

# Industry Perspectives on CCUS: TCGR's CO<sub>2</sub> Capture & Conversion (CO<sub>2</sub>CC) Program

ARPA-E Reactive Carbon Capture Workshop – February 2-3, 2022

John J. Murphy, CEO

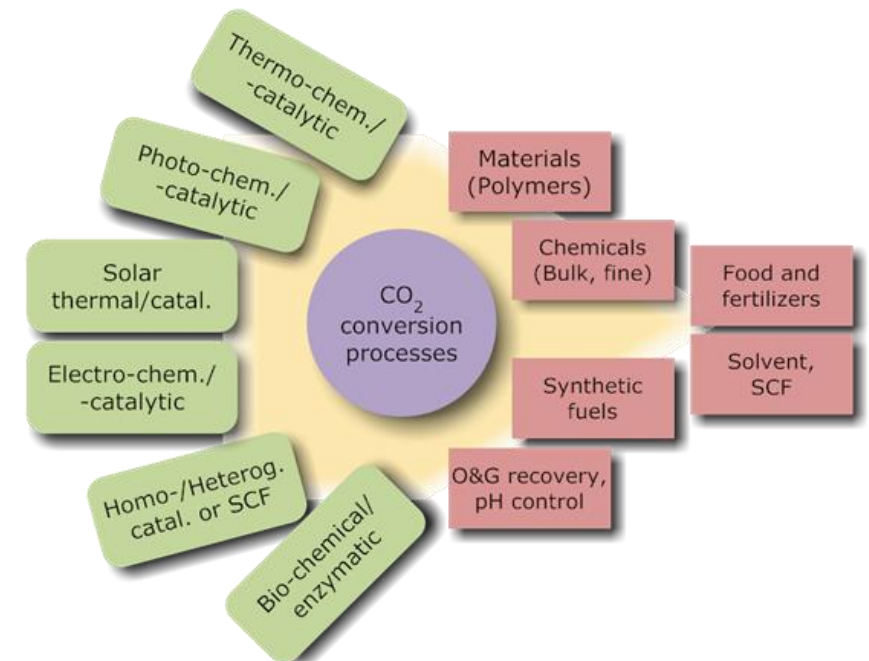
## Who is The Catalyst Group: TCG Consulting (TCGC) and TCG Resources (TCGR)

- A **Global Consultancy** established nearly 40 years ago which serves a diverse spectrum of process industries.
  - Refining, Chemicals, Material Science, Plastics, Specialties, Pharmaceuticals, Environmental, Catalyst Manufacturers, EPCs and Investment bankers
- We are a *Global Technology-Driven Strategic Planning Resource* who serves our clients in two ways: via client directed projects (TCGC) and via various programs and studies (TCGR).
- **Unique Competencies:**
  - **Our Network:** Global network of 150+ scientific & commercial leaders which is unmatched in our industry
  - **Our Experience:** Our longevity in consulting & repeat client business is a testament to the value TCG provides
  - **Our Approach:** Our unique ability to connect process technology developments and market opportunities
    - **Client-centric and highly interactive style**
- Client list includes top global industrial leaders

**...Our Longevity in Consulting & Repeat Client Business  
is a Testament to the Value TCG Provides...**

## Since 2010, TCGR Has Been Operating the CO<sub>2</sub> Capture & Conversion (CO<sub>2</sub>CC) Program

- **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 CO<sub>2</sub> capture and utilization/conversion; including “decarbonization”
- **Designed to** document technically and commercially viable options for CO<sub>2</sub> capture/clean-up as well as its conversion/utilization in useful products which meaningfully address the challenges posed by energy efficiency, CO<sub>2</sub> 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: BASF, Braskem, CEPSA, ConocoPhillips, Clariant/Süd-Chemie, Equinor/Statoil, King Abdullah University of Science & Technology (KAUST), Linde, LyondellBasell, Osaka Gas, Petrobras, PTT Global Chemicals, Reliance Industries, Repsol, Saudi Aramco, and Shell
- **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 CO<sub>2</sub>CC Program follows the well-established model initiated in TCGR's Catalytic Advances Program (CAP) founded in 1995 and operating successfully since then.

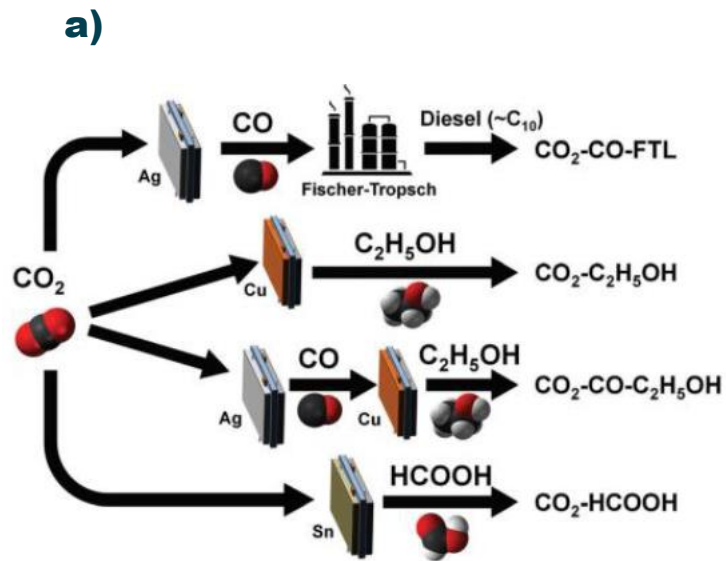
## Representative Study Topics Since CO<sub>2</sub>CC Program Inception in 2010

- *State of the Art and Future Prospects for Catalytic and Electrochemical Routes to CO<sub>2</sub> Conversion*
- *Advanced Materials for CO<sub>2</sub> Capture and Separation*
- *Progress Towards Operating a Viable Business in CO<sub>2</sub>*
- *Catalogue of Most Important Scientific Advances in CCUS Over the Past 3 Years*
- *Permanent Sequestration of CO<sub>2</sub> in Industrial Wastes/Byproducts*
- *Life Cycle Assessment (LCA) for Sustainable Chemical and Polymer Production*
- *Energy Efficiency/CO<sub>2</sub> Mitigation Case Study Series - Vol. 3: Allied Industries*
- *The Role of CO<sub>2</sub> Emissions Reduction in Overall Corporate Sustainability Initiatives*
- *Technical and Commercial Progress Towards Viable CO<sub>2</sub> Storage*
- *Compact Light-Weight CO<sub>2</sub> Capture Technologies for Small- to Medium-scale CO<sub>2</sub> Emitters*
- *Advances in Mineral Carbonation of CO<sub>2</sub>*
- *CO<sub>2</sub> Utilization Beyond EOR*
- *State of the Art and Future Prospects for Electrochemical CO<sub>2</sub> Conversion Routes*
- *Venture Start-Ups for CO<sub>2</sub> Conversion*
- *Progress Towards Cost-Effective and Sustainable H<sub>2</sub> Production*
- *Integration of Renewable Energy in CO<sub>2</sub> Capture and Conversion Processes*
- *Energy Efficiency/CO<sub>2</sub> Mitigation Case Study Series – Vol. 2: Petrochemicals and Chemicals*
- *Energy Efficiency/ CO<sub>2</sub> Mitigation Case Study Series – Vol. 1: Refining and Fuels*
- *Analysis of Demand for Captured CO<sub>2</sub> and Products from CO<sub>2</sub> Conversion*
- *Advances in Technologies for CO<sub>2</sub> Conversion to Fuels; Advances in Technologies for CO<sub>2</sub> Conversion to Chemicals*

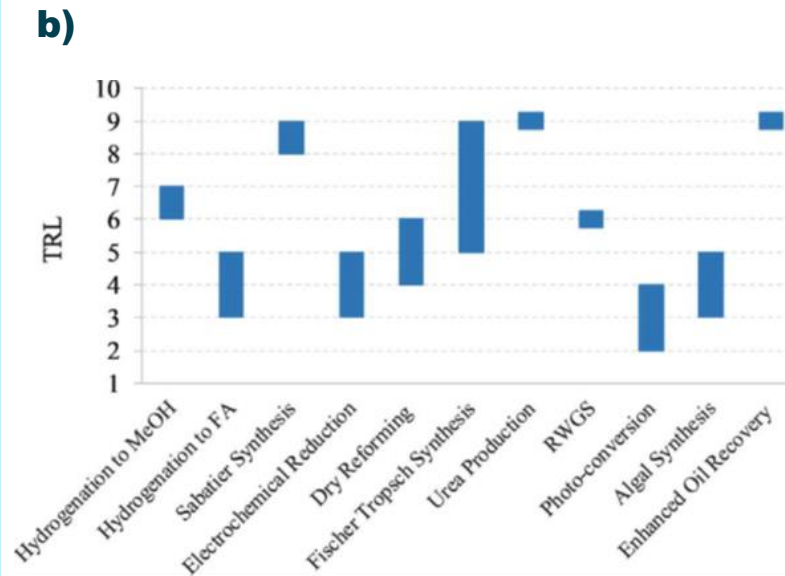


**These topics are among those selected by members as deliverables in the 2010-2021 membership years**

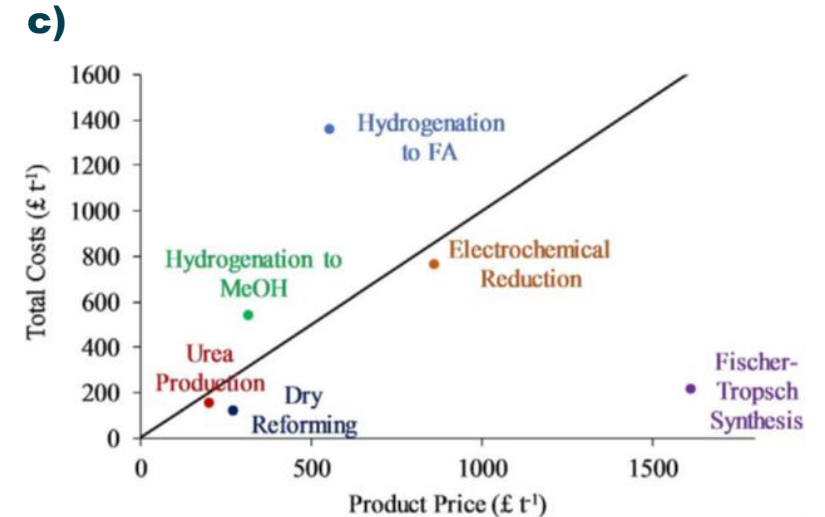
## Selected Findings from a Recent CO<sub>2</sub>CC Program Report entitled “State of the Art and Future Prospects for Electrochemical CO<sub>2</sub> Conversion Routes”:



Schematic representation of different pathways for eCO<sub>2</sub>RR to liquid products.



Technology Readiness Level (TRL) ranges of the considered CO<sub>2</sub> utilization technologies



Total costs (combined CAPEX and OPEX) per tonne of product generated against market price per tonne of product.

The analyses represent the scope of member companies' interests, providing guidance on opportunities for further development.

# Selected Highlights and Lessons from CO<sub>2</sub>CC Program Reports Addressing Integrated Capture/Conversion Technological Approaches Include...

CO<sub>2</sub>CC Program Reports, with topics selected by member ballot and ToFCs shaped by member feedback, include:

- Detailed technical descriptions, including advancements
- Representative economics, allowing for comparisons
- Commentary on remaining hurdles and opportunities

Member companies require:

- Technical metrics: scalability; efficiency; longevity/stability; predictability
- Economic metrics: competitiveness (CAPEX/OPEX); CO<sub>2</sub> footprint/LCA; partnership opportunities

Learnings from CO<sub>2</sub>CC Program operation (since 2010):

- Technology evaluations are aspirational, but practical (forward-thinking)
- Support for progress must be measurable (both time and money)
- Priorities/decisions reflect multiple stakeholders (R&D, SBU, HSE)



**CCU technology selection is unique to each member company, based on their strategies/objectives, current/planned assets and timing/cost.**



## Additional Information and Contact Details...

### The Catalyst Group Consulting (TCG) & The Catalyst Group Resources (TCGR)

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