

# **Application of Catalysts in the Bioeconomy: Advances and Competitive Implications**

## **Multi-Client Study Proposal**

February 2020



# Application of Catalysts in the Bioeconomy: Advances and Competitive Implications

## I. ABSTRACT

The Catalyst Group Resources' (TCGR's) newest multi-client study will address the role of catalysts in the conversion of biomass and the subsequent conversion of those intermediates to finished chemicals. **Specifically, the study will focus on the particular raw materials (e.g., bio-derived sugars, lignocellulosics, etc.) and specific catalyst types (e.g., zeolites, PGMs, etc.) being utilized in biomass upgrading and conversion. It will delineate the producers of the catalysts (and their process technology partners) and specify the targeted conversion materials and routes, highlighting progress towards commercialization as well as remaining hurdles for broader market acceptance, including conversions/yields as well as feedstock availabilities/costs.** TCGR's proposed study will go beyond mere descriptions of technologies and product slates, providing SWOTs and competitive gaps for pursuit in the future landscape – well beyond other current offerings which lack the technical depth, catalyst/process detail and competitive evaluations deemed necessary for commercial success in these areas.

The hallmark of each TCGR multi-client report is “by the industry, for the industry.” This report's charter subscribers (i.e., those who sign up prior to study launch) will be invited to provide input into the final scope and indicate areas of particular importance to them - whether it be application, technology, process, or market participant - in order to provide the most relevance for our subscribers. TCGR's reports go beyond statistics to provide competitive insights and analysis vital to stakeholders in the chemicals, materials, petrochemicals, and refining markets.

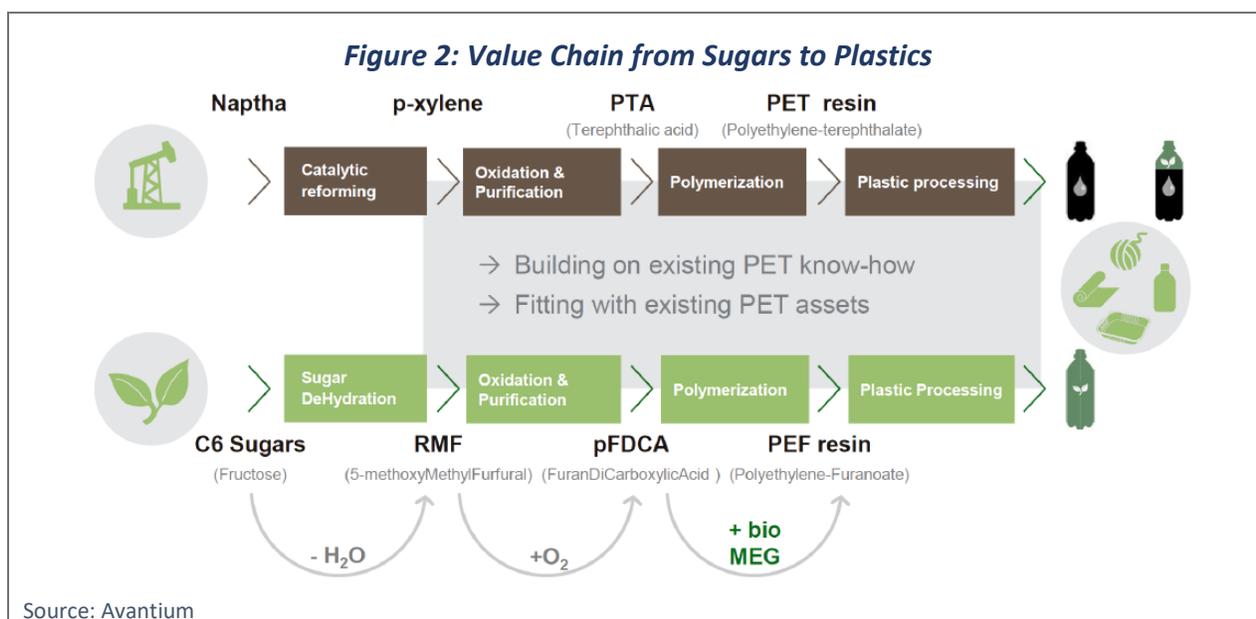
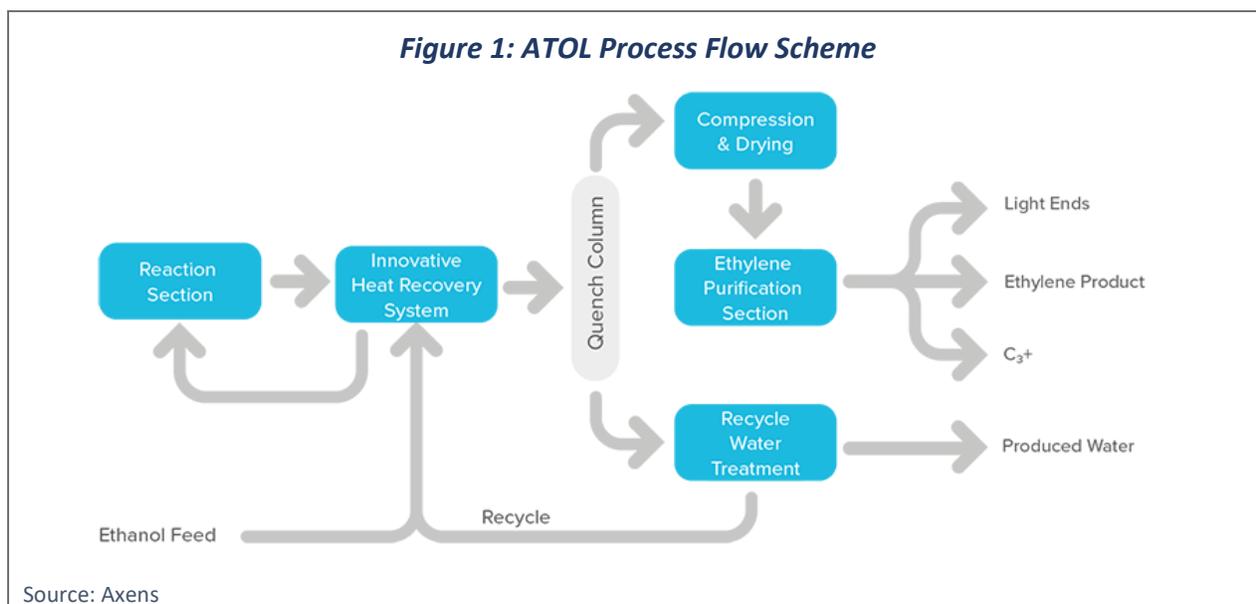
## II. INTRODUCTION

Due to increasing environmental concerns and CO<sub>2</sub> emissions, there has been an increasing demand for renewably-sourced chemicals, culminating in the development of the circular economy concept. Part of this concept is a reliance on biomass as a key feedstock for the production of chemicals. While bio-based production of chemicals like ethanol has been practiced for a long time, newer technologies are expanding the role of bio-based chemical feedstocks for an ever-expanding range of chemicals.

In ever increasing numbers, chemical and polymer companies are announcing sustainability initiatives and setting corporate goals for reduction of wastes and greenhouse gas emissions. For example, Together for Sustainability now counts 22 members representing over \$350 billion in sales (and \$230 billion in spend), green chemistry networks have sprung up around the globe, and numerous companies from oil producers to consumer goods companies, and the chemical providers in between have made commitments to sustainable development. A key lever for sustainability is the replacement of petroleum-derived chemical feedstocks with renewable, plant-derived feedstocks. According to the Bio-based Industries Consortium, the European chemical and polymers industry alone accounted for \$60 billion in sales in the bioeconomy in 2016.

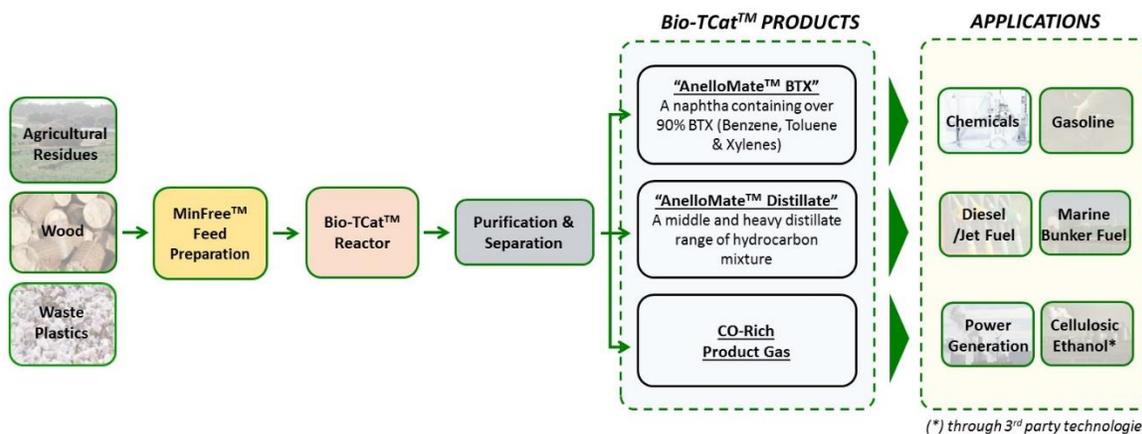
While this number is large and growing, it represents only about 14% of the total addressable market for the European chemical industry, indicating that there is both much room for growth and need for new technologies for those chemicals that are currently only addressable through petroleum feedstocks.

In order to unlock the chemistry, and therefore the value, in plant-derived feedstocks, companies are increasingly looking at catalytic processes to convert a wide variety of feedstocks into an expanding library of chemical raw materials. These processes range from conversion of plant sugars into ethanol and then into ethylene, as in Axens' ATOL technology (Figure 1), sugars into larger molecules, as proposed by Avantium (Figure 2) or Haldor Topsoe's MOSAIK technology, or using a variety of feedstocks to prepare a wide range of chemicals, such as Anellotech's Bio-TCat technology (Figure 3).



**Figure 3: Bio-TCat™ Flowsheet**

*A New Process to Produce Renewable Biofuels and Bio-based Chemicals as an Alternative to Petro-based Products*



Source: Anellotech

Key to the technologies mentioned above, along with the others this study will examine, is the role of catalysts and catalytic process technology in expanding the range of raw materials and end products that can be added to the bioeconomy, including the key monomers for the polymer industry, ethylene and propylene. Also critical are the advances that catalysts can provide to improve conversions/yields in addressing the competitiveness/viability of the bio-derived offerings as substitute products. This study will examine the technologies behind these advances and explore how the catalyst market has been and still needs to adapt to the call for more renewable feedstocks.

### III. THE NEED FOR THIS STUDY

Due to increasing environmental and social drivers, the need for such a study has never been timelier. Many chemical companies and their customers have committed themselves to sustainable development, as consumers have demanded more renewable content and have become more conscious of the environmental impact of their purchasing decisions. Furthermore, growing concern over the role of petrochemicals in driving CO<sub>2</sub> emissions has opened the door for replacement of petroleum-based feedstocks with plant-derived chemicals.

This study will provide an overview of the current and developing markets for the conversion of bio-derived feedstocks, the role of catalysis in creating those feedstocks or in converting those feedstocks to industrially relevant chemicals, and map out other potential target products with a timeline to commercialization as well as the challenges to further adoption, driving R&D and engineering efforts to create further efficiencies, driving down costs and ultimately driving sales.

Critical topics this study will address include:

- State of commercial progress towards production of bio-based chemicals, by feedstock/source and conversion route(s)
- Timelines for commercialization
- Technology advances, drivers and remaining hurdles
- Key global players in development and commercialization of new technologies, including product slates and SWOTs
- Strategies for further implementation

This study also compliments other studies undertaken by The Catalyst Group Resources, demonstrating TCGR's unique capability and resources to deliver exceptional insight. This report will compliment and expand upon previous TCGR multi-client studies such as ***Integration of Biofuels Inside the Refinery Gate*** and ***Biomass Conversion to Biofuels and Biochemicals***, as well as recent technical reports produced for member clients of the **Catalytic Advances Program (CAP)** including ***Circularity in Chemicals***, ***Advances in Methanol to Products***, and ***R&D Advances in Catalysis of Biochemicals***.

#### **IV. SCOPE AND METHODOLOGY**

TCGR's study will assess recent catalyst technology developments enabling the conversion of bio-derived raw materials into industrially relevant chemicals and provide a comprehensive look at the market potential for these technologies - including specific catalysts and process licenses, with SWOTs - to provide insightful, timely advice in both technical and commercial directions. Furthermore, TCGR will evaluate emerging catalytic technologies for the bio-economy, in order to determine additional needs as well as gaps in the present technologies for which there should be market demand for new technologies.

Topics included are:

- Existing and developing catalytic technologies for conversion of bio-based feedstocks, by provider/technology developer
- Catalyst and technology provider supplier profiles, including linkages to bio-chem producers
- Market evaluations of the potential for bio-derived chemicals, and the underlying catalysts and technologies
- Strategic analyses and competitive implications

As depicted in this report's proposed Table of Contents on page 6, it is envisaged there will be four (4) major Sections. **Section III** of this report will provide the current market (size and growth) for the major and emerging bio-derived chemicals, including drivers for their commercial implementation (by chemical) as well as producer profiles. **Section IV** will examine the current commercial catalytic and process technologies for conversion of biochemicals,

detailing potential market opportunities and strengths and weakness (SWOTs) of competing technologies and their developers/suppliers. **Section V** will examine emerging catalysts and catalytic technologies, detailing technology status and hurdles, and commercial implications of the relative state of the technology. **Section VI** will provide an overall competitive assessment, highlighting the technology and market gaps and delineating the future needs for the catalyst industry to support an emerging bioeconomy.

All TCGR multi-client studies are characterized by competitive and strategic insights for industrial and financial companies to evaluate. These include key trends, concerns, and conclusions on the best return on investment (ROI) actions, competitive expectations, and strategic SWOT's on the players. TCGR is noted for its sound strategic advice that comes from nearly 40 years of experience.

TCGR's unique background and established global Dialog Group® ensures expert capability and skill level in this study area. TCGR will utilize numerous deeply experienced experts in catalysts and chemical production to assist us in providing insights beyond what other sources that do not have comparable reach and industrial experience can provide.

## **Application of Catalysts in the Bioeconomy: Advances and Competitive Implications**

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  - A. Ethylene, Ethylene Glycol, and Ethylene Oxide
  - B. Propylene and Propylene Glycol
  - C. Butadiene and butanediol
  - D. 2, 5-FDCA, Furans and Furfural
  - E. Bioaromatics
- IV. Commercial Catalysts and Process Technologies for Conversion of Biochemicals**  
(to include specific catalyst compositions, suppliers and SWOTs, by process and application)
  - A. C<sub>2</sub> Value Chain
    - 1. MOSAIK by Haldor Topsoe for conversion of sugars to MEG
    - 2. ATOL by Axens/Total for Ethylene
    - 3. Hummingbird by TechnipFMC for Ethylene
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  - B. C<sub>3</sub> Value Chain
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  - C. C<sub>4</sub> Value Chain
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  - D. C<sub>6</sub> and higher value chain
    - 1. YXY by Avantium for 2,5-FDCA
    - 2. Bio-T Cat by Anellotech for Aromatics
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(to include specific catalyst compositions, suppliers and SWOTs, by process and application)
  - A. Catalytic Reforming of Biomass to Hydrogen
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    - 2. Chemicals via Oxidations
    - 3. Chemicals via Reductions
  - C. Succinic Acid to Butanediol
  - D. Plant Sugars to Methyl Vinyl Glycolate
- VI. Competitive Assessment of Catalysts and Process Technologies in the Emerging Bioeconomy**
- VII. Recommendations and Conclusions**

*\*As it does in each of its industrially-focused multi-client studies, TCGR will seek input from “charter” subscribers (i.e., those that sign up prior to study launch) to help shape the report’s final scope/TofC. This interactive and client-driven methodology ensures that the final report covers and emphasizes the most pertinent content due to the numerous catalyst/process approaches covering a range of inputs and end-products 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.

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***

## VI. DELIVERABLES AND PRICING

This report is timely and strategically important to those industry participants and observers considering investment, as well as to catalyst and process technology companies evaluating the bioconversion markets. TCGR's report, based on technology evaluations, 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.

**"Application of Catalysts in the Bioeconomy: Advances and Competitive Implications"** will be available in August/September 2020.

<u>Participation</u>	<u>Deadline</u>	<u>Price</u>
<u>"Charter" subscribers*</u>	<u>before April 10, 2020</u>	US\$22,500
<b>Application of Catalysts in the Bioeconomy: Advances and Competitive Implications</b>		
<u>Post-launch subscribers</u>	<u>after launch</u>	US\$25,000
<b>Application of Catalysts in the Bioeconomy: Advances and Competitive Implications</b>		
Report in PDF format, in addition to subscription price		US\$1,000

*\*Charter subscribers (those who sign up for the study before April 10, 2020) will have the opportunity to work with TCGR in defining the scope of the report by delineating areas of particular interest for inclusion in the assessment.*

### **Notice to Members of TCGR's Catalytic Advances Program (CAP) who received the 2019 CAP technical report entitled "Circularity in Chemicals":**

*Due to the complementary nature of this study to TCGR's CAP report from 2019 addressing circularity in chemicals, TCGR is offering a discount of \$1,000 off "Application of Catalysts in the Bioeconomy: Advances and Competitive Implications" to CAP members who received that study. Subscribers are requested to contact John J. Murphy at +1.215.628.4447 or [John.J.Murphy@catalystgrp.com](mailto: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 receipt/selection of that CAP report.*

## ORDER FORM AND SECRECY AGREEMENT

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Please enter our order for “**Application of Catalysts in the Bioeconomy: Advances and Competitive Implications**” to be completed in August/September 2020, as follows:

\_\_\_\_\_ **“Application of Catalysts in the Bioeconomy: Advances and Competitive Implications”** as a “charter” subscriber (i.e., prior to April 10, 2020) for US\$22,500 (US\$25,000 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 US\$1,000.

\_\_\_\_\_ Please send us \_\_\_\_\_ additional printed copies @ US\$250 each.

\_\_\_\_\_ \*\*\* We are members of TCGR’s **Catalytic Advances Program (CAP)** and received the 2019 technical report “**Circularity in Chemicals;**” we are therefore entitled to the US\$1,000 discount off the subscription rate. \*\*\*

**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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