Challenges for the Chemical Industry

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Outline

- Dow Introduction
  - Company profile
  - Contributions and drivers

- Historical Perspective
  - Where do we come from

- Our Industry in Perspective

- Challenges
  - At least one suggestion for direction
    » Bio-processing, chemicals from bio-processing √
    » Distributed (small scale) manufacturing √
    » Retrofit of existing processes √
    » CO₂ Capture and Sequestration √
    » Methane activation √
    » Olefin recovery and separation √
    » Low level heat recovery √
    » New Realities √

- Questions, discussions
The Dow Chemical Company

- Diversified chemical company, harnessing the power of science and technology to improve living daily

1897
Established in Midland, MI

2000
Acquired Union Carbide

2008
Acquired Rohm & Haas

Dow by the numbers

- 35 Countries
- 188 Sites
- 50,000 WW Employees
- 5000+ Products
- 60++ Billion Annual Sales

Unique perspective of commodity landscape and specialty chemicals

Founded on brine chemistry 116 years ago

Large Scale
- Ethylene and polyethylene
- Chlorine and caustic
- Ethylene oxide and ethylene glycol

Specialty Scale
- Metal organics, tri-methyl gallium, tri-methyl indium
- OLED materials
- Chemical mechanical planarization products, photoresists…
Current Dow Feedstock Utilization

Starting Materials = Ethylene & Propylene

**Raw Materials**
- Sun
- Coal
- Gas
- Oil
- Naphtha, C₃, C₄

**Ethylene Cracker**
- Ethane

**Products**
- Propylene
- Polypropylene (27%)
- Oxodecane (11%)
- Acrylic (7%)
- Epichlorohydrin (5%)
- Cumene (5%)
- PO (40%)

- Polyethylene (62%)
- EO (22%)
- VCM (8%)
- Styrene (5%)
- VAM (2%)

Source: 2002 BP Statistical Review
Source: SRI 29G
Source: Chemical Week
Technology Options: Fossil Feedstocks

**Feedstocks**
- Oil
- Gas
- Coal
- Non-Syngas

**Technologies**
- Steam Cracker
- MTO
- MXA
- Oxidative Coupling
- Partial Oxidation

**Olefin**
- \( \text{C}_2\text{H}_4, \text{C}_3\text{H}_6 \)
- \( \text{C}_2\text{H}_4, \text{C}_3\text{H}_6 \)
- \( \text{C}_2\text{H}_4, \text{C}_3\text{H}_6 \)
- \( \text{C}_2\text{H}_4 \)

**Legend**
- Green = current
- Yellow = near term
- Red = long term

\( \text{C}_1, \text{C}_2, \text{C}_3 \)
Large Integrated Manufacturing Sites

Plaquemine, U.S.A.

Terneuzen, Netherlands

Stade, Germany

Freeport, U.S.A.
Sustainability is Crucial to Our Success

- One of the world’s largest (non-utility) industrial consumer of power and steam

3,700 MW of electricity required to operate Dow plants

3,700 MW of electricity
Used by San Francisco, San Diego, & Oakland combined

- Feedstock demand is 800,000 barrels/day

- Leading innovator in cogeneration
  - Increased efficiency with reduced impact on the environment
  - Uses 20-40% less fuel

- Self-generates ~75% of all power & steam

- Operates over $6.2 billion in energy assets & supports $2.5 billion in JV assets

- Operate our own Wastewater treatment

- Operate our own incineration facilities

- We strive to be good stewards because it is good business
Sustainable Chemistry

- Integrated look at chemicals, processes and products
  - Improve safety of manufacturing processes
  - Maximize energy efficiency
  - Maximize the efficiency of raw material use
  - Minimize the use of scarce resources
  - Minimize the return of anthropogenic substances to nature
  - Minimize environmental impact
  - Significantly enhance benefits to society

- Will change the way that some products are made
  - We are seeing “sustainability issues” raised
    - Zero water discharge requests
    - Solvent recovery, solvent recycle
    - Sustainability is good business

- It’s all about balance

- Our products **must** be profitable
  - Alternatives **must** be supported financially
Bio-based Products

- Bio-based product are challenged to compete on a cost basis with hydrocarbon based products
  - The consumer has a very limited willingness to pay a premium for “green products”
    » In products far removed from the end user (commodity), the consumer has even less willingness to pay
  - Several notable examples of this difficulty
    » Poly-lactic acid
    » Chitin and chitin derived materials
  - The lesson: simply providing a “renewable product” does not guarantee acceptance
    » Certainly does not guarantee financial success

- Chemicals and Energy
  - Chemicals have higher value add than fuels
  - In U.S. 3% of the fossil resources used for chemicals against In U.S. 97% for energy usage \(^{(1)}\)
    » Added value of this 3% chemicals is $375 billion
    » $520 billion for the remaining 97%

- Energy (fuels) are the ultimate commodity
  - Bio-based fuels are at a huge disadvantage

- Specialty chemicals, in our opinion, have some promise for bio-derived materials
  - Higher margins, less commodity mentality
  - Some tolerance for a premium

\(^{(1)}\) Bozell and Peterson, Technology Development for the Production of Biobased Products from Bio-refinery Carbohydrates – the US Department of energy’s “Top 10: Revisited
Distributed manufacturing

- Distributed manufacturing may be a partial solution to effective use of biomass
  » Resource radius limitations
    • Biomass cannot economically be shipped past a certain radius
    • 80 – 100 kilometers
  » Stranded resources
    • No pipeline, gas flaring
  » Distributed manufacturing may be used to reduce some transportation hazards
    • Drive to reduce “rail miles” for many chemicals
    • Some materials are too hazardous to routinely ship
    • Still must take place in a professional, tightly monitored environment
  » Political instability
    • Move your asset
    • Walk away

- Challenge
  » We must be realistic … distributed manufacturing is a huge challenge
    • Seeks to reverse ~100 years of consolidation
  » Design philosophy
    • Simply making a plant smaller will not work
    • Design philosophy must be different
    • This is in sharp contrast to the paradigm shown earlier
  » Safety must be a major consideration / concern
    • Certain processes should simply be out of consideration
Maintaining Efficiency Across Lifecycle

- Our processes (physical facilities) have long life spans
  - 30 years is not uncommon … 50 years not unknown
    » Maintenance is performed and parts replaced
    » Instrumentation upgraded
    » Plants are by no means neglected …. but
  - Basic configuration may not have changed … in two generations!

- How do we find and implement process alternatives to improved that meet our economic criterion
  - Energy cost alone will not support total replacement
  - Additional capacity generally will support capital expenditure
  - It must fit into the existing framework
  - We must uncover “all” alternatives
  - Dow has done a great deal of work in Synthesis and Intensification
    » Professor Rakesh Agrawal has done some very interesting work in the area of separations
Reactive Distillation plus Dividing Wall Columns

25% Capital Reduction
30% Energy Savings
Advanced Separations

Current Design

Proposed Design

19 Columns Total

13 Columns Total

Major Reduction in Capital and Energy Costs by Separation sequencing and DWC
Where applicable, one of the most powerful intensification techniques available is Reactive Distillation. Reaction must take place at approximately the same conditions as the separation. Generally thought of as being applicable to reacting away azeotrope. Generally thought of as driving equilibrium limited reactions.
Separation Sequencing

- We have the tools and the techniques to
  - Generate all sequences
  - Simple plus complex
  - Heat integrated sequences
  - Use optimization tools to decide the “best” sequence

- Our challenge
  - Use these tools to build new plants
  - Even more challenging: Use these tools to find better sequences that fit our existing facilities

Extremely challenging but very important
The Chemical Process Industry is not the bulk of the problem
- Our industry is not trivial
- We are in an excellent position (perhaps the best) to do our share
- Depending on the accounting method 5% (1) of global CO₂
  » Many of our larger products produce roughly one mass unit of CO₂ per mass unit of product

CCS is not a technical issue
- CCS is an economic issue
  » Credible estimates $70 - $200 per ton
  » We compete in a global market
  » Unilateral application puts us at an economic disadvantage
- CCS is a litigation / risk management issue

Potential fruitful areas of development
- Enriched oxygen (membranes / PSA) and CO₂ capture on furnace vents
  » Reduces flow requirements
- Optimize fractional recovery for economic benefit
  » We simply do not believe that 90% capture is the optimum number

(1) Technology Roadmap Energy and GHG Reductions in the Chemical Industry via Catalytic Processes 2013 Rights IEA
Methane Activation

- Direct coupling of methane without syn-gas
  - In the interest of full disclosure: Many companies believe in methane to products through syn-gas
    » Fischer–Tropsch process
    » Methanol to Gasoline process (MTG)
    » Syngas to gasoline plus process (STG+)
    » Dow process US8129436B2
      • Our focus is different because our focus is \(C_2=\), \(C_3=\)

- Oxidative Coupling or Direct Coupling of Methane (OCM)
  » The Holy Grail of Hydrocarbons
  » Fundamental problem: the intermediate is more reactive than either the reactant or final product
  » Conventional wisdom says 30-40% conversion to \(C_2\) is the minimum for economic viability
Methane Activation

- How do you change the paradigm?
  - Fractionation under current conversions is not practical

- Remove the intermediate olefin and concentrate the olefin for purification
  - Membrane
    - Larger species permeating
    - High flux more critical than high selectivity
  - Reactive absorption
    - Selectivity, safety and size are issues

http://www.sciencemagazinedigital.org/sciencemagazine/09_may_2014?folio=616#pg90
Olefin Recovery and Separation

- Olefin manufacturing dominated by separation landscape
  - Risk aversion is enormous ... and understandable
  - Cryogenic separation rule
  - Separation of olefin product away from cracked gas would change paradigm

- Can also be extended to olefin recovery from process vents
  - Recycle
    » Places false load on ethylene plant
    » High risk of contamination and / or fouling
  - Adsorption, absorption, membranes
    » Often economically challenged

- Potentially fruitful area
  - Reactive absorption
    » There are safety considerations that must be considered
      • Scales well
        » Could open the door for smaller, more compact olefins production
        » This will be an uphill struggle
    » Facilitated membrane transport
Low Level Heat Recovery

- Large facilities generally have large quantities of low level heat
  - Process facilities are generally well integrated with respect to high level heat
    » Within unit boundaries … reactors to separations
    » Across facilities … electricity, boilers, steam generation, boiler feed water … etc.
  - Condensing temperature limitations
  - Equipment limitations

- Many techniques known for low level heat recovery…
  - Difficult to deliver economic justification
    » In a strange twist, improved energy cost make justification more difficult!
    » May need justification from other sources … carbon credits … etc.

- Well known methods
  - Direct utilization … drying, heating
  - Vapor Compression Heat Pump
  - Organic Rankine
  - Thermo-compressor
  - Refrigeration Cycles

- Utilization of absorption refrigeration cycles
  - Integration with site infrastructure
    » Lower pressure in equipment … improved safety
    » Use on satellite areas
  - Provide to commercial / residential as chilled water
    » Fraught with litigation concerns … cross-contamination risks may make this impossible

- Overarching concern
  - What is our failsafe position?
  - If we design our cooling water for 7-10 C, what happens if the chillers fail?

(1) Ankur Kapil, Igor Bulatov, Robin Smith, Jin-Kuk Kim Advanced Process Integration for Low Grade Heat Recovery
New Realities

- **Water consumption**
  - Historically, simulations have not even counted water
  - Large integrated sites consumption
  - Are we taking water from farms, urban areas?

- **Water is a precious commodity in some areas**
  - Water cost
  - New facilities may need to optimize around water

- **Environmental constraints becoming more rigorous**
  - Requests for zero liquid discharge are not uncommon now

- **Current approach to combustion not rigorous enough**
  - Furnaces, flares, combustion devices receive increased scrutiny
  - Present simulation approach may simply call for “duty”
  - Often ignore the “fired side” of the heat supply
    » NOX per unit of heat?
    » VOC per unit of heat?
  - What is the cost of a “unit of improvement”?
Thank You Questions
BACK UP SLIDES

- BACK UP
Moreover, the production of chemicals from biomass is economically interesting since it has an extremely large added value compared to energy production, while it demands only a fraction of the resources [1]. It has been estimated that in the United States, only 3% of the fossil resources are currently used for the production of chemicals, against 97% for energy usage. However, the added value of this 3% chemicals is $375 billion, against $520 billion for the remaining 97% directed at energy usage [1].
Abstract

The Chemical Process Industry (CPI) has seen a revitalization in the United State in the last several years, due primarily to the shale gas revolution and the abundance of low cost feedstocks. However, challenges exist for our industry, and this talk will address some of the challenges from the perspective of Dow Chemical. Dow has the unique perspective, both from a historical perspective of being 117 years old, and from the perspective of being involved in the entire spectrum of the CPI from the production of basic chemicals to the production of specialty products such as OLED’s. This talk will discuss some of those challenges as well as some possible solutions.