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Crude Oil-to-Chemicals (COTC)

A look inside our technology & economic analyses from the 2019 – 2014 Process and Economics Program (PEP)

*Featured reports in this document are a part of a continuing technology and economics PEP offering on COTC

Crude Oil-to-Chemicals (COTC): "Transformative" technology offers a path to greater refining profitability by converting crude to higher value chemicals, with a scale that would disrupt the global chemical industry

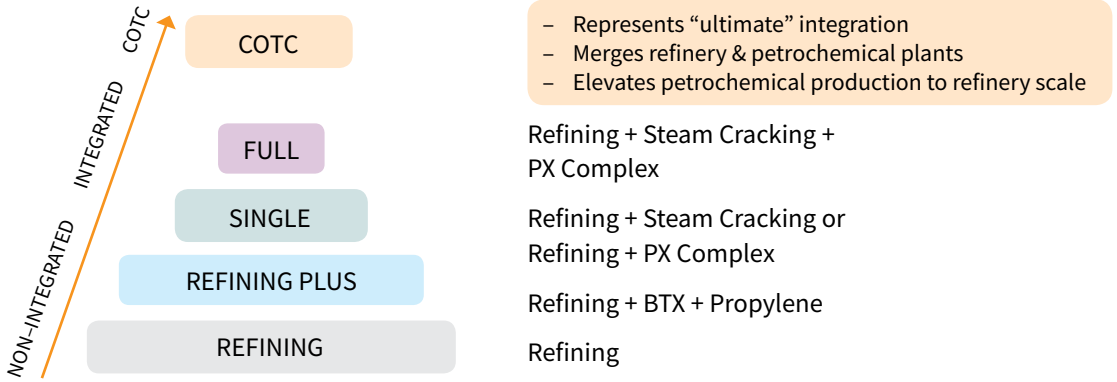
According to our analyses starting in 2015, crude oil-to-chemicals (COTC), a revolutionary technology advancement in refinery and petrochemical integration, could more than double the profitability from a barrel of crude oil for global refiners, according to our new analyses. *The abstracts for the five COTC-relevant PEP Reports and/or Reviews described herein, are included below for more information about these relevant offerings.*

This innovation is driven by a new "push-pull" paradigm in the energy industry. Changes in mobility (transportation) are predicted to reduce the fuel-based demand growth for crude oil, and thus the market is "pulling" the oil industry in a new direction. The oil refiners are seeing opportunity to convert low value oil into high value chemicals and therefore seeking to "push" barrels of oil (displaced and new) into the chemical markets. As such, one of the most significantly disruptive technologies or categories of technologies being developed, based on their sheer volume, is crude oil-to-chemicals. These projects, in effect, cut out the 'middle-man,' and merge a refinery and petrochemical plant into one; while returning great margins to the refiners relative to fuels products.

This innovative new process technology is still in its infancy, but, according to our independent analysis, if built to world-scale, it has the potential to more than double the value refiners can unlock from a barrel of oil. This process is both transformative in terms of its potential, and timely, as refiners face declining future demand for gasoline and fuel production due to carbon emission mandates, greater vehicle fuel efficiency, and an increasing demand for electric vehicles.

We classify the degree of refinery-petrochemical integration according to four levels. COTC can be considered as the ultimate integration by merging refinery and petrochemical operation with a single objective of producing maximum chemicals, exceeding 70% of the barrel producing chemical feedstock as compared to under 10% in a non-integrated conventional refinery (level 1).

COTC configures a refinery to produce maximum Chemicals



IHS Markit has evaluated COTC at multiple levels, starting with projects aimed at converting >40% of the barrel of oil to chemicals instead of traditional transportation fuels. This is significantly higher than about 20% of the barrel to petrochemical feedstocks in the state of art well-integrated refinery-petrochemical complexes such as those in India and in Saudi Arabia.

Specifically, ExxonMobil developed a technology that takes a very light crude to feed directly to a steam cracker. The conversion is estimated at 76% (PEP Report 29J). However, the capacity is limited to 1 to 1.5 million tons of ethylene due to cracker capacity limitation. It's also limited to the availability of a very light crude. Other companies, as shown below with the project status, including Hengli Petrochemical (PEP Report 303A), Zhejiang Petrochem (PEP Report 303A), Hengyi Shenghong and Aramco/SABIC (PEP Report 29J) start from new refinery configuration to produce maximum chemicals in the refinery and to produce maximum feeds to a steam cracker. The chemical conversion is about 40-60% per barrel of oil. But since the projects start from 8 to 20 million tons of crude oil, the amount of chemical produced per project will be very high.

COTC projects update

Project	Refinery Capacity (MMTPA)	P-Xylene Capacity (MMTPA)	Olefin Capacity (MMTPA)	Est. Chemical conversion/ bbl of oil (%)	Investment ($bn)	Start Trial Operation
Hengli Petrochemical	20	4.3	1.5	42	11.4	Dec 2018
Zhejiang Petroleum and Chemical (ZPC) Phase 1	20	4.0	1.4	45	12	Est. Q2 2019
Hengyi (Brunei) PMB Refinery-Petrochem	8	1.5	0.5	>40	3.45	Est. 2019
Zhejiang Petroleum and Chemical (ZPC) Phase 2	20	4.8*	1.2	50*	12	Est. 2021
Shenghong refinery and Integrated Petrochem	16	2.8	1.1	60**	11.0	H2** 2021
Aramco/SABIC JV	20	--	3.0	45	20	2025

* ZPC/UOP press release Jan. 17, 2019 announced that Phase 2 configuration and technology will be changed from Phase 1.
** Based on information obtained by IHS Markit from a visit to Shenghong in November 2018

In addition to Aramco/SABIC's COTC JV, which is ongoing, Aramco signed a joint technology development agreement with Chevron Lummus Global and CB&I (now McDermott) to scale up and commercialize Aramco's Thermal Crude to Chemicals (TC2C™) technology, aiming at 70-80% conversion per barrel of oil to chemicals (PEP Review 2018-06 and PEP Report 29J) . Aramco also signed a joint development and collaboration agreement with Axens and TechnipFMC to accelerate and commercialize its Catalytic Crude to Chemicals (CC2C™) technology, aimed at converting >60% per barrel of oil to chemicals.

Moreover, Aramco signed a license agreement to integrate Siluria's natural gas to olefins technology with its high-olefin cracking process technology (PEP Review 2018-06 and Review 2014-07).

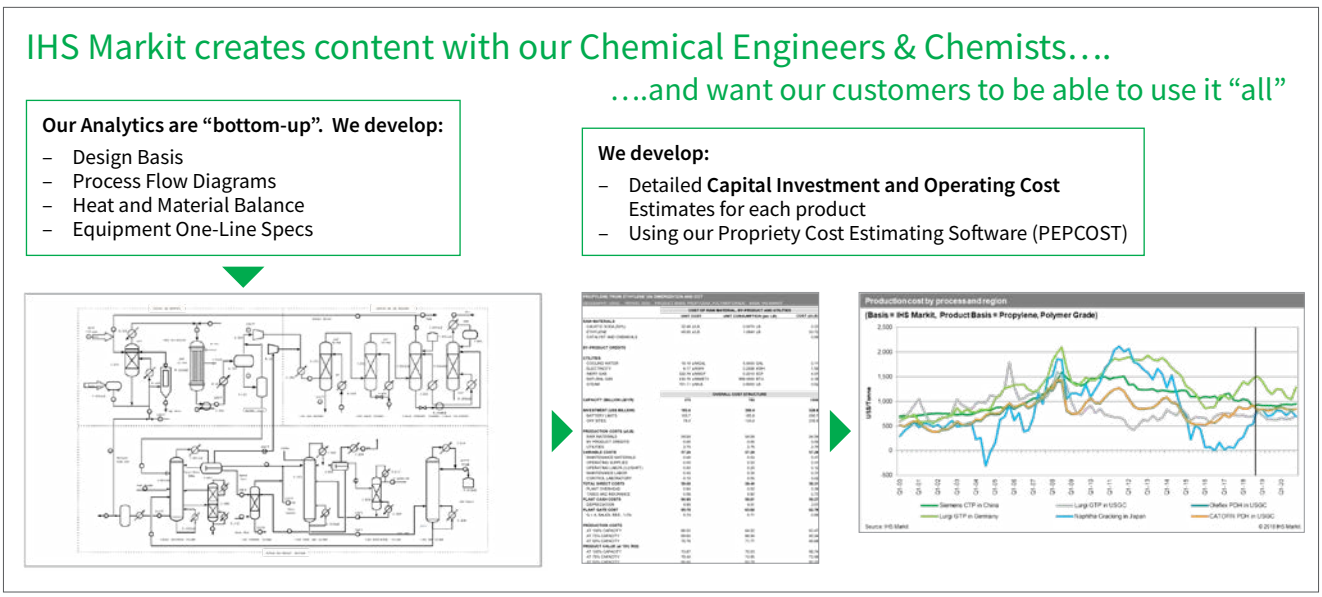
The Process Economics Program (PEP)

PEP provides in-depth, independent technical and economic evaluation of both commercial and emerging technologies for the chemical, biochemical, and refining industries. For 56 years, PEP has and continues to analyze the impact of changes in processes, feedstocks, energy prices, and government regulations on chemical and fuel production economics for our clients

Benefits

New technologies can either offer an opportunity or pose a threat. Prompt and thorough analyses of new developments are crucial to making the proper decision—whether you are exploiting a proprietary technology or responding rapidly to a competitor's move. PEP reduces the time and costs associated with collecting and interpreting the voluminous information needed to assess new technologies.

Clients make use of PEP's independent analyses—which draw on our experts' industry experience in process design, cost estimation, and R&D planning—to make informed decisions. Complementing that expertise are the program's extensive databases ongoing contacts with chemical companies worldwide.



Recent IHS Markit COTC PEP Reports and Reviews

Crude Oil to Chemicals and Oxidative Coupling of Methane: Potential Synergy? PEP Review 2018-06 (April 2019)

Download Press Release

Abstract

On 13 June 2018, Siluria Technologies, Inc. issued a press release announcing that Saudi Aramco Technologies Co., a subsidiary of the world's largest oil company, had purchased five licenses for Siluria's oxidative coupling of methane (OCM) process to make light olefins from methane. Saudi Aramco called the Siluria process a "strong fit" with certain plant configurations for crude oil to chemicals (COTC).

In this review, we present two COTC concept cases. The first is an update of a concept that we first published in PEP Report 29J, "Steam Cracking of Crude Oil" (March 2016), scaled up to 200,000 BPD. We also balance the steam cracking and HSFCC (high-severity fluid catalytic cracking) capacities, which shows that on a third quarter 2018 Saudi basis

net refinery margin (EBITDA) for this concept is over $17/bbl. If this performance could be achieved in the field, such a COTC refinery would rank as the best performer in Eurasia.

We also present a case in which OCM is integrated into the COTC process. Here, the OCM unit cofeeds ethane and propane along with methane, thereby substituting for gas crackers. Here, the extra ethylene produced via OCM from inexpensive Saudi methane appears to roughly balance the increased CAPEX for the OCM and associated units.

Steam Cracking of Crude Oil PEP: Report 29J (March 2016)

Abstract

In January 2014, ExxonMobil officially opened a novel steam cracker in Singapore that produces olefins directly from crude oil. The Saudi Arabian Oil Company (Aramco) has discussed plans to build a crude-to-olefins complex. SABIC is another company that has looked into direct crude-to-olefins. In this report, we examine some of the technologies required to support the direct production of olefins from crude oil.

We present process design studies for the ExxonMobil and Aramco processes. We look at capital and production costs for a facility in Singapore using the ExxonMobil process and compare that process in detail with traditional naphtha cracking. In particular, we lay out side-by-side crude oil versus naphtha comparisons of yield sets, major equipment sizes, and process economics. Our analysis indicates that the ExxonMobil process achieves a $100–200/ton cost advantage vis-à-vis naphtha cracking with only a modest increase in capital expenditures (capex).

We also present capital and production cost estimates for a facility in Saudi Arabia using the integrated Aramco crude-to-olefins process. The Aramco route benefits from a significant by-product value uplift and an advantageous feedstock price spread, the sum of which results in a cash cost advantage of over $200/ton compared with conventional naphtha cracking. Capex is significantly higher, however. These two factors largely cancel one another out. We conclude that the Aramco process shows equivalent to slightly advantageous economics compared with naphtha cracking.

Crude Oil to p-Xylene Hengli Refinery-PX Complex - PEP Report 303 (December 2018)

Abstract

Crude oil-to-chemicals (COTC) technology involves configuring a refinery to produce maximum chemicals instead of traditional transportation fuels. COTC complexes elevate petrochemical production to an unprecedented refinery scale. Because of the huge scale as well as the amount of chemicals that each COTC complex produces, COTC technology is one of the most important and imminent developments in the last three years, and will profoundly affect the global petrochemical and refinery industries.

Section 1 of this report starts with an introduction of recent COTC projects—already started or announced by various Chinese companies and by Saudi Aramco and SABIC—to explain the strategic implications. Among these projects, Hengli Petrochemical's refinery-PX (para-xylene) complex is at the most advanced stage. The plant is being constructed and is expected to start a trial run in late 2018. When completed, the complex is expected to produce 4.34 million tons of PX per year, in addition to 3.9 million tons of other chemicals. This complex, together with two other similar projects in China, will significantly change the supply/demand balance of PX in China and around the world. Hence, we chose Hengli's complex to be the focus of this report.

Section 2 summarizes the overall PX production costs of Hengli's refinery-PX complex, comparing them with PX market price under a wide range of oil price scenarios. This report represents a major undertaking by the IHS Markit Process Economics Program (PEP), and is the first independent assessment of a COTC commercial project. The report should be of interest to all companies seeking to gain insights on how COTC technology works and its potential impacts and implications.

Section 3 provides a discussion of various COTC conversion routes and explains the difference between COTC and other approaches. It is followed by a progress report of the major COTC projects. In the end, we have provided the top-level market overview of PX to evaluate the potential market impact of the three refinery PX complexes in China.

The objective of this report is to elucidate Hengli complex's configuration and the technologies employed, and to assess the production economics of the complex. Section 4 provides a technology review of the configuration and major processes, divided into seven sections—crude distillation, light ends conversion, hydrocracking, aromatics complex, coal gasification, residue de-asphalting and gasification, and lube base oil production. Section 5 presents the production economics of the processes grouped by the seven sections in the complex, and section 6 presents the process economics of the entire complex as well as a scenario analysis.

Crude Oil to p-Xylene Crude Oil to P-Xylene – Zhejiang Refinery-PX Complex- PEP Report 303A (coming August 2019)

Abstract

Crude oil-to-chemicals (COTC) technology involves configuring a refinery to produce maximum chemicals instead of traditional transportation fuels. COTC complexes elevate petrochemical production to an unprecedented refinery scale. Because of the huge scale as well as the amount of chemicals that each COTC complex produces, COTC technology is one of the most important and imminent developments in the last three years, and it will profoundly affect the global petrochemical and refinery industries.

PEP Report 303 published in December 2018 analyzed Hengli Petrochemical's refinery-PX (para-xylene) complex, which started test run of its refinery on December 15, 2018. The complex is expected to produce 4.34 million tons of PX per year, in addition to 3.9

million tons of other chemicals. Hengli's complex is estimated to start operation in 2019. Hengli's configuration is mainly based on hydrocracking of diesel, gas oil, and vacuum residue with technologies licensed from Axens.

Zhejiang Petroleum and Petrochemical (ZPC)'s Phase1 project is also close to mechanical completion and is expected to start trial run in 2019. When completed, this Phase1 project is expected to produce 4.0 million tons of PX, 1.4 million tons of benzene, 1.4 million tons of ethylene and other downstream petrochemicals. The Phase2 project construction has also been started, and when completed, it will have the similar scale and major product yields as the Phase1 with only minor differences in a few downstream petrochemical units. When both phases are completed, it will be the largest COTC project in the world.

ZPC's configuration is mainly based on diesel hydrocracking with technology licensed from Chevron and gasoil hydrocracking with technology licensed from UOP. Instead of hydrocracking of residue, ZPC uses RFCC (Resid Fluid Catalytic Cracking) licensed from UOP to process its vacuum residue. It's the objective of this PEP 303A report to analyze ZPC's Phase1 refinery-PX complex to offer our independent evaluation of the production economics and compare it with Hengli's complex to see the results of different process configurations.

Section 1 gives the status of all announced COTC projects with emphasis on ZPC's project progress and Phase1 and Phase2 main process units and technology choices. Section 2 summarizes the overall PX production economics of Zhejiang Phase1 refinery-PX complex. The economics are evaluated under a wide range of oil price scenarios and compared with Hengli's project. Section 3 provides a top-level PX market projection in China based on the latest status the COTC projects.

Section 4 consists of process description and process flow sheets of major refinery-PX process units. Section 5 presents the production economics of the processes grouped by major process blocks in the complex, and section 6 presents the process economics of the entire complex as well as a scenario analysis.

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Are crude oil to chemicals projects good investments?

"Transformative" technology offers a path to greater refining profitability by converting crude to higher value chemicals. According to our independent analysis, if built to world scale, these technologies will disrupt the global chemical industry.

In this video, RJ Chang, VP of Process Economics Program, discusses updates regarding the upcoming COTC projects, technologies involved, economic competitiveness, long term impact and more.

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