Oil-to-chemicals: New approaches from resid and VGOs

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Crude oil-to-chemicals (COTC) continues to be a powerful industry driver, and a strong trend of high interest to integrated refineries and chemicals producers. This is reinforced by many factors, most notably by forecasts that predict a slowing of transportation fuels growth approaching 2040 (with hybrids and EVs), while the growth in chemicals is expected to increase as the population and middle-class wealth continues to rise, leading to increasing demand for packaging, consumer goods and automobiles.

Numerous corporations have committed a combined \$315 B to reconfigure their assets to produce more petrochemicals than transportation fuels, as revamps as well as to build new grassroots refineries during the next decade. We anticipate that another \$300 B or more will also be announced in the next five years as refiners and chemical companies reassess their positions, knowing that the longer-term outlook for transportation fuels from crude oil is expected to plateau and then decline.

Integration. Considerable flexibility is being offered by petrochemical licensors, particularly in petrochemical resid and vacuum gasoil (VGO) and fluid catalytic cracking (FCC) upgrading units. These global changes include deep catalytic cracking (DCC) from Sinopec, as well as Western leaders such as TOTAL's R2R modifications, and Axens' high-severity FCC (HSFCC) with Saudi Aramco. Technology does not stand still. Advances in catalytic visbreaking may also be important in the future, when looking into advanced lower-cost alternatives and R&D pipelines.

Two main interests for producers are 1) to decrease capital intensity through scale, simplicity and location; and 2) to expand/maximize flexibility toward the use of current (heavier) feedstocks in considering the "oil-to-chemicals" approach. The idea that better utilizing assets from within an integrated refinery site means that you are most likely already dealing at 10-times the size of a world-scale petrochemical plant. Although scale counts, it is also only one of many factors. New advanced configurations will now begin to incorporate the planning of improved efficiency gains and reduced carbon dioxide (CO_2) emissions, as well. In its *2018 Outlook for Energy,* ExxonMobil forecast that by 2040, while energy efficiency gains are expected to nearly double, carbon emissions are only projected to increase by a modest 10% (**FIG. 1**). BP statistics, along with Chevron, IEA and EIA forecasts, also show similar trends.

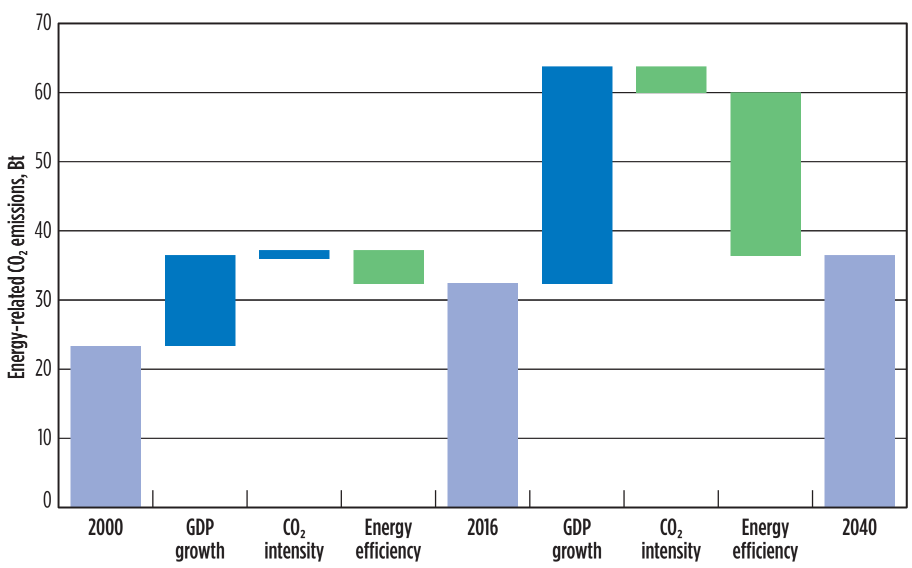

FIG. 1. Energy efficiency gains are expected to nearly double by 2040, while carbon emissions are projected to increase by a modest 10%. (ExxonMobil *2018 Outlook for Energy*).

Company	Location	Cost (\$BIL)	Type	Projected Start up
China				
Zhejiang Petroleum and Chemical[3]	Zhoushan, China	\$20	Greenfield	2019 (Phase 1)
Hengli Petrochemical[3]	Changxin Island, China	\$11	Greenfield	2019
Shenghong Petrochemical[1, 2]	Lianyungang, China	\$11.84	Greenfield	2019
Ningbo Zhongjin Petrochemical (subs Rongsheng Petrochemical)[1, 4]	Ningbo, China	\$5 (est)	Revamp	2018
Saudi Aramco/NORINCO/Panjin Sincen (Huajin Aramco Petrochemical)[3]	Liaoning Province, China	\$10+	Greenfield	2024
SABIC/Fuhaichuang Petrochemical[3]	Zhangzhou, China	NA	Greenfield	NA
SINOPEC/SABIC (Tianjin Petrochemical)[5]	Tianjin, China	\$45 combined (est)	Revamp	Operating, pre-2017
PetroChina[5]	Dalian, China		Revamp	Operating, pre-2017
PetroChina[5]	Yunnan, China		Revamp	Operating, pre-2017
CNOOC[5]	Huizhou, China		Revamp	Operating, pre-2017
SINOPEC[6, 7]	Lianyungang, China	\$2.8	Greenfield	NA
SINOPEC[6, 8]	Caofeidian, China	\$4.2	Greenfield	NA
SINOPEC[6, 9]	Gulei, China	\$4.26	Greenfield	2020
		Total China: \$120.1		
Other Asia				
Hengyi Group[3]	Pulau Muara Besar, Brunei	\$20	Greenfield	2020
Saudi Aramco/ADNOC/India Consortium[3]	Raigad, India	\$44	Greenfield	2025
Petronas/Saudi Aramco (RAPID)[3]	Pengerang, Malaysia	\$2.7	Greenfield	2019
ExxonMobil (Singapore Chemical Plant)[11, 12]	Jurong Island, Singapore	<\$1	Revamp	2023
Pertamina Rosneft[6, 13, 14, 15]	Tuban, East Java, Indonesia	\$15	Greenfield	2025
		Total Other Asia: \$82.7		
Middle East				
ADNOC[3]	Al Ruwais, UAE	\$45	Revamp	2025
Saudi Aramco/SABIC[3]	Yanbu, Saudi Arabia	\$30	Greenfield	2025
Saudi Aramco/Total[3]	Jubail, Saudi Arabia	\$5	Greenfield	2024
KNPC/KIPIC (Al-Zour Refinery)[16]	Al Ahmadi, Kuwait	\$13	Greenfield	2019
Oman Oil Company/Kuwait Petroleum International (Duqm Refinery)[17]	Oman	\$15	Greenfield	NA
		Total Middle East: \$108		
Europe				
MOL Group[18]	Hungary, Croatia	\$4.5	Revamp	2030
		Total Europe: \$4.5		
Total Greenfield: \$215	**Total Revamps: \$100**	**Total Global: \$315**		

FIG. 2. Announced oil-to-chemicals investments, 2019. (TCGR, "Oil-to-chemicals II: New approaches from resid and VGOs.")

In addition to Saudi Aramco/SABIC announcements, ongoing investments in competitive COTC developments are being seen. In a more recent example, private chemical producers Hengli and Rongshengin China are back-integrating their chemical plants to add more than 9 MMtpy of paraxylene (PX) capacity by 2021. This is expected to reduce PX imports by 4 MMtpy, with plans to yield up to 45 wt% of chemicals processing heavy crudes, which will tighten medium-to-heavy crude markets while also adding a 40% surplus to distillates and gasoline markets.

One of the most difficult components has been to understand that all licensors need to prioritize their own businesses. Therefore, they will prefer greenfield investments to revamps—even if these can be accomplished at lower inside battery limits (ISBL) and outside battery limits (OSBL) costs. This is not a criticism but rather a statement of fact based on desired business focus. Moreover, one understanding is to appreciate how existing and new configurations can be tailored towards either aromatics or olefins; however, this may not be the best measure if the goal is to produce more olefins. In this regard, assuming an existing steam cracker, the revamp approach may be quite different.

Advances to heavy oil processes. For processes that convert the higher molecular weight constituents of petroleum (the heavy ends) to products that are suitable for use of feedstocks to the petrochemical section of the refinery, the assessments are broken into groups to include carbon rejection and hydrogen-addition approaches, along with process combinations and new configurations.

- Carbon rejection
- Hydrogen addition
- Combining processes and treatment of intermediates
- Configuration issues and advances
- New processes likely to be deployed during the next five years.

Highlights addressing potential deployment of technology advances, including combinations and configurations include:

- For decades, propane has been the mainstay used extensively in deasphalting heavy feedstocks, especially in the preparation of high-quality lubricating oils and feedstocks for catalytic cracking units. Future units, which may well be derived from the ROSE™ process, will use solvent systems that will allow operation at elevated temperatures relative to conventional propane deasphalting temperatures, thereby permitting easy heat exchange. Other areas of future process modification will be in the extractor tower internals, studies with higher molecular weight solvent, accurate estimation of physical properties of mixed streams, studies in combination with other processes and firming up design tools for supercritical solvent recovery configuration.
- For heavy feedstocks, which will increase in amounts in terms of hydrocracking feedstocks, reactor designs will continue to focus on online catalyst addition and withdrawal. Fixed-bed designs have suffered from (1) mechanical inadequacy when used for the heavier feedstocks, and (2) short catalyst lives (six months or less), even though large catalyst volumes are used [a liquid hourly space velocity (LHSV) typically of 0.5–1.5]. Refiners will attempt to overcome these shortcomings by innovative designs, allowing better feedstock flow and catalyst utilization or online catalyst removal.
- Catalyst development will be key in the modification of existing processes and the development of new processes to make environmentally acceptable distillable liquids. Although crude oil conversion is expected to remain the principal future source of petrochemicals, natural gas reserves are emerging, and will continue to emerge, as a major hydrocarbon resource.
- The detrimental effects of coke are a reduction of support porosity, leading to diffusional limitations and finally blocked access to active sites. Nevertheless, moving-bed or ebullated-bed processes alone—or in combination with fixed-bed reactor technology and/or also coupled with thermal processes employing suitable catalyst with metal retention capacity—represent the most efficient way of handling petroleum bottoms and other heavy hydrocarbons for upgrading.

Critical to an assessment of the oil-to-chemicals potential are the number and types of committed investments to date. A 2019 industry study (TGCR 2019) documents the announced investments declared during the last five years as oil-to-chemicals projects, along with company, location, size of project and investment. Where available and announced, **FIG. 2** includes the wt% fuel vs. chemical targets.

Project examples exist where these considerations have already been reviewed. For example, MOL Petrochemicals, Tiszaujvoros, Hungary, has decided to upgrade its 100,000-tpy facility to produce more polymer grade propylene from steam cracking and refinery feedstocks. It has chosen two steps utilizing Lummus OCT, which will generate increased propylene production, and a CDHydro Deisobutanizer, which will generate an isobutene-rich stream. These modifications are reportedly available for less than $50 MM. The MOL revamp is interesting as it intends to incorporate Innovacat swing fixed-bed technology in the refinery.

Another example is the revamp for the Polish refiner Grupa LOTOS. In 2011, it installed and made operational a new generation of DAO hydrocracking technology as part of a major resid upgrading project called the 10+ Programme. In this case, it raised refining capacity by 75%, focused on higher margin diesel fuels to increase market share and enhanced margins by $5/bbl. In this case, the two units added by Shell Global Solutions were a 45,000-bpd DAO hydrocracker using 50/50 VGO/deasphalter (DAO) straight off these units, with the added DAO unit. What is interesting using Urals feedstock is that the hydrocrackers, inclusive of both hydrodemetalation (HDM), hydrodesulfurization (HDS) and hydrodenitrogenation (HDN), were able to increase conversion from 60% to 85% with a recycle mode.

Based on the information from these examples and assuming the VDU and ADU investments are already in place, then, a solvent deasphalting (SDA) unit (KBR Rose, or Axens Hyvahl or SELEX-Asp) depending on the product slate chosen, is a considered first step at a lower approximate cost of $250 MM–$280 MM. The following issue depends on the existing HDM, HDS and HC capacity.

Takeaways. The ongoing drive for improved profitability profiles, derived by producing petrochemicals as opposed to fuels, has justified the increased pace of the oil-to-chemicals movement. Not only are demands for olefins and aromatics growing more quickly than gasoline and diesel, the profit margins for these petrochemicals are also higher, and even more so when made directly via oil-to-chemicals conversion routes.

Two oil-to-chemicals approaches—carbon out and hydrogen in—have implications across related technologies. Coking will remain a "go to" for carbon-out with any advances outsizing impacts (due to the breath of implementation, e.g., delayed coking); hydrogen supplies will need to increase or become more flexible (without additional energy/CO_2 impacts) to address the range of upgrading requirements. •

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MAJORS LOOK TO STORE JET FUEL AT SEA AS AIR TRAVEL DRASTICALLY CURBED

Major oil companies including BP and Shell are preparing to take the rare step of storing jet fuel at sea as the coronavirus outbreak disrupts airline activity globally, while refiners are shifting to diesel due to the poor margins associated with jet fuel production.

Jet fuel demand has cratered as airlines suspend flights due to the coronavirus pandemic, which globally has infected more than 350,000 people and killed more than 15,000 (as of 3/23/20), prompting travel restrictions from governments around the world, including the U.S. Market participants and refiners have had to scramble to adjust to incredibly low prices.

Storing jet fuel at sea, however, is something of a last resort. The product is sensitive to contamination and degrades more quickly than other refined fuels and especially crude oil, so after a few months, it no longer can be used for aviation, according to analysts.

Jet fuel demand averages about 8 MMbpd, but that has already dropped by about 20%, according to Robert Campbell, head of oil products at consultancy Energy Aspects.

Overall, the oil market could see a record build in supply in April that could overwhelm storage capacity within months, analysts said.

"With European kerosene (jet fuel) stocks near record levels, floating storage is one possibility for surplus jet fuel, though due to strict quality specifications, traders will be reluctant to attempt long-term storage of surplus fuel given the risk of contamination," Campbell said.

Shifting the mix. Storing refined products is more difficult than storing crude oil due to concerns about oxidation, stability and moisture content. Some U.S. refiners have decided to blend jet into the diesel pool, which is presently more profitable. A small amount of jet fuel can be dropped into diesel in crude distillation towers at a refinery, which separates raw crude oil into products with different boiling points.

Refiners can also choose to adjust their fluid catalytic cracking units (FCCUs) to yield less gasoline and more distillate. However, the move could be oversupplying the diesel market in some regions of the U.S. •