



Carbon Dioxide Capture & Conversion (CO₂CC) Program

**A Membership Program offered by
The Catalyst Group Resources (TCGR)**

2019

Abstract...

- **Membership-driven** consortium of industrial organizations/institutes seeking to develop, monitor, and utilize the “state-of-the-art” in technological progress and commercial implementation of CO₂ capture and utilization/conversion
- **Designed to** document technically and commercially viable options for CO₂ capture/clean-up as well as its conversion/utilization in useful products which meaningfully address the challenges posed by energy efficiency, CO₂ life-cycle and overall sustainability issues
- **Founded in** 2010 with nine (9) charter members, including: Chevron, Dow Chemical, ExxonMobil, Evonik, Kaiteki Institute (Mitsubishi), National Institute of Clean-and-Low-Carbon Energy (NICE), Suncor Energy, Total SA, and UOP. Additional members since then include: Braskem, Clariant/Süd-Chemie, Equinor/Statoil, King Abdullah University of Science & Technology (KAUST), Petrobras, Reliance Industries and Repsol
- **Interactive community** which can be installed corporate wide/globally in order to benefit resourcing and collaboration both externally and internally
- **Delivering** timely and insightful information and analyses, accessible exclusively to members and protected by confidentiality agreements, including techno-economic reports, email communications and an annual meeting
- **Resulting** in a value-added relationship among members and with TCG/TCGR, leading to improved (or unique) external partnership and/or investment possibilities



The CO₂CC Program follows the well-established model initiated in TCGR's Catalytic Advances Program (CAP) founded in 1995 and operating successfully since then.

Need/Justification...

- The mitigation and/or control of GHG are now becoming a global priority, with leaders embracing **“the vision”** that by reducing CO₂ through improved efficiency they can improve their profitability - the drivers to implement are significant!
- Among the largest hurdles to achieving **“the vision”** is the development of cost-effective methods to capture CO₂ at commercial scale that approach required levels of \$US 20-25 per m.t. equivalent. Alternatives include the deployment of cost off-setting conversion of CO₂ into useful products or EOR.
- There is an increasing diversity of approaches towards making CO₂ capture and conversion technologically and economically viable, heightening the importance of selecting the best routes for further development. Investing in the wrong approaches could be quite costly; investing too early (or too late) could be catastrophic.
- The impetus is clear! Over the next 5-10 years, GHG will be a multi-billion \$\$ business, in which leaders with the best process technologies and/or positions will reap tremendous rewards.






















TCGR's CO₂CC Program is a uniquely value-added service, different from government-run efforts, in which members receive industrially-focused information, analyses and commentary. The program highlights opportunities, compares alternatives and provides unique insights for its members.

Representation of CO₂CC Program Membership...

The program was launched in January 2010 with nine (9) “charter” members who worked with TCGR in defining the scope and content of the deliverables by delineating areas of particular interest or importance to them; membership interaction remains a “hallmark” of the program.

CO₂CC Program Members Since “Launch” in 2010

 BASF	 National Institute of Clean-and-Low Carbon Energy (NICE)
 Braskem SA	 Petrobras
 Chevron	 Reliance Industries Limited
 Clariant	 Repsol SA
 Conoco Phillips	 Saudi Aramco
 Dow Chemical	 Statoil
 Evonik	 Suncor Energy
 ExxonMobil	 Total SA
 Kaiteki Institute (Mitsubishi Chemical)	 UOP A Honeywell Company
 KAUST	King Abdullah University of Science & Technology (KAUST)



The membership continues to expand and evolve, with industry leaders reflecting an increasing diversity of interests and pursuits

Program Deliverables...



➤ Members of the CO₂CC Program benefit from a four-tiered deliverable approach:

1. **CO₂CC Techno-economic Reports** – Gain competitive advantage through confidential “state-of-the art” studies in CO₂CC. Three (3) state-of-the-art reports annually covering R&D, commercial development and practical “real world” implementation. These exclusive reports are authored by the world’s leading scientists and are peer reviewed. Topics are determined by the membership (via ballot) and report scope/content is shaped by member input.
2. **CO₂CC “Communiqués”** – Timely and focused “window” on the market-place of new developments in CO₂CC. Weekly emails capturing the latest global news on technical, commercial, governmental and regulatory developments and annotated with insights, observations and recommendations for competitive advantage.
3. **CO₂CC “Project Postings”**- Exclusive, members-only corporate opportunity offers for joint technical and/or commercial development. As needed emails covering R&D and strategic partnership opportunities in new technologies/businesses, as offered by members.
4. **Member Meeting and/or Internet-based “Webinar(s)”** – Benchmarking and alliance building events. Throughout the membership year, TCGR convenes exclusive members-only meetings and/or webinars. These allow members to mix with industry peers involved in CO₂CC.

➤ Deliverables are timely and insightful, accessible exclusively to members, and protected by confidentiality agreements.



Note that at no time are member companies expected to contribute content (e.g., R&D results, technology development progress, etc.) for the reports or other program deliverables; the intellectual property of all member companies remains proprietary to them and program deliverables are based solely on publicly available information

Program Evolution ...

- The current **CO₂CC Program** members have interests and needs which continue to evolve, so the program is changing along with them, as follows:
 - 2010-2011: focus on R&D/technology benchmarks
 - 2012-13: movement towards energy efficiency and “real world” lessons learned
 - 2014-2016: emphasis on economically viable opportunities and “fit” within operations
 - 2017-beyond: need for practical implementation and pathways to financial returns
- The **CO₂CC Program** directed efforts in 2019 (and will continue beyond) towards further enhancing the value provided as well as the member experience, including:
 - More frequent and “actionable” *Project Posting* opportunities
 - Exclusive offers of Joint Innovation Projects (JIPs) among members
 - Increased direct communication with liaisons to better align the program with corporate interests

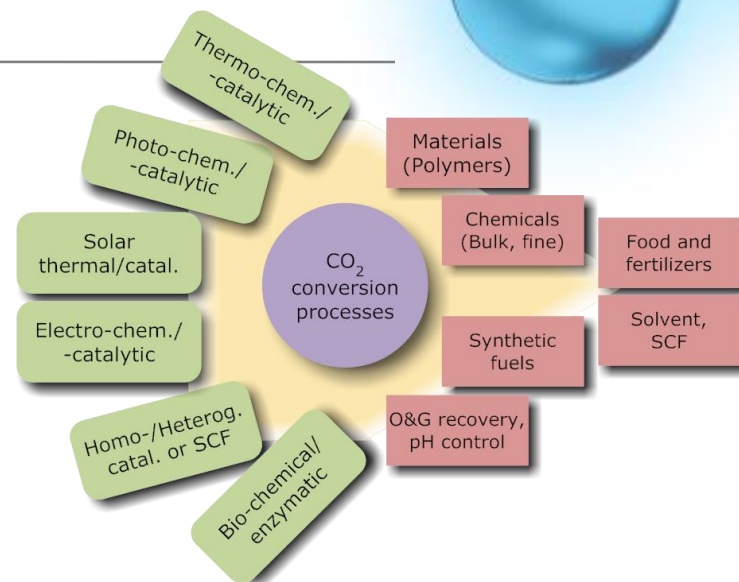


These features will increase the interactivity and potential for partnerships among the membership with the aim of implementing actionable cost-saving projects.

Program Scope ...

The scope of the program is defined by the following parameters:

- CO₂ capture and/or separation
- CO₂ concentration, purification and/or other post-treatment
- CO₂ utilization/conversion (e.g., CO₂ as a feedstock) for use as a fuel or intermediate, including enhanced oil recovery (EOR) applications
- Industrial process improvements and energy saving initiatives which mitigate CO₂ generation
- Energy requirements and/or penalties (plus other costs), including energy efficiency
- Bottom-line financial (income) impacts resulting from CO₂ reduction programs
- Life-cycle considerations and sustainability of CO₂ applications
- GHG/ CO₂ regulation and “cap and trade” developments
- Government-sponsored demonstration and scale-up activities



The breadth of technologies and commercial developments are documented and assessed relative to their technical and/or commercial potential. Efforts are made to relate current developments to past efforts and point out future convergences.

Representative Study Topics Since CO₂CC Program Inception in 2010 ...

- *Advances in Mineral Carbonation of CO₂*
- *CO₂ Utilization Beyond EOR*
- *State of the Art and Future Prospects for Electrochemical CO₂ Reduction Routes*
- *Progress Towards Cost-Effective and Sustainable H₂ Production*
- *Venture Start-Ups for CO₂ Conversion*
- *CO₂ Utilization in Reforming*
- *Benchmarking CO₂ Capture Technology (Vol. 3): Update on Selected Pre-/Oxy-Combustion and Post-Combustion Capture Routes*
- *System Perspectives/Net GHG Benefit of CO₂ Conversion Technologies*
- *Integration of Renewable Energy in CO₂ Capture/Conversion Processes; Integrated CO₂ Capture and Conversion from Flue Gases*
- *Progress Towards Technologically and Commercially Viable CO₂ Conversion to Olefins, Acids and Esters*
- *Energy Efficiency/ CO₂ Mitigation Case Study Series – Vol. 1: Refining and Fuels; Vol. 2: Petrochemicals and Chemicals*
- *Process/Energy Integration in CO₂ Capture: Opportunities and Challenges*
- *Advances in Energy Efficiencies via Separations Technology*
- *Conversion of CO₂ to Syngas and SNG*
- *Analysis of Demand for Captured CO₂ and Products from CO₂ Conversion*
- *Retrofit Suitability of Competing CO₂ Technologies*
- *Advances in Technologies for CO₂ Conversion to Fuels ; Advances in Technologies for CO₂ Conversion to Chemicals*



***These topics have been selected by members
as deliverables in the 2010-2018 membership years***

Study Topics Under Consideration for 2019 and Beyond ...

The following topics, plus those to be provided as “write-in” ideas by members, are under consideration as potential studies in 2019 (and beyond):

- ***Impact of Carbon Taxes on the Refining, Chemicals and Allied Industries?***
- ***Advances in Flare, Associated and Stranded Gas Capture, Conversion and Utilization***
- ***Direct Air CO₂ Capture and Other Net Negative CO₂ Processing Technologies***
- ***Advances in CO₂ Incorporation in Polymers***
- ***Power to X (Chemicals)***
- ***Compact, Light-Weight CO₂ Capture Technologies for Small- to Medium-scale CO₂ Emitters***
- ***Life Cycle Assessment (LCA) of CO₂ Conversion Value Chains***
- ***Advances in Direct Decarbonization of Natural Gas***
- ***Natural Gas as an Energy and Carbon Source for Metallurgic Industries: Impacts on CO₂ Emissions***
- ***Energy Efficiency/CO₂ Mitigation Case Study Series – Vol. 3: Allied Industries***
- ***Optimizing Energy Utilization: Cogeneration and Combined Heat and Power (CHP)***
- ***Technical and Commercial Progress Towards Viable CO₂ Storage***



Program Options and Fees ...

- The **CO₂CC Program** is an annual consortium with two levels of participation in 2019:
 - Patron Membership at \$37,000 per year;
 - Sponsor Membership at \$28,000 per year.
- The Patron membership entitles the subscriber to all three (3) techno-economic reports produced each year. At the Sponsor level, the company selects two (2) of the three (3) techno-economic reports produced each year.
- Once a company has committed to joining the program for two consecutive years (e.g., 2019-20), they may elect to exchange report selections in a given year for previously completed reports. The membership has included this 2-year requirement to avoid companies suspending their memberships without losing report privileges.
- Each member company signs a Corporate Membership Agreement, which fully documents the program content and the way that the program works.
- Examples of selected program deliverables (i.e., excerpts of completed reports, weekly *CO₂CC Communiqué* emails, member ballots, actual report Tables of Contents, etc.) can be made available upon request as can member testimonials.



The Catalyst Group Resources (TCGR) is known for its visionary stance in the identification of new technologies that lead to the development of new markets and industries. The clients who join our programs/studies benefit by being leaders in these new opportunities to their competitive advantage.



Additional Information and TCGR Contact Details...

The **Carbon Dioxide Capture & Conversion (CO₂CC) Program** is available on a membership basis from The Catalyst Group Resources (TCGR)

Further details can be obtained at:

www.catalystgrp.com/php/tcgr_co2cc.php

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