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UNCONVENTIONAL CATALYTIC OLEFINS PRODUCTION II: TECHNOLOGICAL EVALUATION AND COMMERCIAL ASSESSMENT – 2021

STUDY PRESENTATION

October 2021

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UNCONVENTIONAL CATALYTIC OLEFINS PRODUCTION II: TECHNOLOGICAL EVALUATION AND COMMERCIAL ASSESSMENT – 2021

This TCGR multi-client study was launched in June 2021 and completed in October 2021. The study's scope, and specific contents (as depicted in the TofC on pages 13-23 of this presentation) reflect the inputs from a group of "charter" subscribers who, prior to study launch, indicated their priorities for coverage, areas to be expanded/deepened and focal points for emphasis. These are leading industrial developers, suppliers, and end-users of olefin production technologies.

I. ABSTRACT

The "energy transition" is impacting and changing the priorities and thinking on conventional olefins production. This report highlights and documents the shifts toward: 1) biomass and recycled waste feedstocks to the cracker and FCC units, trending toward the higher production of bioethylene and biopropylene for bio-PE and bio-PP; 2) the significant investment and progress toward electrification, highlighted by The Cracker of the Future Consortium; and 3) the emphasis on ESG, GHG reduction and improved energy efficiency. There are also a significant number of parallel developments in hybrid unconventional olefin production processes to suit local flexibilities, which could be standalone or integrated into the overall activities brought about by the industry's drive towards "oil-to-chemicals".

It is clear that the "status quo" has changed. How producers and process licensors respond to these changes moving forward will in large part determine which chemical and plastic producers will remain leaders. The "Power-to-X" approach, in this case to olefins, will play an important role in final production costs. There are also potential breakthrough technologies, like: 1) CO_2 to olefins; 2) the Coolbrook Roto Dynamic Reactor (RDR) technology; and 3) the "holy grail" of C_1 conversion to olefins, which is making progress, albeit still needing to reach commercial targets.

"Oil-to-Chemicals" is also an important driver, as TCGR has documented for lighter feedstocks/products in previous reports. One of the key findings is that the FCC unit will continue to be modified to produce more olefins, a broader range of olefins and also to accept pyrolysis, biomass and plastics upgraded feedstocks. This will no doubt lead to further hybridization of production units. This hybridization trend would also apply to crackers. For example, ExxonMobil's pretreatment of light crude oil directly to olefins, stands out as other ways to improve flexibility and costs.

Needless to say, the production of olefins continues to be a very important and dynamic industry segment. Many commercially important opportunities continue to exist for VC and PE investors, with or without government supported R&D programs and funds, where the U.S. and EU will remain powerful supporters. There is also a growing pool of funds in the financial community which is supporting "green funds" and perhaps more surprisingly, funding from foundations and large consumer corporations, like Unilever, P&G, Google, and IBM looking to "green" their products and images. But do not be blindsided: the growth is in Asia/Pacific, India, China and the Middle East. All these regions/countries are pursuing the same R&D programs, with notable developments taking place in China.

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In this report, TCGR has carefully and critically documented these key and important changes. Part of the big picture is to appreciate that sometimes the basics need attention, and this is one of them. As the executive, your key takeaway should be to not lose sight of these factors.

It probably is also not a surprise that today, conventional steam cracking is still the most economical solution to producing olefins. However, we have discovered through research and interviews around the industry that while economics will remain an important, if not the most important driver, a window does appear to be opening for other technology solutions to compete against steam cracking. Subscribers will have varied motivations: they could be catalyst developers, technology licensors, or end-users; they may be feedstock advantaged or forced to comply with new environmental regulations. The report points out situations where TCGR identifies specific advantages for a given problem for subscribers to better understand their own situations and strategies as well as the competitive landscape.

Lying at the very center of the petrochemical industry is the production of olefins - ethylene and propylene - which contribute not only to a host of other commodity and building-block chemicals, but to so many of the products and essential parts of daily life for consumers all over the world. As we enter this new decade, refiners and petrochemical companies will see demand for fuels, petrochemical intermediates, plastics/rubbers, and other products change, while calls for increased circularity and environmental consideration will increase.

For decades, steam cracking has been the dominant method to making olefins, but the same pitfalls that existed in the past will continue going forward, such as high energy requirements, large quantities of produced greenhouse gas (GHG) emissions (mainly in the form of CO_2), the ethylene/propylene ratio and propylene deficit, and feedstock inflexibility. Not to mention, despite cheaper feedstocks, CAPEX/OPEX and required process energy haven't changed much in the last decade (see ***Figure 1***, below).

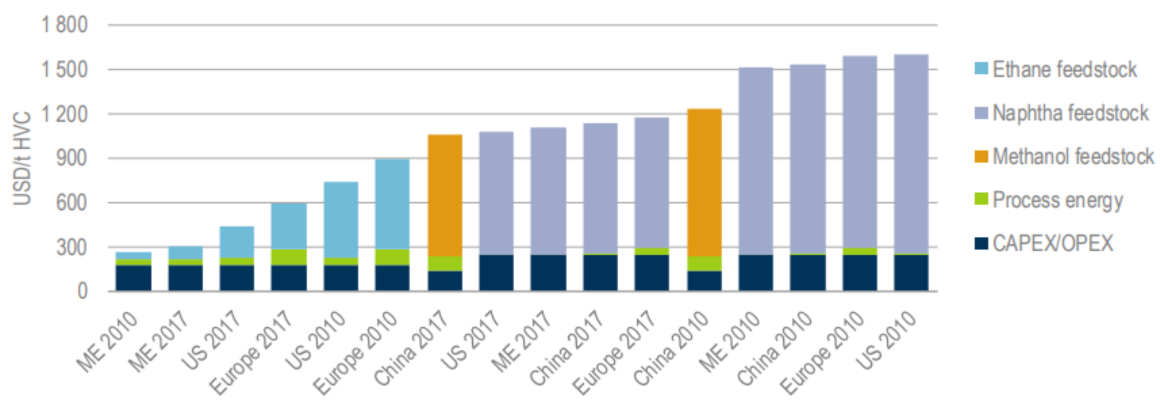

Figure 1: Costs of producing chemicals for selected feedstocks and regions (International Energy Agency, 2018)

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It is clear that the topic of olefins production merits revisiting via a new industry benchmarking study, to both update the progress (or note the lack of advances) made in unconventional technologies, but to also put them up against developments achieved since the 2013 benchmarking report, addressing such topics as:

- What results have been attained in achieving commercially viable "green" and circular $C_2^=$ and $C_3^=$ products?
- What do process/catalyst improvements yield in CO_2 footprint reductions, life cycle analyses, and overall sustainability towards NetZero2050 objectives?
- What other unconventional catalytic methods have emerged and/or are near commercialization?
- What improvements and updates have taken place over the last several years to traditional thermal methods?
- What is the potential for the "holy grail" of direct C_1 conversion, resid to olefins (via direct oil-to-chemicals routes) and advanced olefin/paraffin separations (e.g., CMS OptiPerm)?

This recently completed report addresses all these issues – the propylene deficit, feedstock availability and flexibility, world scale production vs. stranded, modular, or small-scale production, and environmental issues pertaining to resource utilization, life cycle analysis, and GHG emissions. This is done by analyzing new technologies against the status quo, to see which are in position to solve the different issues presented above. Subscribers are able to come away with a better understanding of where their own technology fits in this landscape or possibly which solutions are right for their own operations. They are able to identify technological gaps and hurdles to overcome and how to plan their strategic and/or commercial objectives in the coming years. Lastly, they can comprehend what the role of catalysis will be in addressing the challenges that exist for olefins production and more broadly, the petrochemical/chemical industry.

II. INTRODUCTION

To emphasize how some of the above drivers play out, we can take a look at how U.S. dry shale gas production has doubled since the beginning of 2013 (U.S. EIA, 2020a). In that same time, regional and global growth rates for ethylene and propylene have remained steady, at over 3% and 4%, respectively. In addition, both are expected to continue this trend over the next several years, and possibly longer, with ethylene even increasing to over 4% CAGR (Dickson et al., 2019). This has led to increasing on-purpose propylene production, due to the ethane rich U.S. shale gas, which is forecasted to continue throughout the decade.

The propylene gap is just one of many areas that this study addresses, both from the point of view of understanding the economics and landscape of the current industry status quo, propane dehydrogenation (PDH), in addition to the technology behind other on-purpose methods that are still in the pipeline. Some other drivers behind unconventional olefins technology include better pre-treatment and post-process separations, increased feedstock flexibility (including utilization of in-place assets like FCC units), and also what many consider to be the holy grail, direct methane (C_1) conversion.

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TCGR's 2013 study set out to answer the following question: Can catalytic olefins production displace thermal crackers in the next decade, based on improvements in yield and/or energy efficiency and reductions in cost and/or GHG emissions. The answer at that time was simply "no," based on the capital investments in ethane cracking in the US and lack thereof in novel technologies. However, in the current (2021) situation, the answer is more complicated than that.

A. Progress in Commercial Technology

There are numerous technologies in the current commercial landscape, spanning from traditional steam cracking, FCC, and PDH, to newer and more innovative catalytic cracking methods. Re-visiting and updating the technology evaluations in the 2013 report, in addition to ones that have emerged, has proven crucial in determining the gaps and drivers for R&D.

- The world has traditionally required approximately 6 mil MT/yr (Tullo, 2020) of ethylene capacity additions, much of this recently achieved through steam cracking investment in the United States. However, some of these planned capacity additions may never come online, and due to the shale boom, these additions have major implications on propylene supply. TCGR has analyzed this market and included the major technology updates.
- KBR offers a suite of olefins technologies, of which, the ACO™ Process (as it was called at that time) was featured in the 2013 report. While two units had been built in Asia, KBR has switched focus. The Selective Cracking Optimum Recovery (SCORE™) pyrolysis technology is a type of furnace design for mixed-feed crackers which also includes an enhanced product recovery section. For improved propylene production, KBR offers MAXOFIN™ FCC technology for gas oil/resid feeds, K-PRO™ PDH technology, and K-COT™ (catalytic olefins technology), which can produce up to a 2:1 propylene:ethylene ratio depending on the feedstock (see ***Figure 2***). K-PRO™ is designed with a precious-metal-free catalyst for stand-alone propylene production.

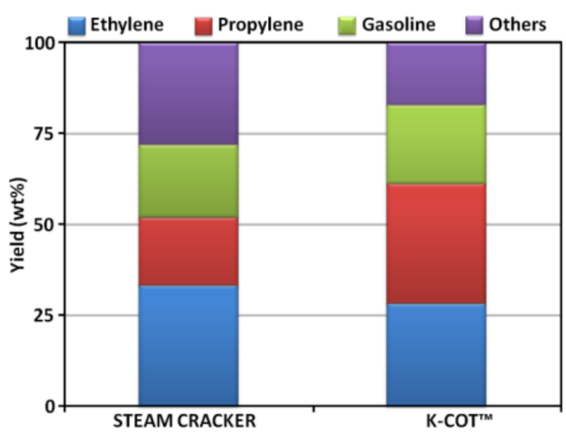

Figure 2: Product yields of conventional steam cracker and KBR K-COT™ process (Corma et al, 2016).

- Sinopec Shanghai Research Institute of Petrochemical Technology (SRIPT) Olefins Catalytic Cracking (OCC) Process – Sinopec began developing the technology in 2000, and now has three commercial plants in operation ranging from 60-200 kT/yr, with another plant scheduled for commissioning in 2020 (Teng, J. et al., 2020). Ideally suited for integration with MTO plants, but

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also steam crackers or refineries, the OCC Process converts low-value C_4/C_5 by-product streams into polymer grade ethylene and propylene (see PFD in ***Figure 3*** below).

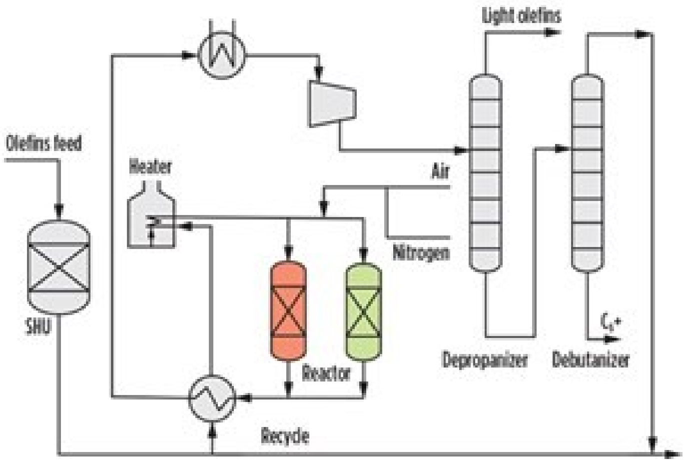

Figure 3: Process flow diagram of SRIPT OCC process (Teng et al., 2020).

- Refinery FCC units have been a source of propylene for many years, and there have been developments to increase yields and tailor units to be more flexible. Some of the levers available to refiners to promote increased yields of light olefins include different reactor technology (additional risers, downers), higher reaction temperature, feed atomization, catalyst:oil ratios, recycle streams, and addition of zeolite catalysts/additives (Corma et al., 2016). TCGR has updated subscribers on the specifics of these advances across various processes which include, but are not limited to, the KBR MAXOFIN, Indian Oil Indmax, Shell MILOS, and KFUPM/JCCP/Saudi Aramco/Axens Higher Severity FCC (HS-FCC) processes.

- There are several commercialized PDH processes, which include the industry standard UOP Oleflex and Lummus Catofin processes, but also other offerings from Linde/BASF/Statoil, Snamprogetti, KBR, Dow and ThyssenKrupp. Capacity investment in PDH technologies has and will continue to increase, which has led to advances in catalyst and reactor technology.

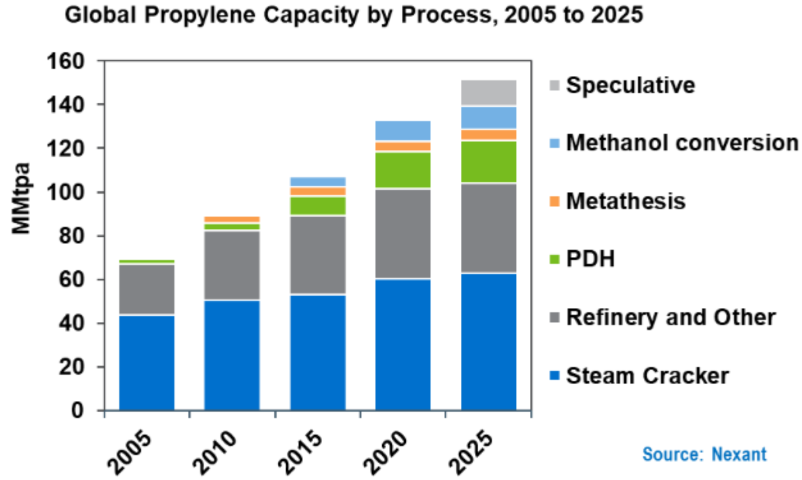

Figure 4: Global propylene capacities by process, 2005-2025. (Rabenhorst, 2019).

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B. Development of New Technologies

Critical to this update are the new technologies that have arisen since the 2013 report, addressing such questions as what stage of development they are in, and what would it take to see them commercialized? Progress deemed in the scope of the report include the following, as representative examples:

- Siluria Technologies has entered into multiple joint operations (one with Saudi Aramco, one with Met Gas) to advance/commercialize methane and natural gas to propylene technologies.
- Scientists at the Dalian Institute of Chemical Physics (DICP) have investigated the nonoxidative conversion of methane to ethylene with the use of singe iron sites embedded into a matrix of silica (see ***Figure 5*** below). This has led to a joint agreement by DICP, SABIC, and China National Petroleum Corp. to research catalysts and process development in nonoxidative conversion of methane to olefins (MTO), aromatics, and hydrogen.

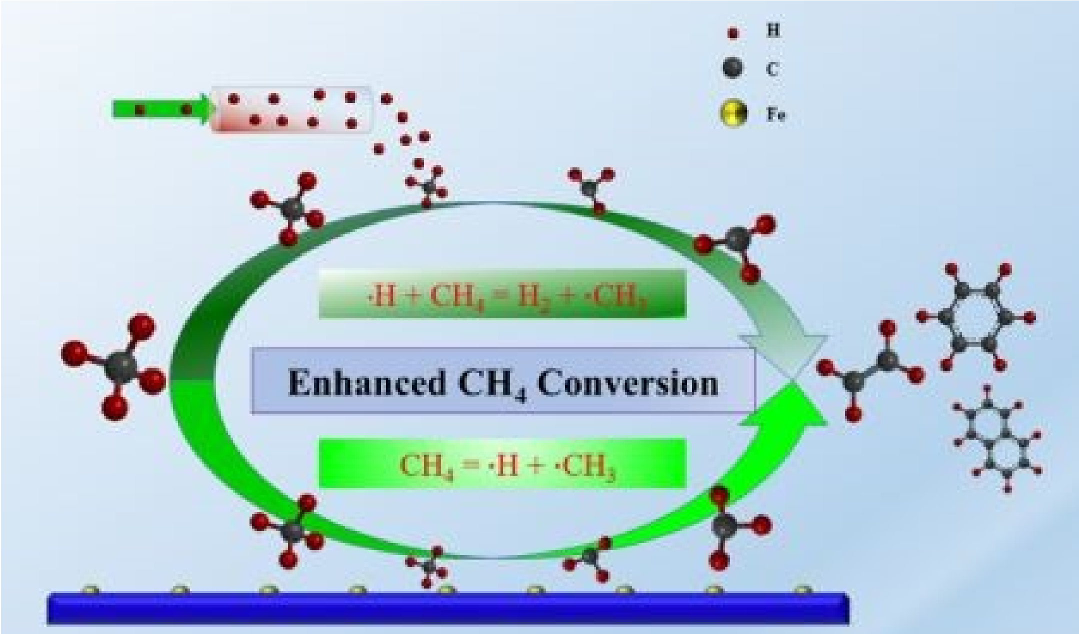

Figure 5: Single Fe sites in a silica matrix generate both methane and hydrogen radicals, which go through gas-phase C-C coupling to form ethylene (in addition to other useful products like aromatics and hydrogen). (Hao et al., 2019)

- Chiyoda has developed a process for catalytically cracking naphtha which doubles $C_3^=$ yield while reducing energy consumption by 15%. It uses a composite (Fe, Ga, Al, silica) zeolite catalyst in a fixed-bed reactor at lower temperature and no steam, producing 30% $C_3^=$ and 20% $C_2^=$. Chiyoda plans to continue pilot operations until 2022 and then move into commercial applications.
- Omega Process – Catalytically cracks C_4/C_5 feeds, ideally integrated through an existing FCC/DCC, to make olefins. Now licensed through TechnipFMC, the first commercial unit at Mizushima Works in Japan was started in 2006.
- ENI and SABIC entered into an agreement in February of 2019 to jointly develop the Short Contact Time Catalytic Partial Oxidation (SCT-CPO) technology for conversion of natural gas to syngas and olefins.

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- Mitsubishi Ethylene-to-Propylene (ETP) – Mitsubishi has developed a process to produce propylene in a single step, mainly using ethylene as a feedstock, but also ethanol and methanol. They have also, jointly with JGC Corporation, developed the Dominant Technology for Propylene Production Process (DTP Process) to convert olefins and methanol to propylene in an adiabatic fixed-bed reactor, boasting low energy consumption and CO_2 emissions.
- There are several routes to producing "green" olefins by the catalytic dehydration of ethanol to ethylene. Companies like Braskem, Chematur, BP, and IFP/Axens with Total are in various stages of developing these technologies (Mohsenzadeh et al., 2017).

Indirect, yet potentially important, routes to olefins - utilizing enhanced olefin/paraffin technologies – were proven worthy of assessment, including:

- CMS/Braskem Optiperm™ - Compact Membrane Systems (CMS) and Braskem are jointly evaluating a pilot plant for the development of their olefin/paraffin separation technology. It is designed to be a bolt-on technology to upgrade stream quality. The pilot plant will evaluate the technology under industrial conditions for an extended period of time.

III. THE NEED FOR THE STUDY

There is much to update the industry on since TCGR's last report on this topic, as it has been a busy decade. The United States has increased its production of crude oil, natural gas, and natural gas liquids, to the point that it has become a net exporter of energy for the first time since the 1950s (U.S. EIA, 2020b). This has led to new petrochemical investment throughout the U.S. that has not been seen in decades. The middle class, along with the overall population, continues to grow globally, as people in Asia, the Middle East, and Africa are increasing demand for petroleum derived products. The effects of a changing global climate and increased awareness for a circular economy have led to calls to reassess how we produce and utilize energy. Lastly, it is projected that over the coming decades, gasoline- and diesel-powered engines will be overtaken by hybrid and electric engines. This has led to the "oil-to-chemicals" trend, one uniquely covered by TCGR (see below), in order to find ways to satisfy the demand for petroleum products, including olefins, in the ever-changing landscape.

Olefins technology licensors and leading olefins producers will always look to capitalize on these trends, by improving their costs of production, energy efficiency, feedstock flexibility, and product yields. The time has come for an update on how these factors will be addressed by the industry over the coming decade. This recently completed study answers the following key questions:

- What feedstocks will be available by region in the coming years and how are both current/conventional and new technologies equipped to handle these?
- What are the strengths and weaknesses of various process technologies (catalytic-bed reactors, FCC, crude-to-chemicals, etc.)? What engineering and financial hurdles are still needed to be overcome? How far away are specific technologies from commercialization?
- How do the process economics compare under the current state of feedstock price and availability and technology status?

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As TCGR has done over the years, we answer this question "***for the industry***" with contributions "***by the industry***," utilizing our broad and extensive network of DIALOG GROUP® consultants and industry contacts. TCGR is uniquely positioned to provide an independent, thorough analysis that covers the space between the commercial and technical perspectives. This new 2021 update complements a broad library of TCGR multiclient reports from over three decades, as can be seen by the below list of reports since TCGR's 2013 report, ***"Unconventional Catalytic Olefins Production: Commercial Vision and Breakout?"***:

- ***Oil-to-Chemicals II: New Approaches from Resid and VGOs*** (June 2019)
- ***Catalytic Conversion of Syngas to Chemical Products III*** - report exclusively for members of TCGR's Catalytic Advances Program, CAP (2018)
- ***Oil-to-Chemicals: Technological Approaches and Advanced Process Configurations*** (December 2017)
- ***Advances in Olefin Co-monomer and Polyolefin Production*** - report exclusively for members of TCGR's Catalytic Advances Program, CAP (2016)
- ***Advances in On-Purpose Technology for Mono- and Di-Olefins*** - report exclusively for members of TCGR's Catalytic Advances Program, CAP (2016)
- ***Natural Gas Conversion vs. Syngas Routes: A Future of Convergence***
    - ***Vol. 1: Natural Gas to Intermediates and Feedstocks to Syngas*** (October 2014)
    - ***Vol. 2: Syngas and Natural Gas Conversion to Products*** (November 2014)
- ***Advances in Olefin Purification via Catalysis and Sorbent Materials*** - report exclusively for members of TCGR's Catalytic Advances Program, CAP (2014)

References:

1. U.S. Energy Information Agency (U.S. EIA, 2020a). "Natural Gas Weekly Update." Accessed **February 7, 2020**. https://www.eia.gov/naturalgas/weekly/
2. Dickson, Duane, et al. "The Future of Petrochemicals – Growth Surrounded by Uncertainty." Deloitte. **2019**.
3. Corma, A, et al. "Crude oil to chemicals: light olefins from crude oil." Royal Society of Chemistry. **September 2016**.
4. U.S. Energy Information Agency (U.S. EIA, 2020b). "The United States is expected to export more energy than it imports by 2020." **January 29, 2020**. https://www.eia.gov/todayinenergy/detail.php?id=38152
5. Teng, J. et al. "Advances in the OCC process for propylene production." Hydrocarbon Processing. **March 2020**.
6. Tullo, Alex. "Petrochemical makers look ahead to an uncertain decade." Hydrocarbon Processing. **March 2020**.
7. Rabenhorst, Randy. "On Purpose – What's Driving New Propane Dehydrogenation Projects in North America?" Nexant. **June, 2019**.
8. Mohsenzadeh, A, et al. "Bioethylene Production from Ethanol: A Review and Techno-economical Evaluation." *ChemBioEng Reviews*. **February 2017**.
9. Hao, Jianqi, Schwach, Pierre, Fang, Guangzong, Guo, Xiaoguang, Zhang, Hailei, Shen, Hao, Huang, Xin, Eggart, Daniel, Pan, Xiulian, and Bao, Xinhe, ACS Catalysis **2019** *9* (10), 9045-9050

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IV. SCOPE AND METHODOLOGY

TCGR's update first establishes the state-of-the-art of the conventional olefins landscape, discussing any notable improvements made to traditional thermal steam cracking technologies over the last 7-8 years. This **Section III** includes an update on recent capacity additions as well as planned plant openings in the foreseeable future. We analyze how feedstocks have changed over the years and forecast how they will continue to do so over the next decade. This will have obvious impacts on the strategic commercial and R&D directions that will be utilized.

Section IV and **Section V** are the core of the study – discussing the improvements and discoveries made to unconventional catalytic olefins production methods since the 2013 study. Unlike that previous study, we have extensively documented the growing interest in direct methane/C_1 conversion, in addition to the major on-purpose propylene technologies. We have separated this all into an analysis of currently commercialized and near-commercialized (Section IV) and the directions being undertaken throughout industry and academia in R&D at the lower TRLs (Section V).

New to this updated study is **Section VI**, a section specifically dedicated to comparing the process economics of various commercialized and near-commercialization technologies. Both conventional and unconventional technologies have been laid out, they will be benchmarked from the process economics point-of-view. Section VI also includes Life Cycle Assessment (LCA) and overall GHG impact analyses.

Lastly, additional unique value is presented in **Section VII** and **Section VIII**, where TCGR examines how companies can maximize investment returns and effectively position themselves in the global olefins market. Just as it was 8 years ago, the olefins industry is constantly at a crossroads. There are numerous drivers that are encouraging companies to invest in new catalytic production methods. TCGR's analysis not only helps identify those drivers and provides examples of where and how they are unfolding in the marketplace, but provides invaluable competitive intelligence and strategic analysis.

The timing of this new study is once again critical, as there is an ever-present interest in unconventional technologies despite the growing investments in thermal steam cracking. TCGR has answered and addressed the many questions surrounding this topic, as well as those that have arisen based on "charter" subscriber input/feedback.

> *In order to heighten the value-added from study participation, TCGR worked with "charter" subscribers (i.e., those who signed up for the study prior to its formal "launch") in order to define the scope of the report by delineating areas of particular interest for inclusion in the assessment. For details on the study scope, the report's actual Table of Contents appears on the pages 13-23.*

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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.

Using our in-depth knowledge of molecular structures, process systems, and commercial applications, we offer a unique combination of business solutions and technology skills through a range of client-focused services. Often working as a member of our clients' planning teams, we combine our knowledge of cutting-edge technology with commercial expertise to:

- Define the business and commercial impacts of leading-edge technologies
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- Lead and/or manage client-sponsored R&D programs targeted through our opportunity identification process.
- Provide leading information and knowledge through:
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The client-confidential assignments conducted by The Catalyst Group include projects in:

- Reinventing R&D pipelines
- Technology alliances
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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

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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 olefin production, from both established and developing catalytic routes. 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, **"*Unconventional Catalytic Olefins Production II: Technological Evaluation and Commercial Assessment – 2021,"*** was launched in June 2021 and completed in October 2021.

Participation	Deadline	Price
Post-production subscribers	after completion (October 2021)	$24,000

Unconventional Catalytic Olefins Production II: Technological Evaluation and Commercial Assessment - 2021

Report in PDF format, in addition to subscription price	$1,000

Notice to Subscribers of TCGR's 2013 *"Unconventional Catalytic Olefins Production: Commercial Vision and Breakout?"* Study:

*Due to the complementary nature of this study to TCGR's 2013 report in this area (namely **"Unconventional Catalytic Olefins Production: Commercial Vision and Breakout?"**), TCGR is offering a discount of $1,000 off to subscribers of that earlier study. Subscribers are requested to contact Chris Dziedziak at +1.215.628.4447 or cdziedziak@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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Please enter our order for ***"Unconventional Catalytic Olefins Production II: Technological Evaluation and Commercial Assessment – 2021"*** completed in October 2021, as follows:

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In signing this order form, our company agrees to hold this report confidential and not make it available to subsidiaries unless a controlling interest (>50%) exists.

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FIGURES

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TABLES

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