Productivity Advances for Syngas, Olefins and their Derivatives

Multi-Client Study Proposal

September 2017

TCGR THE CATALYST GROUP RESOURCES™

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Productivity Advances for Syngas, Olefins and their Derivatives

I. INTRODUCTION

There is an ongoing need to improve the energy efficiency and productivity of existing syngas, olefins and olefins derivatives processes because of the improvement in incremental technologies, and catalysts which are retrofittable into existing operations. These include the extension of turnaround maintenance cycles by reducing coking, more energy efficient refractory wall linings and new catalysts, like Johnson Matthey's new CATAMAX™ metal foil catalysts for syngas manufacture. When olefin and olefin derivatives processes are examined there are significant feedstock pretreatment and also product post-treatment separation processes that will allow for feedstock recycle e.g. olefins/paraffins separations into such processes as propylene/propane separation, in polyolefin (PO) and acrylonitrile operations. The opportunity to examine these advantages from a single information source in a systematic way, is a unique opportunity for technology licensors, EPCs, as well as producers and catalyst manufacturers.

TCGR's proposed assessment entitled **"Productivity Advances for Syngas, Olefins and their Derivatives"** will systematically review the largest top three (3) maintenance and productivity improvement challenges to improved profitability – for each value chain – and provide pipeline improvement reviews on what the leading edge solutions being practiced today, including what is around the corner in the next 2-3 years. TCGR has, over the years, provided many syngas, olefins and olefins derivatives benchmarking reports (see Qualifications). What is unique about this study is the hands-on operating focus on existing investments, rather than on just new processes and catalysts, i.e. new CAPEX.

The results will provide practitioners, developers and prospective partners/evaluators, especially major global chemical (olefins and olefin derivatives) producers, with the commercially proven tools needed to evaluate retrofit options during their next planned turnarounds, via mixing and matching unique solutions in combinations that will add substantially to their bottom lines. Each improvement will be documented and reinforced by field interviews from existing practitioners so that subscribers can verify industrial sources independently for chosen specific routes via an Appendix Directory on company contacts.

II. BACKGROUND

Turnarounds present the opportunity to evaluate the installation of different process improvements, that will save energy, improve productivity and lead to added flexibility and the reliability of operations. These might involve better generation catalysts, new co-catalysts which improve selective yields, better passive internals for reduced pressure drop, more active in-reactor internals for scavenging to control poisons, better process controls or better heat recoveries. On the bolder side, new and novel internal reactor designs with improved intensification are also being developed that might eventually prove to have shutdown economics over traditional approaches in the future, like internal reactive catalytic distillations, stacked bed internals and the like, which carry out more than one type of reaction and/or reaction/separation in the same reactor, rather than two separate steps.

This study is aimed at providing organized insights into these new developments, as well as benchmarking their advantages for deployment into major processes, e.g. the olefins thermal cracker, on-purpose olefins production (FCC, PDH), EO/PO production, as well as syngas derivatives such as GTL, hydrogen, methanol, oxo-alcohol and acetyls production, etc. The types of advances from a process perspective will include catalysts, active media, coke reduction through catalytic coatings, improved catalyst regeneration, reactor internals and separations within the reactors. Note: separations external to the reactor will not be covered (see TCGR's **"The Separations Report: Commercial, Technical and R&D Assessment in Refining, Petrochemical/Syngas, Natural Gas and Industrial Gases"** multi-client study for details).

Examples of some of the novel technologies that can offer retrofit processing advantages abound! Extending the coking life and improving the energy efficiency of thermal crackers can be had by adopting SCG Chemicals' emisspro™ furnace refractory coating, which helps lower both CO_2 emissions, as well as reduce overall fuel consumption, by capturing and emitting heat back into the furnace (see Figure 1). Another approach is to use BASF's QTech™ ethylene tube catalytic coating which reduces coking and extends turnarounds significantly.

To expand on the SCG Chemicals example, about 70-90% of the heat adsorbed in a firebox or radiant section of a furnace is transferred by radiation. Even a small improvement of radiation heat transfer can be transferred into an important increase in production yields or an important decrease in fuel gas consumption. In 2012, an olefins steam cracker of 1.7 MIL mt/yr. having 8 furnaces was retrofitted with emisspro™ which provided a fuel savings of 9,000 mt/yr. and a GHG reduction of 25,000 mt/yr.

Figure 1. Benefits of using Emisspro™

Source: SCG Chemicals

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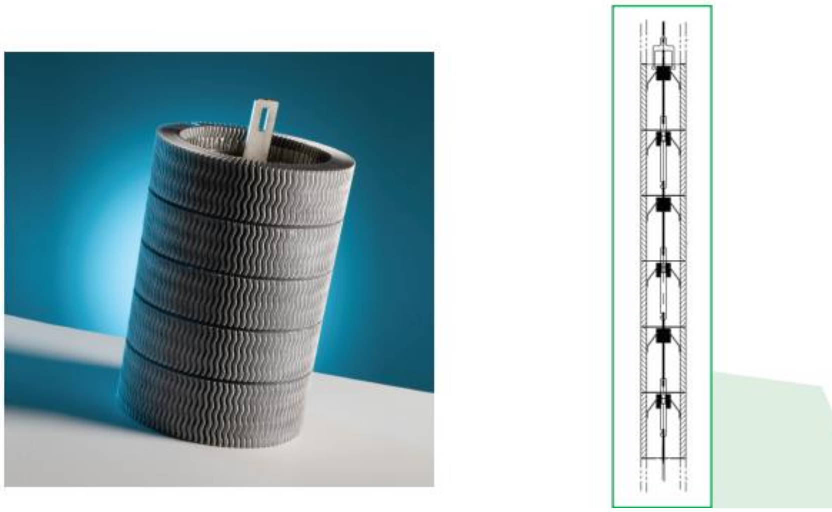
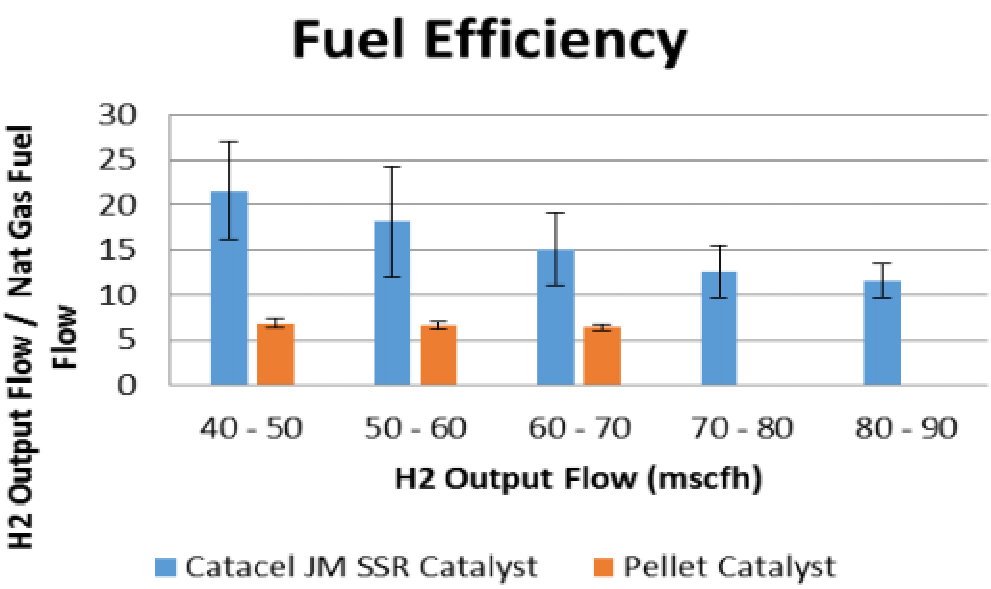
In a different example, Johnson Matthey retrofitted a steam reformer (for hydrogen production) in the U.S. in February, 2015 with CATACEL™ SSR metal foil reforming catalysts which replaced conventional Ni pellet catalysts in the reformer tubes (see Figures 2 and 3). Data showed a sustained H_2 production rate increased from 71,000 scfh to 85,000 scfh, as well as a fuel savings.

Figure 2. Catalyst and Stackable Tube Configuration
(right: Catacel's Stackable Structural Reactor (SSR®); left: SSR® stack inside a reformer tube)



Source: Catacel Corporation, Stackable Structural Reactor (SSR9®) Technology White Paper No. 102

Figure 3. Fuel Efficiency at Various Operating Ranges



Source: Catacel Corporation, Stackable Structural Reactor (SSR9®) Technology White Paper No. 102

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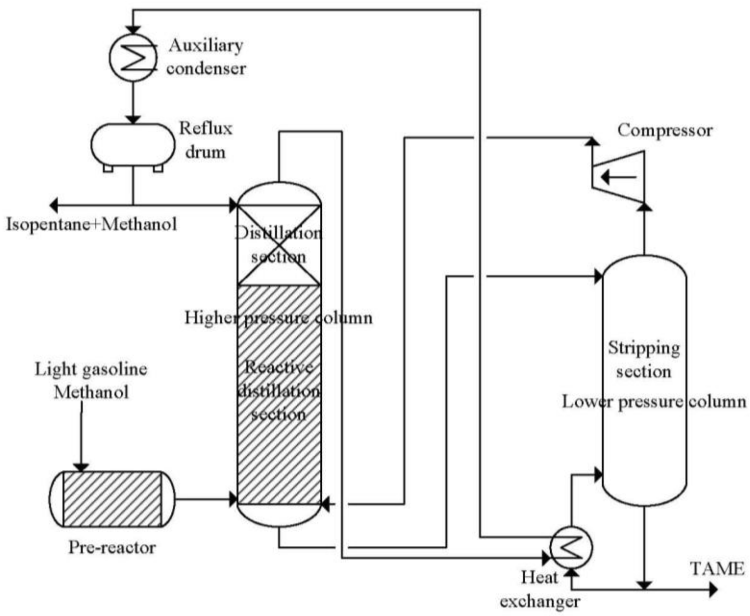
In another example, for gas-phase reactions, Evonik Industries is spearheading the ROMEO™ project developing a 2 in 1 reactor, aimed at removing product continuously as it is formed (via membranes) pushing the reaction equilibriums in hydroformylation, therefore reducing both energy consumption and emissions by 80% and 90% respectively, and also eliminating the post reactor product distillation separation step. This type of approach should be applicable to other reactions as well.

Figure 4. The Scheme of Catalytic Distillation Process



Source: AIChE

In separate developments, Superior Upgrading Technologies is piloting hydrodynamic cavitation, and extreme shear process technologies which could be deployed into any suitable refining or chemical process where the advantage would be to potentially reduce the energy consumption in liquid processes. ExxonMobil (EMRE) also is pursuing a similar approach under their JDA with Arisdyne Systems called Controlled Flow Cavitation (CFC™).

To improve the energy efficiency of PDH plants, Clariant has deployed its Heat Generating Material (HGM) in their Catofin® process. HGM is an innovative metal-oxide material which is designed to significantly increase selectivity and yields, while saving energy and also reducing emissions. There are other similar approaches based on novel materials which could apply this same concept to different chemicals (products) where reactors can be enhanced with co-catalyst technologies as well. It is also possible in another example, to add co-catalyst that improve conversions. A typical recent example would be the addition of homogeneous slurry catalysts into fixed bed hydrocrackers to improve the conversion profile and yields of products more selectively but this approach is also applicable to olefin and olefin derivatives processes as well.

TCGR's proposed report will also review some retrofit technologies that can improve product yields via pretreatment, e.g. UOPs MaxEne™, in reactor separations like membrane reactors and combined catalytic distillations, e.g. CB&I's CD Hydro® or post recycle steps like paraffin/olefins membrane separations from CMS and Imtex.

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III. THE NEED FOR THE STUDY

This report is unique, in that it assembles in a systematic way, commercially available options on a global basis that can be used by syngas, olefins and olefin derivatives producers to enhance the productivity, lower energy consumption and reduce GHG emissions as retrofit options. As demonstrated, these developments are happening globally in different countries, and perhaps not obvious to companies and persons operating at the country or regional level. Take the examples of emisspro™ from Thailand, BASF ex Germany, Arisdyne Systems in the U.S. The point to the subscriber being that no study has yet been completed that documents together, comparatively, these disparate sources of information into one study.

From a chemicals producer point of view, the need to access the best and latest but commercially proven options, extending the life and/or returns on each of the products and processes reviewed which are currently in production. Therefore, the ROI in subscribing to this study will be repaid in several orders of magnitude, just using one or more of these technologies, which based on the Proposed Table of Contents (TofC) (see page 7) can be looked at in combinations e.g. reforming(syngas) + Hydrogen, or reforming + methanol. Different combinations including On-purpose Propylene + PO or thermal cracking + EO will demonstrate how better configurations show sustainable advantages.

TCGR also appreciates the need for lower CAPEX, fast returns with paybacks of less than three years (< 3 years). So, in addition to creating a cameo on each option, a ranking will be provided at the end of each section based on the average commercial experience, with a range given for each.

IV. SCOPE AND METHODOLOGY

This report focuses on delivering commercially proven technologies that are available to retrofit into existing operations during your next maintenance turnaround cycle. It reviews two value chains; 1) the thermal crackers to produce olefins, on-purpose olefins production and the main olefin derivatives processes and; 2) the reforming unit to produce syngas and the main derivatives products (excluding ammonia). The style will be to compose "cameos" of advantaged retrofit technologies that have less than three (3) years payback, then rank them, also providing subscribers with the commercial contacts to pursue their implementation. We expect the chosen improvements will provide an increase in existing throughput, i.e. capacity increase, reduce energy consumption through improved efficiency, and/or reduced GHG emissions or a combination of the above.

Via a market-driven approach, all TCGR "charter" subscribers will have the opportunity to contribute to the shaping of this report's contents and Table of Contents prior to the study being undertaken, notably the cameo's to be completed in Sections III and IV. This approach provides considerable value-added to the participating subscribers.

To provide more detail on the content of **Sections III and IV** and the methodology, we provide the following perspectives. On each of the key processes an introduction will capture the current state-of-art, as well as the key process strengths and weaknesses e.g. a SWOT, then the subchapter will follow with the cameo on each of the top three improvements for each individual process. This same format will be followed in both Sections III and IV.

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In **Section V**, we will analyze the results from both Sections III and IV, as well as highlight new R&D directions pertaining to the hottest subjects and document those, as well as provide guidance as to where cross-overs and multiple approaches may lead to further process intensification and synergies.

In **Section VI**, we provide our final conclusions and recommendations. What will be importantly captured here will be recommendations to companies on how to focus their future R&D programs and investments moving forward.

TCGR will use in-house and external resources, as well as expertise from within industry, as well as our highly-regarded DIALOG GROUP® in order to complete:

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

A proposed/preliminary Table of Contents is provided on the following page in order to depict the breadth and depth of the study as envisioned. Please also visit the Qualifications statement (page 8) as this shows the numerous similar successful multi-client report TCGR has undertaken in both syngas and olefins over the last fifteen (15) years.

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Preliminary Table of Contents*

PRODUCTIVITY ADVANCES FOR SYNGAS, OLEFINS AND THEIR DERIVATIVES

**Charter subscribers (those who sign up for the study before September 29, 2017) will have the opportunity to work with TCGR to further refine the scope of the report by nominating specific cameos for Sections III and IV as well as delineating areas of particular interest for inclusion in the assessment.*

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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. TCGR has completed the following reports relevant to qualifications:

- **Natural Gas vs Syngas Routes: A Future of Convergence (2014).**
  - **Vol. 1: Natural Gas to Intermediates and Feedstocks to Syngas**
  - **Vol. 2: Syngas and Natural Gas Conversion to Products**
- **Unconventional Catalytic Olefins Production: Commercial Vision and Breakout (2013).**
- **GTL/XTL: An Assessment of the Technologies, Business and Competitive Landscape (2012).**
- **Syngas Production and Conversion to Products- Technology and Commercial Update (2011).**
- **Efficiency Gains Through Catalyst and Process Technology Advancements in Refining and Chemicals Industries (2009).**
- **Syngas Production and Conversion to Products: A Strategic Assessment of the Technologies, Markets & Competitive Landscape (2007).**
- **Alternative Energy and Fuels Technology: Emerging Catalytic Processes to Improve Efficiencies and Yield (2005).**

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
- Develop technology strategies that support business objectives.
- Assess technology options through strategy development, including:
  - Independent appraisals and valuations of technology/potential
  - Acquisition consulting, planning and due diligence
- Provide leading-edge financial methodology for shareholder value creation
- Lead and/or manage client-sponsored R&D programs targeted through our opportunity identification process.
- Provide leading information and knowledge through:
  - World-class seminars, conferences and courses
  - Timely technical publications

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

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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 enhancing syngas, olefins and their derivatives production. TCGR's report, based on technology evaluations, commercial/ market assessments and interviews with key players will go 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, **"Productivity Advances for Syngas, Olefins and their Derivatives"** is expected to be available in December, 2017.

Participation	Deadline	Price
"Charter" subscribers*	before September 29, 2017	$18,500
Productivity Advances for Syngas, Olefins and their Derivatives		
Post-launch subscribers	after September 29, 2017	$20,500
Productivity Advances for Syngas, Olefins and their Derivatives		
Report in PDF format, in addition to subscription price		$1,000

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ORDER FORM AND SECRECY AGREEMENT

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Please enter our order for **"Productivity Advances for Syngas, Olefins and their Derivatives"** to be completed in December, 2017, as follows:

____ **"Productivity Advances for Syngas, Olefins and their Derivatives,"** as a "charter" subscriber (i.e., prior to September 29, 2017) for $18,500 ($20,500 after study launch)

____ Please enter our order for the study to be delivered in PDF (Adobe Acrobat) format for use across our sites/locations (i.e., site license) for an additional $1,000.

____ Please send us ______ additional printed copies @ $250 each.

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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