The Catalyst Group Consulting

Global Megatrends in the Catalyst Industry

Topsøe Catalysis Forum
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Catalysis Today is Indispensable & Strategic

**Catalysis: Over a Century of Progress**

- The first heterogeneous catalytic process was introduced in 1875, the Pt, $\text{SO}_2 \rightarrow \text{SO}_3$ to $\text{H}_2\text{SO}_4$
- Catalysis was first coined in 1835
- From gasoline to aspirin

![Catalysis Timeline Diagram](image)
Catalysis is crucial to provide for the future energy needs, health and welfare of our planet...

~50% wealth driven by emerging economies

>9 billion people will live on this planet by 2050

Macrotrends Drive Economic Growth...
+10 year increase in average life expectancy by 2050

HealthCare/ Medical

Food
30% more food will be needed by 2050

Middle Class

Construction/Housing
70% of the world population will live in cities by 2050

Transportation

Energy
50% more primary energy will be needed in 2050

+3 billion people will be added to the middle class

100% increase in global road transport by 2050
Macro-feedstock Changes

North America
- New capacities based on shale gas
- Export of NGLs/LPG based-products

China
- Strong domestic demand driving capacity
- Abundant coal to support coal-to-chemical
- New Shale Gas investment

Europe
- Ongoing restructuring of olefins/petrochemicals
- Focus on innovative chemistry

Middle East
- Diminishing feedstock advantages due to shale gas (USA) and coal (China)
- Export hub for raw materials and base products

South America
- Focus on renewable resources
- Will remain net importer of chemicals from US
How does this drive change in catalysis
 Solvents/Aromatics
 Olefins
 Oxo-Alcohols/Plasticizers
 Amines
 Monomers
Catalysts

- Zeolites (ZSM-5), MCM-22,
- Pt on Alumina
- Improved membrane separations
- Bioaromatics
- On-purpose trends

Drivers

Technology Trends

- More advanced and open catalyst market, as licensed process market grows older
- Better catalysis opens up technology to independent 3rd party catalyst suppliers leveraging producer technologies e.g. TDP, methylation etc., e.g. SK, CPC and others
- Science of nanoparticle manipulation in zeolites advances regarding yield, conversion and selective isomerization
- New integrated worldscale PET/PX plants of 1.5 MIL mt/yr means older producers with smaller plants need to revamp or close
- Shifts in feedstocks for crackers in N. America creates C₅ + Deficits. Asia naphtha coking from resid causing quality sourcing problems feeding a supply/demand imbalance.
- China’s growth slowing in PET textiles, loss of market share to India, Vietnam and elsewhere
Olefins

Uses & Growth (000 mt/yr)

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Drivers

Technology Trends

- New MTO, MTP zeolite catalysis becoming more competitive as technologies mature
- Olefins oxidation catalysis eg direct PO, ethylene to MEG(PRPG), and ethylene derivatives catalysis from biocatalysts and/or catalysts being challenged (see ethylene derivatives)
- Will Bioethanol and/or bioglycerine become a favored feedstock?
- PRC coal-to-olefins driven by MTO/DMTO will be challenged by N. American MeOH shipment to PRC East Coast. There are process and quality considerations as well
- Higher growth in PP and PP exports from N. America shale gas being evaluated by XOM, Formosa, Braskem and PTT Thailand. +5% pa growth opportunity.

Catalysts

- Pd on Alumina
- Cr on Alumina
- Alumina Oxides
- On-purpose olefins
- Catalytic unconventionals-Camol
Oxyoalcohols/Plasticizers

Uses & Growth

- Plasticizers (mtpa)

Drivers

- Technology Trends
  - Phthalates under REACH phase out
  - New C7 spearheaded by BASF
  - PRC overcapacity, OCED balanced
  - New hydroformylation catalysts

Catalysts

- Butanol/Butanal, C4-C12
  - Co hydrocarbonyl catalyst
  - Rhodium Catalyst
  - Phosphine – Modified Co Catalyst
Amines

Uses & Growth

Catalysts

- Alkylamines – Co or Ni based catalyst
- Large but traditional market
- Bio-driven revolution
- Discuss Elevance model and metathesis

Drivers

- Swing between fatty amines and petrochemical feedstocks
- Improved buss hydrogenation process – split feeds
- Business shift to ASEAN

Technology Trends
Monomers

Uses & Growth

Drivers

Catalysts

- VCM (HgCl2 on activated carbon)
- VAM – Pd on silica
- EB – AlCl₃ or zeolite (ZSM-5)
- PTA-Polyesters
- Olefins for Polyolefins
  - Metallocenes – Single Site vs. Ziegler Natta

Technology Trends

- Lower cost of olefins unconventional olefins
- Direct methane conversion OCM vs. other routes
- Trend away from PVC plasticizer products
Challenges to address this change…
Future Challenges Drive Commercial and Technical Change...

Signs of Increasing Technology Globalization

- R&D collaborations in different industries are increasing on a multinational basis between companies
- Industry consolidations between companies are multinational, e.g., BASF/Engelhard
- R&D centers of excellence for different scientific disciplines receive multinational funding
- Catalyst industry consortia are increasingly multinational, e.g., TCGR’s Catalytic Advances Program (CAP)
- Conferences and meetings on key catalytic science subjects are multinational
- Web-based applications are creating global information and database sourcing
Catalyst Impact...

• 18 products use 80% of the energy & emit 75% of GHGs
• Improvement of catalysts **AND** related processes can yield significant energy reductions
• ICCA/DECHEMA/IEA Technology Roadmap “Energy and GHG Reductions in the Chemicals Industry via Catalytic Processes” 2013
Top Chemical Energy Emissions Processes
Future Challenges Drive Commercial and Technical Change...

Key Emerging Scientific Platforms

- Alternative feedstock processes: biomass, heavy oil/tar sands, coal, coke, etc.
- Asymmetric (chiral) synthesis
- Selective oxidation catalysis
- Molecular engineering and modeling
- Combinatorial catalysis: discovery and optimization
- Single-site catalysis
- Global catalytic information systems, e.g., reaction databases
- Biocatalysis and biomimics
- Enantiomeric amplification, rate enhancement
Feedstock and Technology Options

- Naphtha:
  - Steam Cracker: \( \text{C}_2\text{H}_4, \text{C}_3\text{H}_6 \)
  - MTO, MTP: \( \text{C}_2\text{H}_4, \text{C}_3\text{H}_6 \)
  - MTX: \( \text{C}_2\text{H}_4, \text{C}_3\text{H}_6 \)

- Syngas:
  - Oxidative Coupling: \( \text{C}_2\text{H}_4 \)
  - Partial Oxidation: \( \text{C}_2\text{H}_4, \text{C}_3\text{H}_6, \text{others} \)
  - New Activation: ?
Technology-Innovation Satisfy Producer Demand Choices

Catalysis as a Science is Complex
Multi-Disciplinary Nature of Catalytic Sciences

Manipulating Nature at the Atomic Level

Source: TCGR Intelligence Report, 2012
TCG and It’s Capabilities

How we can assist Haldor Topsøe.....
Who is The Catalyst Group?

• A Global Consultancy established more than 30 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 (TCG Private Consulting) 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
    o 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...
A Structure for Success: TCG’s Unique Methodology

• Global professional organization of 150+ people, 15 full time employees, 65+ in extensive field network. Virtual company.

• Client-centric approach and highly interactive style

• A highly specialized global network of The Dialog Group® consultants
  – Since TCG’s formation in 1982, the concept of a virtual subcontracted technical organization to provide consulting services was a founding principal.
  – The best expertise for each specific customer problem in a cost-effective manner on a worldwide basis
  – Experienced consultants with many years of industrial proactive and real-world “know how”
  – Provides one of the strongest field intelligence technology networks of any consultancy, continually feeding HQ with information

• Providing Global Support, Flexibility to adapt to specific client needs while being highly Focused on the project scope and deliverables

• Numerous collaborations with Universities and National Laboratories

• Strong client collaborations to innovation centers as clients
The Catalyst Group Resources (TCGR): TCG’s “Resource” for Ongoing Monitoring of Technical and Commercial Developments...

TCGR delivers its value-added services via:

- **Membership Programs – TCGR Brings People Together to Advance the Technology**
  - **Catalytic Advances Program (CAP)**
    - R&D consortium used to leverage research and innovation by sharing resources and experiences to address challenges
    - Designed to provide a technical update on commercially viable advances in catalysis, as well as benchmark commercial advances in catalysis and process technology
  
  - **Carbon Dioxide Capture & Conversion (CO₂CC) Program**
    - 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

- **Enhanced Oil Recovery (EOR) Beyond CO₂ “Game Changer” – 3rd/4th Generation CO₂/Chemical Flooding**
  - Based on an industrial consortium that will be membership driven, to address the challenges of reduced cost EOR technologies for oil recovery. It is envisaged this will involve a unique combination of petroleum, specialty chemical, field services and CO₂2/GHG infrastructure investors.
  - One of the first deliverables will be a CONSORTIUM ROADMAP - a study which places all participants on the same page, as to the well documented issues and challenges. This will be followed by a consortium membership meeting to discuss the roadmap findings and define next steps.
The Catalyst Group Resources (TCGR): TCG’s “Resource” for Ongoing Monitoring of Technical and Commercial Developments...

TCGR delivers its value-added services via:

• **Multi-Client Studies**
  – **The Asia-Pacific Catalyst Industry: Markets, Technologies and Manufacturers**
    o The GDP growth rate for Asia/Pacific was estimated to increase by 5.4% in 2014. As Chinese growth slows, but remain strong in a global context – the prognosis for growth in Asia Pacific (excluding China) is positive. These countries are experiencing growing (i) urbanization, (ii) middle classes and (iii) government subidation.
    o TCGR will first explore and document new chemistry and processes involving direct methane conversion progress (to side-step syngas) to intermediates and products, as well as to document progress in reducing the economic cost(s) and GHG environmental impact of existing/proven technologies. We will then assess progress involving natural gas and syngas conversion chemistry and catalysis for production of intermediates and products, again assessing the costs (energy and other, including CO2 emissions reductions) relative to existing/proven technologies.
    o The catalyst industry has always exceeded global economic GDP growth! In this report, between 2013-2019 it is forecast to grow at +5.4% p.a. Catalysis drives the progress and innovation across our modern global society, producing over $15 trillion annually, from gasoline to aspirin. It is therefore of vital strategic importance to your business development, opportunity and planning for success. It is at the heart of new product/process manufacturing, energy efficiency, productivity and profits!

• **Knowledge & Training Seminars - Aromatics**
  o Meeting with leading minds in aromatics to benchmark the competitive landscape in terms of cost of manufacturing and profitability
TCG – Expands Business Development Bandwidth

- **Boutique enterprise**
  - Unique technology and market integration skills
  - Customized single client projects
  - Excellent contacts with all players – large, small, academia
  - ~ 25 single client projects/year

- **Flexible Business Model**
  - Project specific model – opportunity development
  - Client specific model
    - Internal Resource extension
    - On-demand consulting with easy transition
    - Easy budgeting and project flexibility