work order target for the day," Mastellari said. "This provides engagement and accountability."

DAILY RECAP VISUAL BOARD

SAFETY	OPERATIONS	MINOR CAPITAL PROJECTS	MIQA INSPECTIONS	STATUS
RECOGNITION	MAINTENANCE	MINOR CAPITAL PROJECTS	DISCOVERY WORK	PROBLEM SOLVING SESSIONS, ACTION ITEMS ANNOUNCEMENTS



WEEKLY CHECK IN CHECK OUT BOARD

	MAINTENANCE RYG INDICATOR	CAPITAL PROJECT1 RYG INDICATOR	CAPITAL PROJECT2 RYG INDICATOR	COMMISSIONING RYG INDICATOR
Objectives				
Results				
Barriers, challenges, risks				

Figure 39. Data for Visual Board management courtesy of Chris Vaughn

EXCELLENCE IN EXECUTION

With bigger outlooks amid increasingly squeezed budgets, reduced margins, aging assets and pressure to improve productivity and efficiency; one of the key priorities across both Maintenance and Turnaround departments is to look for innovative solutions to age old problems while achieving operational excellence.

Operational Excellence is much more than just the mechanical execution of turnarounds, top managers believe. "Operational excellence happens in all phases of the turnaround – Planning/Scheduling, Execution, and Critique," Vaughn said. "Significant energy and effort take place years or months before a turnaround is executed. Operational excellence cannot happen in execution if it doesn't happen in the planning and scheduling phase."

Operations, Maintenance, Capital, Contract Administration are all stakeholders in every phase of the turnaround and the teamwork, or lack the hereof, can influence the performance during execution.

"The teams that I had the privilege of leading took a focused approach towards operational excellence in identifying the turnaround scope, scheduling the work activities and understanding the commissioning sequence," Vaughn said. "We have completed several successful turnarounds because the team was focused in all phases including critique."

CRITIQUE

Post-event feedback is important as it provides the reality check of what went right or what went wrong during the turnaround or maintenance event beyond scheduling and budgets. Keeping track of problems is important to progressively avoid these pitfalls again and can be the motivation to develop a new system.

"Organizations are holding themselves and other organizations accountable in the critique and action plans that we developed," Vaughn said. "Complacency is the biggest risk when performing critiques. Teams need to be introspective and work to develop their skills in the gaps identified in critiques."

DESIGN FOR RELIABILITY

INSIGHT FROM DOW'S RELIABILITY PROJECT LEADER

Maintenance teams spend a lot of time fighting fires and end up unable to give enough attention to finding ways to prevent failures that cause downtime, expensive damage and safety issues.

Even though companies often plan maintenance projects months or even years in advance, some 68% of US refiners and chemical plants still fail to deliver their planned shutdowns, turnarounds and outages on time, according to Oracle Corporation.







Since turnarounds are by definition a lost profit opportunity, any delay in executing them adds to production losses, and undermines shareholder value and regulatory compliance.

Richard Ellis, Reliability and Maintenance leader at Dow has been involved in supporting the companies comprehensive \$6 billion investment plan to increase ethylene and propylene production in the US Gulf Coast.

His job has entailed establishing design for reliability and maintainability (DFRAM) requirements for projects based on business objectives, hiring team members, coaching and mentoring team members in the capital project process, and interface with project engineers and project managers.

Ellis' philosophy is that reliability is a design attribute and begins in the design process, meaning that the maximum level of reliability a plant can achieve is set by its' design.

Most designs are not following this and instead once a plant is in operation, most actions taken have one of two outcomes: lowers reliability due to less than adequate repair; or closes the gap on "maximum achievable reliability" by restoring equipment to its' original operating condition, Ellis said.

Very few companies are using capabilities of tools like reliability modeling such as Monte-Carlo simulation currently to virtually design plants and test their production outputs prior to starting design.

"I have always found it ironic that no petchem company would consider building a new plant without doing a process simulation to validate the chemical streams, but virtually none do Monte-Carlo simulations to see if those chemical streams can achieve the level of production output the business needs to meet its strategy," Ellis said.

BUILDING A DESIGN FOR RELIABILITY PROGRAM

Reliability can be added into the design and this is done by maintenance and reliability professionals learning how to communicate to executives, Ellis said.

Maintenance and reliability professionals need to be able to clearly articulate how reliability and maintainability can be linked to business profits. Business leaders measure what they care about, mainly the profits generated from production. Too many maintenance professionals still talk about failure rates and repair times, concepts that don't mean anything to a business leader.

With ever-increasing complexity in construction projects today, it has never been more important to build effective plans/processes to deliver projects not only on time, on budget and safely, but also perform reliably following commission and start up.

Early collaboration is essential, ensuring everyone is working towards the same goals.

This includes designing projects for a service and/or region, then selecting appropriate construction materials which stand the test of time: not break after four years when the turnaround is six.

There should be regular contact with capital projects, using a front-end loading method, with stage gates along the way and including deliverables.

Some organizations have standalone engineering groups, but there can be a lack of knowledge about what DFRAM is, and what the need to design for reliability principals are and why they important. The Project and Reliability elements of a capital project then have competing score cards.

The project manager is primarily concerned with safety, cost and schedule, so it is difficult to manage the trade-off between lowest installed cost and long-term cost of ownership.

There is also the idea that early maintenance involvement drives up costs and creates questions around who shoulders these costs. The dilemma for organizations is how to assess where the greater investment goes in order to reduce costs in the long term.





For this reason the capital project team and the maintenance team should, from the outset, take accountability for different priorities.

Technology is rapidly penetrating the way work gets done, making it safer and smarter. Data is being viewed as an asset. It bridges islands of systems and connects local silos with global sharing. Data provides the ability to compare equipment or systems performance across facilities.

Reliability organizations innovators are introducing machine learning which can make predictions on inputs and provide insights on recognized patterns and smart workflows which track process status in real time, manage handoffs between different groups, and provide statistical data on bottlenecks.

ACHIEVING THE GOAL OF PREDICTIVE MAINTENANCE

INTERVIEW WITH FLORIAN BUDER, CEO PRUFTECHNIK

Nearly two-thirds of owners plan to increase their investments in digital technologies over the next three to five years, although digital is not one of the top plant investment areas for owners today, according to consultancy Accenture. While this spending is set to increase, only 19% of refiners rated digital as one of their top three priorities for spending on plant efficiency and productivity over the next three years in a survey of over 200 executives conducted by Accenture. When asked to identify the most important benefits that digital technologies will provide, respondents most often cited more-effective plant management (63% of respondents), reducing operational risk (59%) and more-efficient and predictive maintenance (54%).

Predictive maintenance isn't cheap or one size fits all. The conditions that affect lifespan aren't the same at every plant, leading to machines needing repair or replacement at different points in time. Recommended maintenance schedules found in equipment manuals are based on failure statistics and averages.

Avoiding failures that impact production is time-sensitive and critical, and yet there were 2,200 unscheduled shutdowns in the US alone between 2009 and 2013, an average of 1.3 incidents a day, costing roughly \$20 billion per year, according to Deloitte Insights. It's no wonder that 54% of owners said their spending should be on predictive maintenance.

For more efficient, proactive rather than reactive approaches, there is predictive maintenance.

Predictive maintenance techniques are designed to help determine the condition of in-service equipment to predict when maintenance should be performed. This approach promises cost savings over routine or time-based preventive maintenance because tasks are performed only when warranted.

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PRUFTECHNIK has been helping clients achieve the goal of predictive maintenance through various strategies.

The company has converted the industry from aligning machines with dial gauges to Laser Shaft Alignment starting in 1984 with the introduction of the first laser alignment system known as OPTALIGN.

Later, PRUFTECHNIK invented the first Roll Alignment system based on Yaw, Roll, Pitch of laser gyroscopes (PARALIGN) and in 2018, the company launched one of the most affordable and quickest high-speed data collectors in the market. Florian Buder, CEO of PRUFTECHNIK discussed predictive maintenance strategies with Petrochemical Update.





01. How can maintenance departments begin to shift from a reactive to a sustainable predictive maintenance model?

A change of mindset is required, and you need the buy-in from upper management. There must be a vision. A reliability DNA needs to be created or exist.

Once this is achieved, it is necessary to find the right personnel who can lead this project. This can be a combination of in-house engineers as well as external consultants and solution providers such as PRUFTECHNIK.

Furthermore, clear and measurable KPIs need to be generated and monitored.

Progress must be measured to embed the predictive mindset in the company in the long run.

Once employees, colleagues, management and executives see the cost savings, the smoother work execution, the less panic modes and eventually more earnings while getting a competitive advantage, it is no doubt that you have created a sustainable predictive maintenance model.

02. What do you believe is the most important aspect of a predictive maintenance strategy?

The most important aspect is to have clear goals, proper objectives, formulate the right strategy and execute with applicable measures. What do I mean by that? Let's look at a tangible example:

Let's assume you want to make sure to increase the reliability of your rotating assets by establishing a Condition Monitoring program based on Vibration Analysis:

Goal: Lower breakdowns, increase machine life and availability

Objective: Plan shutdowns based on measured results and actual health condition of the rotating assets

Strategy: Collect data manually per criticality of asset. The more critical, the more often you need to collect data with a portable instrument or consider permanent monitoring with an Online Monitoring system.

Measures: Invest in right solution/technology, train staff or outsource

03. How do you strike the balance between productivity and performance while achieving lower maintenance costs?

It is indisputable that these parameters go hand in hand. Performance and Productivity will automatically go up by lowering maintenance costs if you align your machines with high precision maintenance tools such as a Laser Shaft Alignment.

Precise alignment pays off in many ways to improve performance and productivity.

- Reduce power consumption
- Decrease wear on bearings, seals, shafts and couplings
- · Avoid overheating of bearings and couplings
- Reduce vibrations in shafts and foundation bolts
- Significantly reduce damage to shafts and foundation bolts.

ROI can easily be calculated with modern calculators. We have a great example on the PRUFTECHNIK website. https://www.pruftechnik.com/fileadmin/pt/_Common/Roi/index.html





04. What do you think are the main barriers in achieving the goal of predictive maintenance?

The main barriers to getting to predictive maintenance are often buy-in from management, human resources, skilled labor and making smart choices of who to partner with.

To reach this goal, evaluate every technology and the people behind it. Local support is as important as the soft and hardware technology itself.

05. What types of technological advances should the industry be focused on right now to achieve the best maintenance and reliability?

The focus should not be on the latest buzz words in the reliability world. Focus on best practices and focus on proven methods while acquiring the most modern interfaces and grow with those while always looking outside the box.

OPERATIONAL EXCELLENCE AND CONTINUOUS IMPROVEMENT

CASE STUDY WITH DOW'S CHRIS LEONARD

At Dow Chemical, innovation, and investing in its people is key to success and driving continuous improvement.

"In Dow, operational excellence in maintenance and turnarounds means we strive to be the safest, most cost-effective teams for delivering reliability, maintenance, turnarounds, and projects. We also ensure our assets operate in an environmentally sound manner, and we meet our customers' expectations," said Chris Leonard, Reliability Project Director at Dow.

"This is achieved through integrated (operations, maintenance, projects), empowered teams working as a highly skilled, highly leveraged, highly productive and innovative work force coupled with consistent, effective corporate metrics to gage performance."

"Dow's work processes coupled with our people's knowledge, skills, and teamwork enable our success," he added. Industry 4.0

Recently, Dow has implemented its own version of Industry 4.0 targeted specifically for manufacturing.

"It is important understand the innovations in technologies available and how best to exploit them to improve the bottom line," Leonard said. "This positions Dow operations as a leader in the Fourth Industrial Revolution by identifying opportunity and narrowing our focus so we are ready to deploy people and capital as available."

Powered by five support technology thrusts; analytics, robotics, digital thread, process control/process automation, and mobile solutions, these enablers provide the smart technology and real time data needed to define value generation for Dow and establish Dow as a top competitor in a rapidly changing environment

"This effort is a breakthrough initiative in our operations strategy that is designed to improve productivity and competitiveness while driving continued growth and raising enterprise-wide performance," Leonard said.

CONTINUOUS IMPROVEMENT

Dow has embraced a policy of Continuous Improvement and utilizes several key processes and tools to ensure that Continuous Improvement is a way of life for its employees.

"Top down support is critical. From the CEO to the shop floor, it is understood that for Dow to be competitive, we must continue to improve and exceed our customers' expectations in a safe and environmentally sound manner," Leonard said. "As such, we have to continually improve employee access to the Continuous Improvement support needed for success."

Applying this approach to Dow's efforts in improving holistic reliability from raw material to customer delivery has led not only to the liberation of billions of pounds of production, but also improved performance in areas not historically associated with reliability such as accurate customer invoicing, Leonard said.







Training and investing in people are a key part of the continuous improvement plan.

"Our people are our greatest asset. We invest not only in skills and knowledge training, but also help them understand the behaviors needed to operate and maintain our assets reliably," Leonard said. "We invest in our leaders in unique ways to help them understand how to motivate their organizations to achieve results."

Continuous Improvement is built into everything Dow does and is an expectation of every employee, but training employees in every continuous improvement enabler would not be value added, Leonard said. Instead, the Dow approach is to provide information on the continuous improvement enablers and allow employees to customize their learning based on what they need for success in their role or project.

"Ensuring the continuous improvement mindset or culture is sustained takes constant reinforcement from every level," Leonard said. "Part of the effort requires our employees to know where to find effective and efficient training on the enablers they need as well as who the subject matter experts are that can help accelerate their progress."

"In addition, the key to success is to make continuous improvement personal...something that every employee can act on and contribute to overall improvement," he added.

SHUTDOWNS & TURNAROUNDS INSIGHTS

NEXT EVOLUTION BEST PRACTICES FOR SHUTDOWNS AND TURNAROUNDS

Petrochemical and refining turnaround teams can significantly improve cost, schedule and management of their turnaround and capital projects if they turn to next evolution best practices; such as scope index benchmarking, effective site leadership, contract strategy, risk-based scope reviews, and schedule optimization, according to Tom Mankowski of AP-Networks.

Why do some of the front runners achieve predictable and competitive turnarounds and others achieve predictable performance, but not competitive performance? What extraordinary practices could be quantified and become industry norms?

Mankowski is the Practice Area Manager, Turnaround Consulting for AP-Networks and gave a presentation on The Turnaround Performance Paradigm and Turnaround Value Practices at Downstream 2018 in Galveston.

While the turnaround industry has gradually improved over the years mainly in the safety arena, there is still plenty of room for improvement, however, he said while speaking at the event.

"The laggards are not predictable and not competitive," said Tom Mankowski of AP-Networks. Meanwhile, the frontrunners are more predictable, but not necessarily more competitive."

AP-Networks wondered what set the front runners apart and embarked on a research study to statistically correlate specific practices to competitive event performance.

The methodology was to use AP-Network's Turnaround Readiness Index (TRI), an online turnaround planning and preparation readiness assessment tool or questionnaire, and then analyze the data further.

The Turnaround Pyramid is a tool AP-Networks uses to quantify the readiness of a turnaround at different points in time. Scores are varied on a rating system of 1 to 5. The index allows AP-Networks to predict the outcome of the turnaround. As many would assume, turnaround readiness drives predictability performance.

"As people are better prepared for turnarounds, their performance improves...schedules and costs improve with schedules seeing the greatest success," Mankowski said.







Figure 40. Turnaround Readiness Index. Image: AP-Networks

Then, AP-Networks took it a step further to look at the same TRI data with respect to what best practices impact performance.

All sites have work process, but some have taken it a step further. For the sake of the AP-Networks exercise, the best practices were organized as follows

Common Practices – Adopted concepts - E.g., Turnaround Work Process, Scope Development Process Industry Proven Practices – Somewhat adopted concepts - E.g., Compliance, Assurance, Milestones, Scope Freeze, Event Integration 3. Turnaround Value Practices

Next Evolution or Turnaround Value Practices (TVP) - E.g., Scope Index Benchmarking, Effective Site Leadership, Contract Strategy, Risk Based Scope Reviews, Schedule Optimization

The study revealed that the turnarounds that are using Common Practices fell in the weak to average index.

The turnarounds teams that followed the Industry Proven Practices scored average up to optimal.

The turnaround teams with the greatest success are those who utilize the Next Evolution best practices or TVPs.

"Digging in further, the turnarounds that value Next Evolution or TVPs further define those who can hit an optimal level of readiness...those practices out of the ordinary...those practices that are specifically targeting improving specific areas of turnaround prep," Mankowski said.

"Effective site leadership, steering teams, strategy teams, contract teams, risk-based review, scope index benchmarking. We see various levels of effectiveness across the board. The sites doing this well are distinguishing themselves from others," he added.






Figure 41. TRI with Turnaround Value Practices Incorporated. Image: AP Networks

TVPs are out-of-the ordinary value practices used to improve the readiness and performance outcomes of the event. TVPs are not just standard tasks; instead, they follow a defined and distinct methodology and must be followed for the entire turnaround or event.

TVP outcomes and results are formally documented and actions are tracked to completion.

Each TVP should be applied during the various turnaround strategy, planning, scoping, preparation, and execution phases. TVPs are to be facilitated outside of the Event Team by experienced, independent, and credible facilitators.

AP Networks stresses a three-step priority system: execute the plan right, execute the right scope, execute the scope right. Executing the plan right by improving planning readiness and the use of benchmarking to drive predictability.

Execute the scope right by improving planning readiness and the use of benchmarking to drive predictability and competitiveness.

"Looking at your influence in expenditure curves, we know we have the most influence on a turnaround in the early stages. When we are deciding on projects and scopes, this is when we have the biggest influence," Mankowski said. "When we get to execution, we don't have a lot of influence. The way we get these areas right is executing the work at the right time."

Execute the right scope by improving planning readiness, use of benchmarking, and applying TVPs which drives predictability and competitiveness.







Figure 42. Image: AP-Networks

"It's not just about focusing on readiness and communication but adding strategic and tactical practices and also focusing on 20% of the things that make the 80% of difference, Mankowski said. "This is what drives us to the top, the best of the best."

MORE CAPITAL PROJECTS INTEGRATED WITH TURNAROUNDS THAN EVER BEFORE

Improved margins mean more capital projects are on the books and more projects are now executed during the maintenance turnaround window, adding new challenges for managers.

Turnaround managers are often brought in to project planning too late for effective project-turnaround integration, experts say.

Capital project work as a percent of turnaround work has grown from just 2% in 2006 to more than 20% in 2016 and 2017, according to consultancy AP-Networks.

Capital spending increased 6.0% in 2017 and will grow 6.3% by the end of 2018 and 6.8% in 2019, reaching \$48 billion by 2022, the American Chemistry Council said.

Scheduled plant outages, turnarounds and shutdowns increased by 5% in 2017, with the petroleum refining industry seeing the biggest increase, according to Industrial Info.

Refiners will increase planned maintenance spend by 38.5% to \$1.3 billion in 2018, according to Industrial Info. The chemicals-processing sector will see a 4% increase.

TIME AND MONEY

Companies are willing to spend the money to expand and are in a rush to do so, but they don't want to lose money from lost production in the process.

Integrating capital projects with turnarounds can minimize downtime, saving time and money.





Since an outage at a refinery or a petrochemical plant typically runs for 45 days in execution, 60 days spec to spec, taking two in one year does not make economic sense.

However, lack of effective project-turnaround integration is cited as the top reason for turnaround failures, according to AP-Networks.

"The most challenging state of construction component, in my opinion, is the integration of capital projects with the turnaround realm," said Joe Jackson, Process Quality Assurance at LyondellBasell.

The larger the percent of capital work to be executed within the turnaround window the larger the risk for schedule and cost overrun, according to AP-Networks.

"Capital projects typically function on their Front-End Loading (FEL) timeline. A project's point in common with that of a turnaround is the delivery of the Issue for Construction (IFC) packages," Jackson said.

"IFC package information equates to scope for that turnaround, which needs to be delivered at the same time as the Turnaround plan-to-plan calls for," Jackson added. "That is why it is important to ensure that the Capital Project FEL timeline is aligned with the Turnaround timeline with the same IFC delivery date being common to both."

Project definition, feasibility and design approvals must occur a year or so before the turnaround team is formed so that detailed engineering can be completed and matched up to integrate turnaround and capital project activities.

EFFECTIVE PLAN

When it comes to integrating capital projects into turnarounds, competitive performance stems not from the dollar amount of the project or resources, but from how effective organizations are in planning for the events.

Companies must refine schedules to get ideal timing and look for lessons learned across the entire company portfolio of sites.

"The problem is that the turnaround teams are often brought in too late," Jackson said. "The turnaround team should become involved with capital projects as soon as the team is initiated."

"The turnaround manager needs to become involved with the project as soon as possible after engaging in the role," Jackson said. "Our plan-to-plan initiates integration activities at T-29 to seven months following project kickoff."

A good integrated schedule will reflect the split of turnaround activities during the three phases of pre, during and post and will align key project milestone dates with turnaround needs, he added.

TURNAROUND TEAM MANAGES

Project teams should be integrated into the turnaround process to the degree that the turnaround team manages the schedule and the physical work in the field, Jackson said.

"The handover should begin at pre-turnaround and stay with the turnaround team all the way to the end," Jackson said.

For a capital project less than \$10 million, this type of integration would need to happen at least two years before the project is executed to deliver the IFCs and overlap the IFCs and make sure they line up at the right time, Jackson said.

Having a consolidated plan in place ensures consistency and alignment, but it is important that the company sticks to that plan.

"There must be continuity in planning. You must have a holistic outlook on the entire project. If you plan and schedule, the pieces come together. But you must work the plan," Jackson said.







SCHEDULING TOOLS

LyondellBasell is one of many chemical companies using the Primavera solution by Oracle – a project management tool to handle large-scale, highly sophisticated and multifaceted projects by breaking them down into thousands of separate activities – to address planning and to schedule all events to a level 5 detail.

LyondellBasell uses print outs from this solution for a strategy they utilize called the Three Shift Look Ahead. This strategy monitors accountability and helps the team to stay on top of the plan.

The charts, print outs from the Primavera Scheduling software, show the execution team the schedule for the next three shifts. Craft and managers can look at the Look Ahead and manage this shift's work as well as see what is next.

"What tends to typically happen in these events is that the schedule gets sent out, and people start doing their own thing and there is no accountability," Jackson said.

"But if you work the plan, you are doing things in the sequential order in which they need to happen from all the logistical issues and aspects. The very best practice is to stay on schedule, stick to the schedule and work that plan," Jackson said.

The Three Shift Look Ahead follows the activities on a shift by shift basis.

CHECKS AND BALANCES

For this process to be effective, status reports must be accurate and that means establishing a system of checks and balances.

"The historical dilemma for anyone in this field is that people report where they want to be instead of where they are," Jackson said. "This is where the Ronald Reagan quote 'trust but verify' comes into play."

LyondellBasell combats that by sending people out periodically to do a checks and balances and make sure that what is reported is indeed completed.

"I recently heard that a lesson is not learned until you do something different," Jackson said. "It's one thing to talk about change for next time, but it is another thing to go forward and make the adjustments and negate the gap."

OPTIMIZATION FOR TIMETABLES OF TURNAROUNDS

Insights and Establishing a long-range strategy with Shawn Hansen, AP-Networks

With budgets and labor hours in the millions, and risks into the billions, shutdowns and turnarounds present enormous management and budgeting challenges for the energy sector.

Turnarounds are critical to the bottom line of refinery and chemical companies. These can be major events impacting a company's profits for every day of lost production, and potential harm to plant reliability if the turnaround is performed poorly. Safety and environmental risks are also a hazard.

Optimization for timetables of turnarounds is more important now than ever before, according to analysts at AP-Networks. Long-range planning done well with effective strategy and scope can level staffing needs and risks, improve budgets and schedules.

FIVE-YEAR PLANS MAY NOT BE LONG ENOUGH FOR MAKING STRATEGIC DECISIONS

The turnaround work process is often focused very heavily on two years out as a kick off to turnarounds. But the long-range plan is focused on five to 10 years out, and many are pushing this out even further now, AP-Networks said.

"To understand the next five years, we have to understand what's happening beyond the next couple of years," said Shawn Hansen AP-Networks Vice President, Research, Data Analytics, and Benchmarking. "Five-year plans may not be long enough





for making strategic decisions, key decisions that may impact subsequent turnarounds."

The five-to-ten-year considers: turnaround cycles, turnarounds and catalyst changes; capital projects, known and anticipated; inspections and safety programs; and plant and corporate initiatives.

The long-term plan is reviewed regularly and has multiple stakeholders including operations, maintenance, and commercial engagement.

CHANGING START DATE-FAILURE RISK

The refining industry has struggled to execute large, highly complex turnarounds on budget and on schedule. AP-Networks data indicate that more than two-thirds of turnarounds exceed their planned cost and schedule by 10% or have a trip after startup. 40% of turnarounds experience a cost over-run or schedule delay of more than 30%.

One of the key findings in AP-Networks research is that almost 50% of turnarounds change their start date at least once. This is now correlated to turnaround failure and risk.

Reasons for changing the start date are varied: mechanical issues, labor, supplies, environmental, or changing business conditions. AP-Networks notes that in some cases, facilities are changing these turnaround start dates multiple times, as much as four times or higher.

"Changing a turnaround start date is a leading indicator of failure. It substantially increases the risk that you are going to overrun on costs and schedule. It's one of the components that goes into our risk register," Hansen said.

SCOPE DONE WRONG

The turnaround work scope is the most critical item related to performance outcomes, as it is the foundation for cost, schedule, and plant reliability.

Minimizing the amount of scope and the level of scope growth during the turnaround execution window is the primary driver of competitiveness. Yet, despite the importance of turnaround scope, historically there have been several challenges with scopes in turnaround planning.

Top Challenges with Scopes in Turnaround Planning include:

• TheLong-Range Plan is used for budgeting. Often lacking relationship between scope and budget – Striving for a top quartile budget regardless of scope – Are the 75% of turnarounds outside the top quartile successful?

• Turnaround teams are not involved in setting long-range cost and schedule targets and understanding of risks.

• Trade-offs between Lost Profit Opportunity (LPO) and risk are difficult to understand.

The Turnaround Work Process is fast and focused on single events.

Some of the common issues out there is that the long-range planning is used for budgeting, but it often lacks relationship between budget and scope.

"Often, the budget is established by some other target and we are striving for a top quartile budget, we want to be in the top 25%. The number one way that we overrun our turnaround costs and schedules is by having unrealistic targets," Hansen said. "What this is saying is without having the scope defined we are trying to be in the top quarter. This means 75% of us are not going to be successful. And this is not going to have a scope that is going to drive success and reliability either."

Another challenge is that turnaround teams are often not involved in setting the long-range cost and schedule targets and developing the understanding of the risks. As a result, these long-range plans are established by commercial teams who may not understand complexities of the turnaround and the risks involved. A risk profile is never created as thoroughly as it could be done.





SCOPE SUPPORTS BUDGETS, STAFF AND RISKS

A baseline scope supports budgeting, staffing, and risk management. The scope can be used to develop conceptual cost and schedule estimates. Conceptual estimates can be used to investigate alternatives to optimize business value and risk trade-off.

Scope relates to cost, schedule, and risk. A baseline scope supports budgeting, staffing, and risk management. Scope can be used to develop conceptual cost and schedule estimates, Hansen points out.

Preliminary Scope numbers help set expectations. Numbers will include turnaround interval, the scope selection process, inspection programs and risk-based inspections. A preliminary worklist might include: Reactors, Vessels, Towers, Rotating Equipment, Fired Heaters, Exchangers; as well as conceptual numbers for piping, valves, instruments, and electrical. Conceptual estimates can be used to investigate alternatives to optimize business value and risk trade-off.

Optimizing scope selection helps companies reduce spending by minimizing the scope, keeping scope at manageable levels, and enabling more effective turnaround execution by eliminating the typical industry scope 'churn.'

OPERATOR CASE STUDY-INTERFACE MANAGEMENT

As capital projects become larger and more complicated, requiring numerous work packages distributed across multiple contractors, some owners are improving the outcome through interface management solutions.



Figure 43. Environmental issues disrupted a project but interface management helped get the project back on track.

Petrochemical Update hosted a webinar case study exploring how the use of successful Interface Management for a \$13 billion greenfield Canadian oil and gas project with thousands of interfaces mitigated some major risks by controlling issues from an early stage of the project's life cycle.

Kelly Maloney, an expert in EPC and owner interface management implementation, and Stephen Airey, an industry veteran with 25 years of global project execution experience at BP, Shell, and Husky Energy led the webinar discussion.

The Construction Industry Institute (CII) defines Interface Management as the management of communications, relationships, and deliverables among multiple interface stakeholders.

"Experienced project managers and interface managers are looking for better ways to identify, record, monitor, and track all project interfaces – everything from flange connections between pipelines to complex tie-ins to existing facilities," said Kelly Maloney, senior product manager with Coreworx for Interface Management.







CASE STUDY

The project discussed in the webinar was a \$13 billion total installed cost (TIC) project located in a remote northern location in Canada. The name of the project was withheld.

The site was so remote that infrastructure, roads and buildings to support development and construction of the site all had to be built.

"Even with the challenge of such a remote location, the project was considered one of the best undeveloped long-term aspects in the region," Maloney said during the webinar. "This was based on product quality, size, and production volumes which were 194,00 barrels/day and mine life, which was supposed to be more than 60 years."

Complexity was high involving both upstream and downstream, infrastructure, accommodations, mine, production, pipeline and transportation facilities and brownfield tie ins that had to be managed. The construction was a very long project running six years from FEED to on-stream.

"The project was very complex and had all the hallmark characteristics that contribute to a high-risk capital project. This type of complexity and risk is not uncommon in today's projects," Maloney said. "What sets this project apart was some of the additional challenges this project had to overcome and how they successfully addressed these difficult and unique challenges."

PROJECT CHALLENGES

This project interfaced a top 10 risk with three joint venture partners including the operator, 10 globally dispersed contractors and a full spectrum of contract types.

CONTRACTOR TURNOVER

Contractor turnover is a high risk for any project and it materialized on this project. The challenge the team had was violations in the field where they had to dismiss and remobilize a contractor.

Luckily the disciplined approach they had migrated through engineering and into construction meant they had captured those soft interfaces, who had committed to do what and when, and whether those tasks or activities had been completed.

"This allowed the discovery team to come in and know where the project was when the contractor stopped as well as help them with any potential litigation that might come up and bundle up the scope of work that was outstanding to support rapid tendering and remobilizing for the new contractor," said Stephen Airey, director of global projects and solutions for CoreWorx.

"They used the interface register to get the new contractor up to speed," Airey added. "They were able to rapidly transition from a very difficult phase and bring on a new contractor to complete the work smoothly. Here interface management enhances that contract tendering process."

EARLY GREENFIELD/BROWNFIELD OPERATIONS

The project team had processes and procedures in place for maintaining safe handover of tie-ins.

Early on there was a No lost time incident (LTI) between a contractor handover, but the team knew the project needed additional checks and balances.

"Recognizing the number of actors in the field, they knew they needed additional checks and balances on top of their best practices," Airey said. "This drove soft interfaces confirming who would do what, when, and what they would supply."

Interface documentation and the status of agreements were captured in the handover binders to add another layer of safety, security and reassurance.







CRITICAL MILESTONES

A big issue was the large number of contractors and limited schedule integration for high level detailed dependencies. To meet critical milestones, the team had five contractors in one geographical area and one week to complete interface tie-ins for these detailed activities.

Coreworx Interface Agreements established priority and drove collaboration by making sure that scope and execution timelines were aligned. Collaboration ensured a safe and successful completion.

ENVIRONMENTAL/WEATHER RISKS

The Northern Canada location meant a risk for floods and forest fires and potential activity and site shutdown. The project team focused on the critical path and potential risk impact plan for worst case scenario.

"These environmental and weather concerns always end up on a risk register. This team had a lot of plans in plans in the event of a weather emergency, including evacuation and shutdown plans," Airey said.

The worst weather cases did materialize, as floods and major forest fires both shut down the entire site for weeks. Coreworx Interface agreements captured the outstanding scope and the team effectively recovered and prioritized scope to ensure a safe and successful re-start, Airey said.

In 2016, a major wildfire began southwest of Fort McMurray, Alberta, Canada. With an estimated damage cost of C\$9.9 billion, it is the costliest disaster in Canadian history, according to the Insurance Bureau of Canada.

Catastrophic flooding in the same area was also added to the list of weather dangers experienced during this project's lifecycle.

This project team lost multiple weeks on their schedule in different scope areas from these disasters.

Interface Management enhanced the procedures the team had for stop work, demobilize, and remobilize because the team captured what had been done up to that point of stop work.

"When the project team remobilized, they knew what needed to be done immediately to complete the schedule, what was secondary priority, and what they could potentially push off and put on to the next team," Airey said.

"Interface Management allowed them to effectively recover and prioritize to stay on schedule. It enhanced their current business plans and procedures to create additional value to the team," Airey added.

CONSISTENCY ACROSS SITES

Despite a consistent process applied to all turnarounds now, 40% miss their schedule and/or budget targets by 30% or more. However, there is a big opportunity for the industry to manage turnarounds more effectively.

Integration of capital projects into turnarounds is one of the key reasons for this lack of consistency. It is difficult to identify where the gaps are, and assessments are not identifying the problem efficiently.

Some organizations take a very site-specific approach where they try to understand how each site is doing its own turnaround. Often this knowledge is internal and not well documented, so if staff move on it can take time for new staff to get up to speed. Increasing resilience and helping to share best practices are key drivers.

Overall, there is general agreement on the overall flow of the work process, but progress needs to be made on standardization and the sharing of best practices.





PROCESS ENGINEERING / TECHNOLOGY

CRUDE OIL TO CHEMICALS- MAJOR DISRUPTOR

As global demand for chemicals grows faster than demand for transportation fuels, companies are looking at ways to configure refineries into crude oil to chemical (COTC) plants. The rise of big national oil is coming in the Middle East as soon as 2025 and could be a major disruptor, analysts predict.

"The oil companies recognize that demand for oil for fuel will likely decline with the rise of electric cars, so they are looking to invest in using their crude for petrochemicals," Joseph Chang of ICIS said.

"They are not going to sit by and let the US take more market share in chemicals with shale gas. The Middle East will usher in a wave of new capacity through massive investments by 2025."

Several COTC projects being planned or started in Asia and Saudi Arabia threaten to reshape the global petrochemical industry in the coming years.

In lieu of producing transportation fuels, these COTC plants can convert crude oil directly to chemical feedstocks.



Image: ICIS

COTC signal a new era in the global petrochemical industry, writes IHS Markit.

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. (IHS Markit)

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. (IHS Markit)





Crude Oil-to-Chemicals and Other Disruptive Technologies Will Have a Significant Impact on the chemical industry, IHS Markit Says.

The convergence of COTC and oxidative coupling of methane (OCM) are poised to have a very significant impact on the chemical industry, according to analysis by Don Bari of IHS Markit released in June 2018.

"The objective is to shift the product slate derived from a barrel of oil to a range of 40% to 80% chemical feedstocks and non-fuel products, up from the traditional range of 15% to 25 %, in order to significantly increase the value of crude oil reserves," Bari writes.

For example: The global demand for ethylene and propylene are 160 million tonnes/year and 111 million tonnes/year per year, respectively, and at approximately 4% annual growth rate, the required global annual capacity additions would be 6.4 million tonnes/year and 4.4 million tonnes/year of ethylene and propylene, respectively.

These volumes could nearly be supplied from two large-scale 200,000 barrel-per-day COTC complexes.

If multiple COTC facilities are eventually built, the export dynamics would, over time, change significantly and put pressure on olefin and feedstock-related derivative exports from the U.S.

According to IHS Markit estimates, U.S. exports of these olefin and feedstock-related derivatives will reach approximately 14 million tonnes/year by 2020.

PETROCHEMICAL / REFINERY INTEGRATION

A decade or so ago, refining was the big dog and petrochemicals was the tail of the dog. The money was in crude oil and refined products.

Refined products include gasoline, jet fuel, and diesel. Transportation fuels such as gasoline and diesel are at the core of most refineries' product slates and make up the largest share of refined product offtake.

Global refined product demand has experienced an average growth rate of 1.3% annually since 2000, according to IHS Markit.

The outlook for the next decade is less rosy, with demand growth from 2020 to 2030 expected to average only about half the rate of the prior period. This slowdown will continue into the 2030s, with absolute demand growth peaking in the latter half of the decade before entering a gradual decline in the 2040s, according to IHS Markit.

Facing flat or declining market demand for refined products, refiners are bracing for lower sales and profits. In contrast, petrochemicals market demand continues to rise and grow in importance.



Figure 44. Image: IHS Markit





In the coming years, several headwinds will pressure growth in transportation fuels further: reduced fuel usage, substituting traditional fuels for electricity or renewables as well as government regulations.

At the same time, population growth alone will drive petrochemical demand.

By 2040, IHS Markit expects 9.2 billion inhabitants living and thriving on the planet, an additional 1.6 billion people compared with 2017.

"Even if the petrochemical per-capita consumption rate remains unchanged from 2017 levels, the overall volume of products consumed will increase significantly as a simple consequence of serving more people," IHS Markit writes.

In addition, as more people move from lower to middle economic classes, a shift in consumer focus will lead to more spending on petrochemical based products including plastics, cosmetics, appliances, mobile devices, electronics and packaging.

How can refiners use growing petrochemical demand to help their businesses survive and thrive? One possible solution the industry will consider over the next few years involves finding new ways to integrate refinery and petrochemical operations.

CONCLUSION

Cheap and abundant natural gas supplies, infrastructure, skilled labor, middle class demand, and tax incentives are among the incentives for downstream capital investment in the Americas.

The US Gulf Coast remains an attractive region in North America for chemical-related investments because of skilled workers, storage capacity and other supply chain infrastructure.

The Northeast region of the US is on its way to becoming a second chemicals hub, because it is so central to feedstock natural gas supplies and the downstream consumer.

Canada and Mexico are quickly becoming attractive places for investment in the Americas.

Canada is rich in natural gas and prices are at all-time lows, just when demand is escalating in Asia and India; pushing the export and construction potential the continent holds for the petrochemical industry closer to reality.

The newly agreed upon "new NAFTA" is positive for the US because Canada and Mexico are the number one and two destinations for US exports. The new trade deal is called the United States-Mexico-Canada Agreement (USMCA), refreshing the original agreement in place since 1994.

Meanwhile, China is the number three top destination for US exports and trade wars will have impact as new facilities come online.

The Middle East will not sit quietly for long, however. Growth in the Middle East and China is likely to take place in 2025, likely changing trade routes again.

While attention turns to the momentous growth in North America for now, EPCs, owners and the firms that service them are focusing on how to be the most efficient, cost effective and technologically advanced they can be.

Companies can use the rapid growth to their advantage by adjusting best practices and better defining their growth strategies.

Predictive maintenance, reliability, communication techniques, integrated schedules, and harnessing new technologies while maintaining human connection are a few of the opportunity's companies can use in this time of rapid growth and change.



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