

Oil-to-Chemicals II: New Approaches from Resid and VGOs

**Multi-Client Study Presentation
(study completed June 2019)**

July 2019



Oil-to-Chemicals II: New Approaches from Resid and VGOs

STUDY COMPLETED!

This TCGR multi-client study was launched in January 2019 and was completed in June 2019. The study’s scope, and specific contents (as depicted in the ToFC on pages 9-17 of this presentation), reflect the inputs from a group of “charter” subscribers who indicated their priorities for coverage, areas to be expanded/deepened and focal points for emphasis in opportunity identification. These are leading industrial developers, suppliers, and end-users of oil-to-chemicals based technology.

ABSTRACT

At the core of this study is the fit of different configurations now available from both licensors and new pipeline technologies that increase the flexibility and decrease the OPEX of petrochemicals production. Key references to this focus are given by Shell and Chevron Lummus Global (Ref. 1, Ref. 2) which are central to discussing recent installations by Hyundai, Grupa Lotos and the FEED studies for Aramco. How these stack up against historical benchmarking is to the benefit of subscribers. More than half the report will be dedicated to these changes (see the actual ToFC on pp. 9-17).

I. INTRODUCTION

Crude Oil-to-Chemicals (COTC) continues to be a powerful industry driver, and a strong trend of high interest to all integrated refineries and chemicals producers in Asia/Pacific, China, the Middle East and Eastern Europe! This is reinforced by a number of factors, most notably the forecasts which predict a slowing of transportation fuels growth approaching 2040 (with hybrids and EV’s), while the growth in chemicals is expected to increase as the population and middle class wealth continues to rise, increasing demand for packaging, consumer goods and even including automobiles (see Figures 1 and 2).

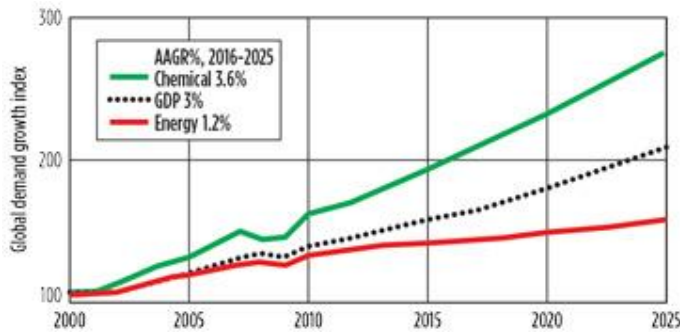


FIG. 1. Global chemical demand growth is forecast to outpace GDP and energy demand. Source: IHS.

II. BACKGROUND

TCGR’s Original Study: *Oil-to-Chemicals I*

In response to these trends and requests from industry supporters, TCGR undertook its first comprehensive industry study “***Oil-to-Chemicals: Technological Approaches and Advanced Process Configurations***” which was completed in December, 2017.

Ref. 1 Shell “Next Level Hydrocracker Flexibility” unlocking high performance in today’s turbulent markets; www.shell.com/globalsolutions; Ref. 2 CLG “New Hydroprocessing Approaches to Increase Petrochemicals Production,” www.clg.com.

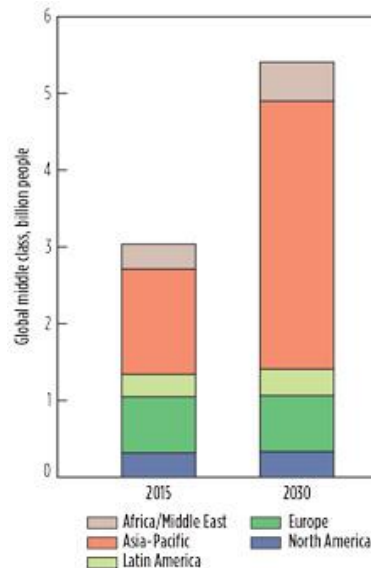


FIG. 2. A growing middle class is creating new demand for products made with chemicals. Source: The Brookings Institution

In that study, which benchmarked ExxonMobil's Singapore, ethylene cracker advances against the then proposed Aramco/SABIC Oil-to Chemicals project (TC2C™), we examined the technical and economics of greenfield vs revamp options for advanced configurations with new pipeline technologies in commercial and pilot for the next 5-10 years, which concluded that using light tight oils (LTOs), condensates and LNG's with feedstocks 35 API and higher with low metals and sulfur, indeed a ratio of 80/20 chemicals to fuels was achievable, with an advantage of up to \$200/mt of margin was available over utilizing naphtha feedstocks.

TCGR's "Oil-to-Chemicals II"

Fast forward to today. As a result of TCGR's 2017 report, and the overwhelming interest and ongoing field discussions as a consequence, **we have been convinced by industry leaders to revisit the subject area because our first report, while extremely valuable, did not cover or closely examine existing infrastructures configured more towards Resid and VGO feedstock processing, in an effort to re-examine options for "Carbon-Out", i.e. Flexicoking, Visbreaking, Other, etc. and "Hydrogen-In" i.e. Slurry HC, Resid HC, Other, etc., TCGR has examined these and newer options which offer a different but plausible approach.** This presentation outlines this new complementary study, so that between both of the two reports, subscribers are able to achieve an A to Z perspective, with special notes in between, on the range of options available to producers considering alternative feedstocks.

There is considerable flexibility being offered by petrochemical licensors, in particular petrochemical Resid and VGO FCC upgrading units today, so our intent was to document these in more detail. These are global changes including 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. The most interesting thing about this second report, is that all technologies do not stand still. Advances in catalytic Visbreaking will also be important in the future, when looking into advanced lower cost alternatives and we have examined these R&D pipelines. This is something that TCGR brings to the table, which is unique from other sources.

The "**Oil-to-Chemicals II**" report provides subscribers with:

- Technical state-of-art (SOA) detail on recent 3-5 year improvements that have been commercialized.
- A professional assessment of advantages and disadvantages on each process technology.
- Publicly available economics for each standalone process technology.

In the study's **Section V** (see pages 9-17 for the actual ToFC), where the majority of the report has focused, "Holistic Economics and Approaches to Complexes," TCGR examines how to combine different process units to maximize CAPEX savings as well as reduce OPEX and emissions.

The results provide practitioners, developers and prospective partners/evaluators, especially the major global chemical (olefins, aromatics) producers, with the tools needed to evaluate technology options in specific case study applications, via mixing

and matching unique solutions, in order to determine viability in practice or worthiness of further investment.

III. THE NEED FOR THIS STUDY

The timing is now! Already a large number of companies are closely examining their own responses and investments, bearing in mind each of these investment objectives will be site specific influenced by feedstock choices, product slates/markets, energy/utility balances, capital/operating efficiencies, and health, safety and environmental (HSE) performance. It is clear from public domain information (e.g., the ongoing announcements by ADNOC, MOL and others) to see the progress in differentiation that is already underway. Perhaps, somewhat surprisingly, the interest from China is quite large also, as shown in TCGR’s presentation from the 2017 study (see: <http://www.catalystgrp.com/wp-content/uploads/2017/12/PRES-Oil-to-Chemicals-December-2017-1.pdf>).

Of the two main interests of producers, are: 1) to decrease the capital intensity through scale, simplicity and location; and 2) expand/maximize flexibility towards 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 most likely you are already dealing at 10x, plus, the size of a world-scale petrochemical plant. Although scale counts, it is also only one of the many factors. New advanced configurations will now start to incorporate the planning of improved efficiency gains and reduced CO₂ emissions, as well. ExxonMobil in its 2018 Outlook for Energy forecast that by 2040, while energy efficiency gains are expected to nearly double, carbon emissions are only projected to increase by a modest 10%. BP statistics along with Chevron forecasts, IEA and EIA also show similar trends (see Figure 3).

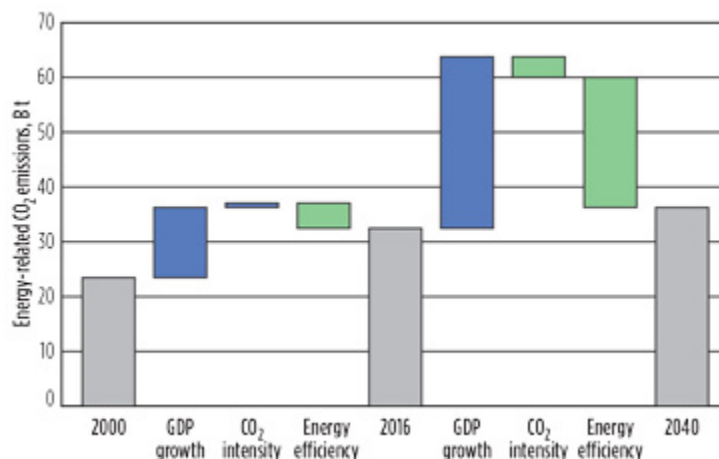


FIG. 3. Energy efficiency gains are expected to nearly double by 2040, while carbon emissions are projected to increase by a modest 10%.
Source: ExxonMobil 2018 Outlook for Energy.

Regarding competitive crude-oil-to-chemicals (COTC) developments, in addition to Saudi Aramco/SABIC announcements, we have already seen ongoing investments from others. In an example (Hydrocarbon Processing, 8/21/2018), private chemical producers Hengli and Rong Sheng in China are back-integrating their chemical plants to add over 9 MIL mt/yr of paraxylene (PX) capacity by 2021. This is expected to reduce PX imports by 4 MIL mt/yr, 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.

IV. SCOPE AND METHODOLOGY

As seen in the report's actual Table of Contents (TofC) that appears on pages 9-17, **Oil-to-Chemicals II** closely examines heavier crude(s) of 35 API and lower product slates, along with the drivers and a five year forecast on market availability, pricing differentials using case studies of the larger volume types in **Section III**. These case studies, as examples, are used to compare and contrast the attributes (advantages and disadvantages) as compared to a similar analyses conducted in TCGR's **Oil-to-Chemicals I** report completed in December 2017.

This **Oil-to-Chemicals II** report is aimed at being complementary to this first report. Subscribers will notice that they are designed to be like two book-ends allowing the reader to interpret how a range of heavier feedstocks can be upgraded in a beneficial way to take advantage of opportunity crudes, and obtain some chemical upgrading value-added.

Section IV provides significant detail on the existing State-of-Art (SOA), as well as newer advancements in (A) Carbon Rejection processes e.g. Visbreaking, delayed coking and deasphalting; (B) Resid FCC e.g. Milos, R2R, Flexicracking, DCC and others; and (C) Hydrogen Addition processes, e.g. slurry HC, ebulating bed.

Subsections (D) and (E) examine configuration issues and advances on how best to utilize and deal with constraints; e.g. CAPEX, OPEX and tricks and traps noted by TCGR's Dialog Group® technical and commercial experts within these processes, who have decades of industry experience.

Section V takes the results derived from **Section IV**, and translate them into economic comparison examples, with different process unit configurations to maximize CAPEX savings, reduce OPEX and/or reduce emissions, i.e. CO₂ footprint. The latter also contains life cycle analysis (LCA) comments/highlights.

Section VI completes competitive and strategic implications analyses. **Section VII** depicts final recommendations and conclusions.

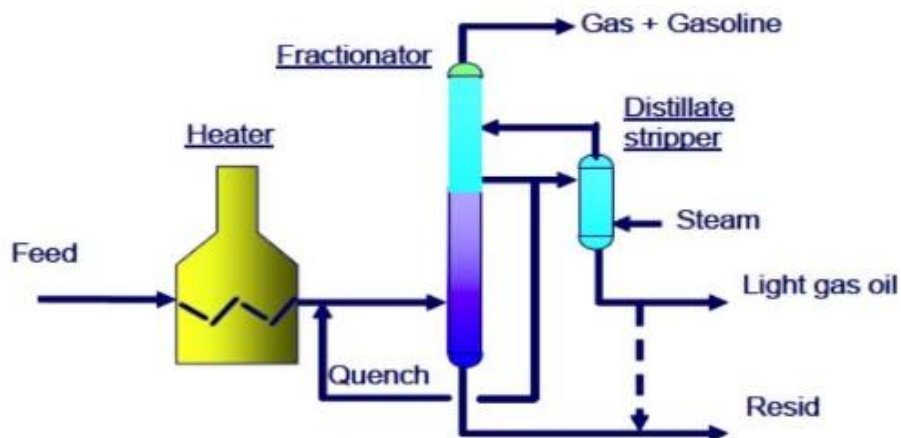


FIG. 4. A schematic diagram of a Visbreaker unit.
Source: Visbreaking – Chemical Engineering Process, 2012.

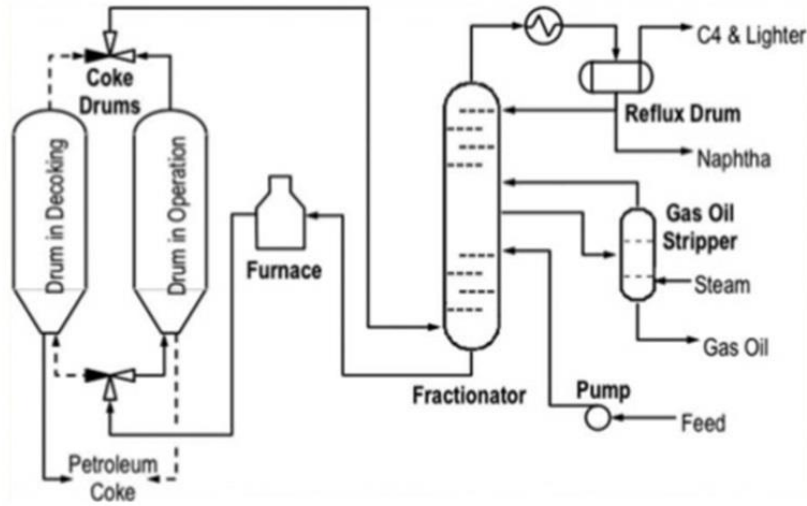


FIG. 5. Delayed coking. Source: Visbreaking and Delayed coking, 2016.

This ***Oil-to-Chemicals II*** study highly complements TCGR’s ***Oil-to-Chemicals I*** study completed in December 2017, which restricted feedstock analyses to 35 API and higher, NGLs and LTOs. At that time, that step was necessary based on the need to contain the scope, within achievable bounds. Clients have been asking TCGR to revisit the topic; now this has been completed.

TCGR has used in-house and external resources, as well as expertise from within industry, and our highly-regarded Dialog Group ® in order to complete:

- Technology evaluations
- Patent reviews and analyses
- Representative economics
- Market drivers/needs
- Competitive implications and SWOTs (developers vs. users)

An actual Table of Contents (TofC) appears on pages 9-17 in order to depict the breadth and depth of the study.

As it does in each of its industrially-focused multi-client studies, TCGR has sought input from “charter” subscribers to help shape the report’s scope/TofC so that it covers and emphasizes the most pertinent content due to the large amount of activity and the numerous areas that might be of interest.

V. QUALIFICATIONS

The Catalyst Group Resources, a member of The Catalyst Group, works with clients to develop sustainable competitive advantage in technology-driven industries such as chemicals, refining, petrochemicals, polymers, specialty/fine chemicals, biotechnology, pharmaceuticals, and environmental protection. We provide concrete proven solutions based on our understanding of how technology impacts business.

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- Provide leading information and knowledge through:
 - World-class seminars, conferences and courses
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The client-confidential assignments conducted by The Catalyst Group include projects in:

- Reinventing R&D pipelines
- Technology alliances
- Technology acquisition
- Market strategy

We have built our consulting practice on long-term client relationships, dedication, and integrity. Our philosophy is clear and focused:

***We Provide the "Catalysts" for Business Growth by Linking Technology
and Leading-Edge Business Practices to Market Opportunities***

VI. DELIVERABLES AND PRICING

This report is timely and strategically important to those industry participants and observers both monitoring and investing in the development and implementation of technologies for the conversion of oil-to-chemicals from heavier feeds (e.g., resids and VGOs) vs. LTOs. TCGR's report, based on technology evaluations, commercial/ market assessments and interviews with key players goes beyond public domain information. As a result, subscribers are requested to complete and sign the "Order Form and Secrecy Agreement" on the following page.

The study, "***Oil-to-Chemicals II: New Approaches from Resid and VGOs***" was completed in June 2019 and is immediately available.

Oil-to-Chemicals II: New Approaches from Resid and VGOs

<u>Post-production subscribers</u>	<u>after June 26, 2019</u>	\$24,500
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Oil-to-Chemicals II: New Approaches from Resid and VGOs

Report in PDF format, in addition to subscription price	\$1,000
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** Charter subscribers (those who signed up for the study by January 18, 2019) had the opportunity to work with TCGR to further refine the scope of the report by delineating areas of particular interest for inclusion in the assessment.*

* * * * *

Notice to Subscribers of TCGR's "Oil-to-Chemicals I" report (Dec. 2017):

Due to the complementary nature of this study to TCGR's previous report in this area entitled "Oil-to-Chemicals: Technological Approaches and Advanced Process Configurations" (completed in December 2017), TCGR is offering a discount of \$1,000 off "Oil-to-Chemicals II: New Approaches from Resid and VGOs" to subscribers of that study. Subscribers are requested to contact John J. Murphy at +1.215.628.4447, or John.J.Murphy@catalystgrp.com if further details are required or to determine if your organization is entitled. When completing the order form, please make sure to indicate your company's subscription to the earlier report.

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OIL-TO-CHEMICALS II: NEW APPROACHES FROM RESID AND VGOs
(June 2019)

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