Opportunities in Chemical Engineering: Domestic Shale Gas

Sharon Robinson
Oak Ridge National Laboratory

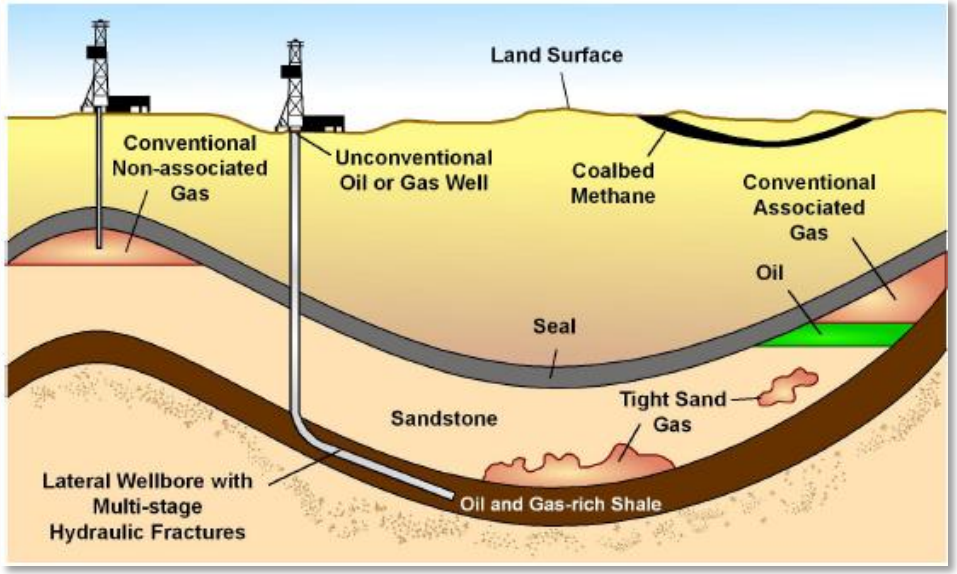
Bruce Eldridge
Process Science & Technology Center
University of Texas at Austin

March 27, 2014

Technology innovations have created opportunities for unconventional oil and natural gas production

- Unconventional natural gas includes shale gas, natural gas from tight sands formations and coal bed methane
- US natural gas production has risen 25% in 5 years primarily driven by shale gas production
- Technology innovations are responsible
  - Long horizontal drilling
  - Hydraulic fracturing
  - Seismic imaging

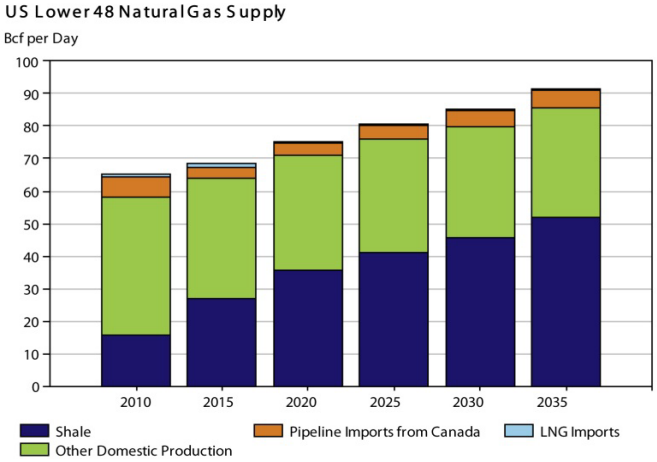
Hydraulic fracturing injects water, sand, and additives to create fissures in rock formations containing oil and natural gas



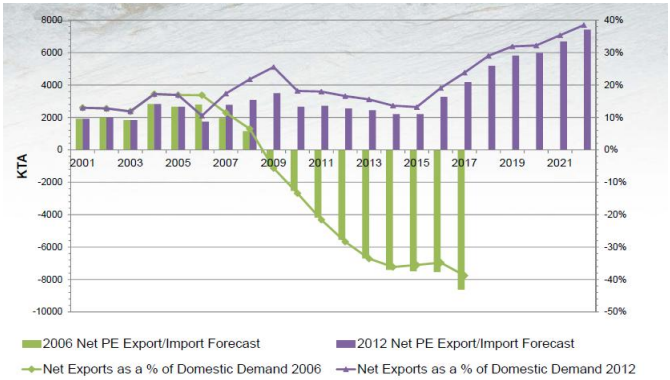
Source: IEA

Unconventional oil and natural gas is transforming America's energy economy

- Natural gas demand decreased by 28% from 1997 – 2009 due to high natural gas prices and international competition
  - Significant off-shoring occurred
  - Petrochemical industry went from being a net exporter to importer
- Shale gas production rose from 2% to 37% of the US output between 2000 & 2012
- Continued increases are predicted to make the US a net exporter again by 2020 and reach "energy independence" by 2035



Source: IHS CERA



Source: IHS Chemicals

Petrochemical competition in the global market has been changed by unconventional oil and natural gas

- UK - $9.2/MBTUs
- Japan - $8.1
- Germany - $7.9
- US dropped from $7.4 to $2.4 due to shale gas
- Canada - $6.1
- China - $5.8
- Brazil - $3.6
- India - $3.4
- Ukraine - $2.8
- Russia - $1.5

US industry will benefit from unconventional shale gas production

Additional Output Arising from Shale Gas

Industry	$ Billion
Chemicals	70.22
Plastic & Rubber Products	33.28
Fabricated Metal Products	5.81
Iron & Steel	5.03
Paper	3.70
Aluminum	1.69
Glass	0.66
Foundries	0.62
Total	121.00

Source: *Shale Gas, Competitiveness and New U.S. Investment: A Case Study of Eight Manufacturing Industries*, American Chemistry Council, May 2012

Impact of shale gas on the industrial sector in the US

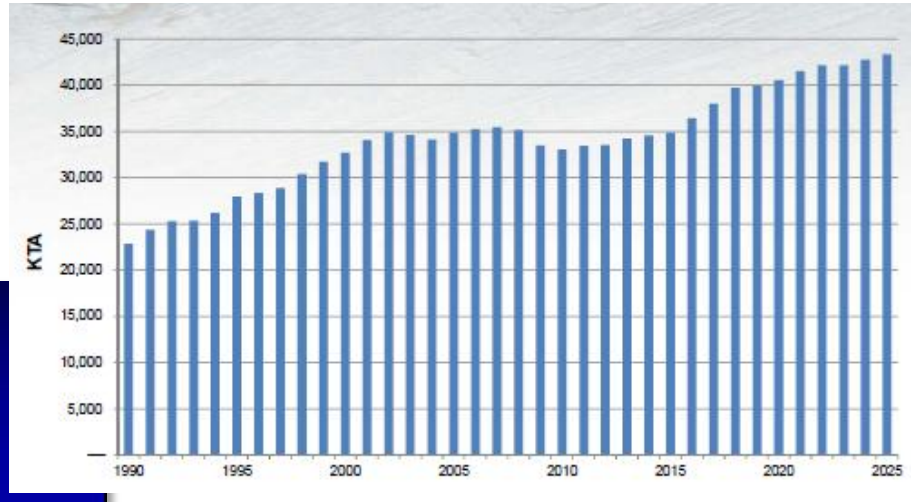
- Generates 200,000 new, direct jobs in eight manufacturing industries
- Generates an additional 979,000 jobs in the supply chain and elsewhere in the economy through the indirect and payroll-induced economic effects
- Generates 1.1 million jobs in construction, capital goods manufacturing, in their supply chains, and elsewhere
- Generates $26.2 billion in annual federal, state, and local tax revenue from the growth in output
- Directly generates a $121.0 billion increase in the output of the eight industries
- Directly generate $72.0 billion in capital investment and construction activity to build and/or expand capacity, leading to a $207.6 billion one-time boost of economic activity

Source: ACC

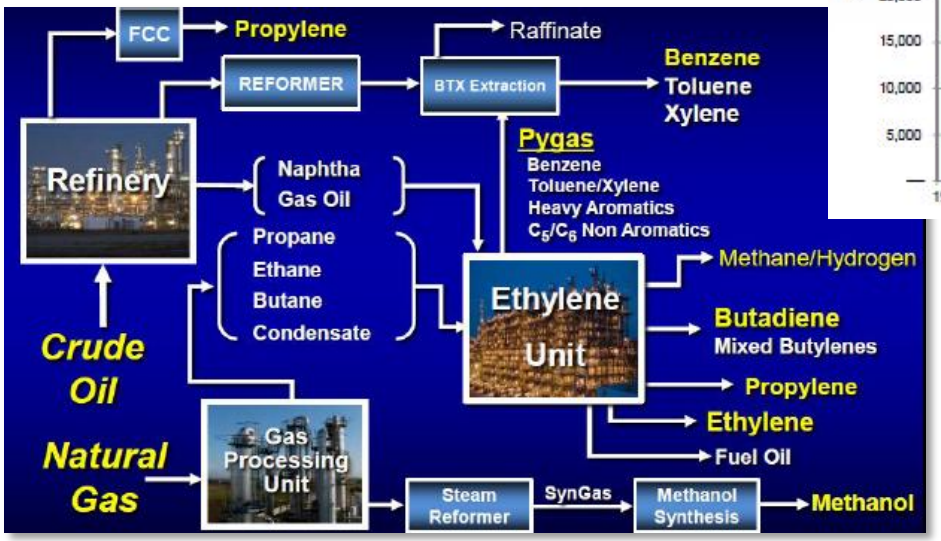
Petrochemical industry receives the largest benefit

- Industry has recently invested $15B in ethylene production, increasing the capacity in the US by 33%
- 50 chemical projects worth over $55B are expected over 5 years

Total North America Ethylene Capacity



Source: IHS Chemicals



Planned new ethylene facilities in the United States

Company	Location	Capacity (thousands of metric tons per year)	Start-up date
Chevron Phillips Chemical	Cedar Bayou, Texas	1,500	2017
Dow Chemical	Freeport, Texas	1,500	2017
ExxonMobil	Baytown, Texas	1,500	2016
Formosa Plastics	Point Comfort, Texas	800	2016
Occidental Chemicals	Ingleside, Texas	500	2016
Sasol	Lake Charles, Louisiana	1,500	2017
Shell Chemicals	Monaca, Pennsylvania	nd	2017

Source: ACS

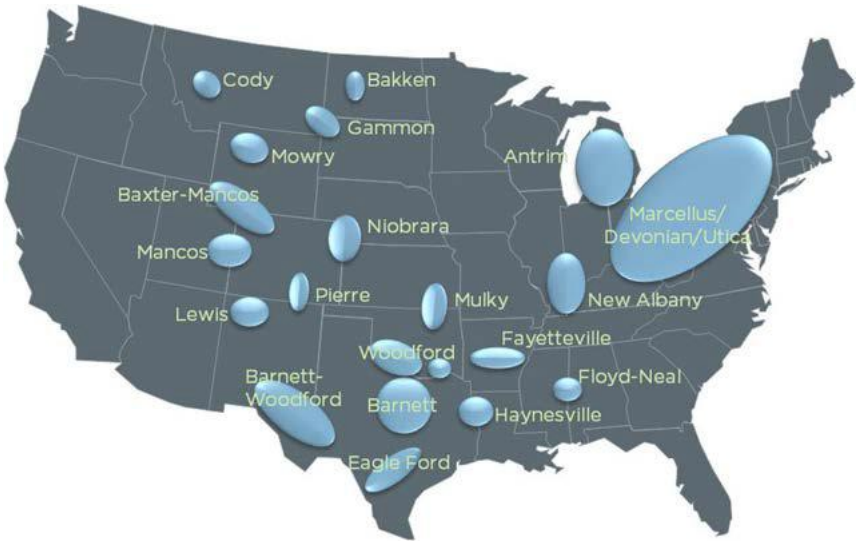
Low-cost chemicals resulting from unconventional shale gas could have impacts down the supply chain

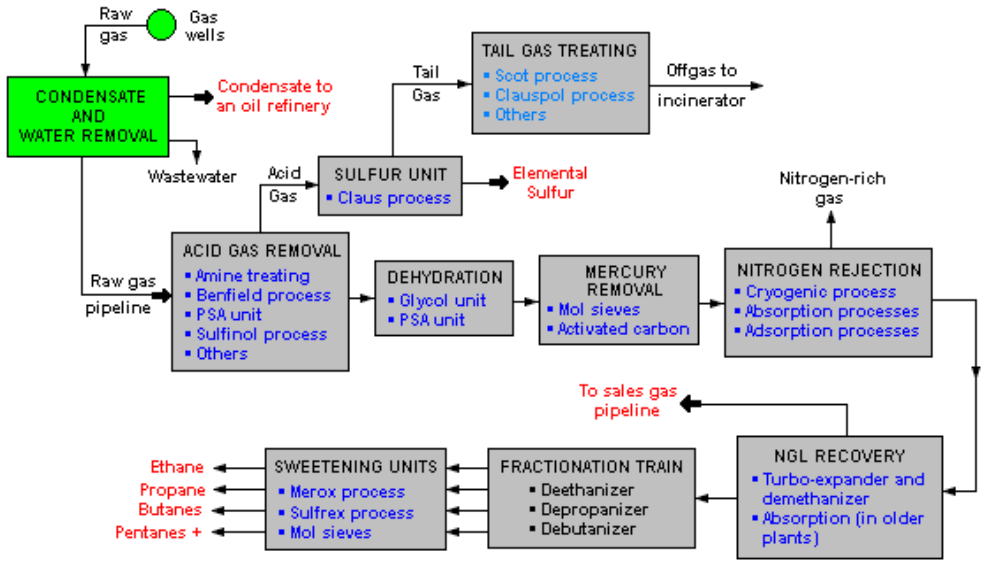
- Low-cost chemicals could create opportunities for plastic-based substitutes for other materials
- Low natural gas prices could create an incentive for companies to expand production facilities in the United States
- Increases in commercial distribution of ethane and ethane-based raw materials could trigger new innovations and investment in new technologies
- R&D initiatives leveraging ethylene-based chemistries that replace petroleum-based products may predominate
- Companies might also look for longer-term sourcing relationships and partnerships with raw material suppliers to help with developing new products

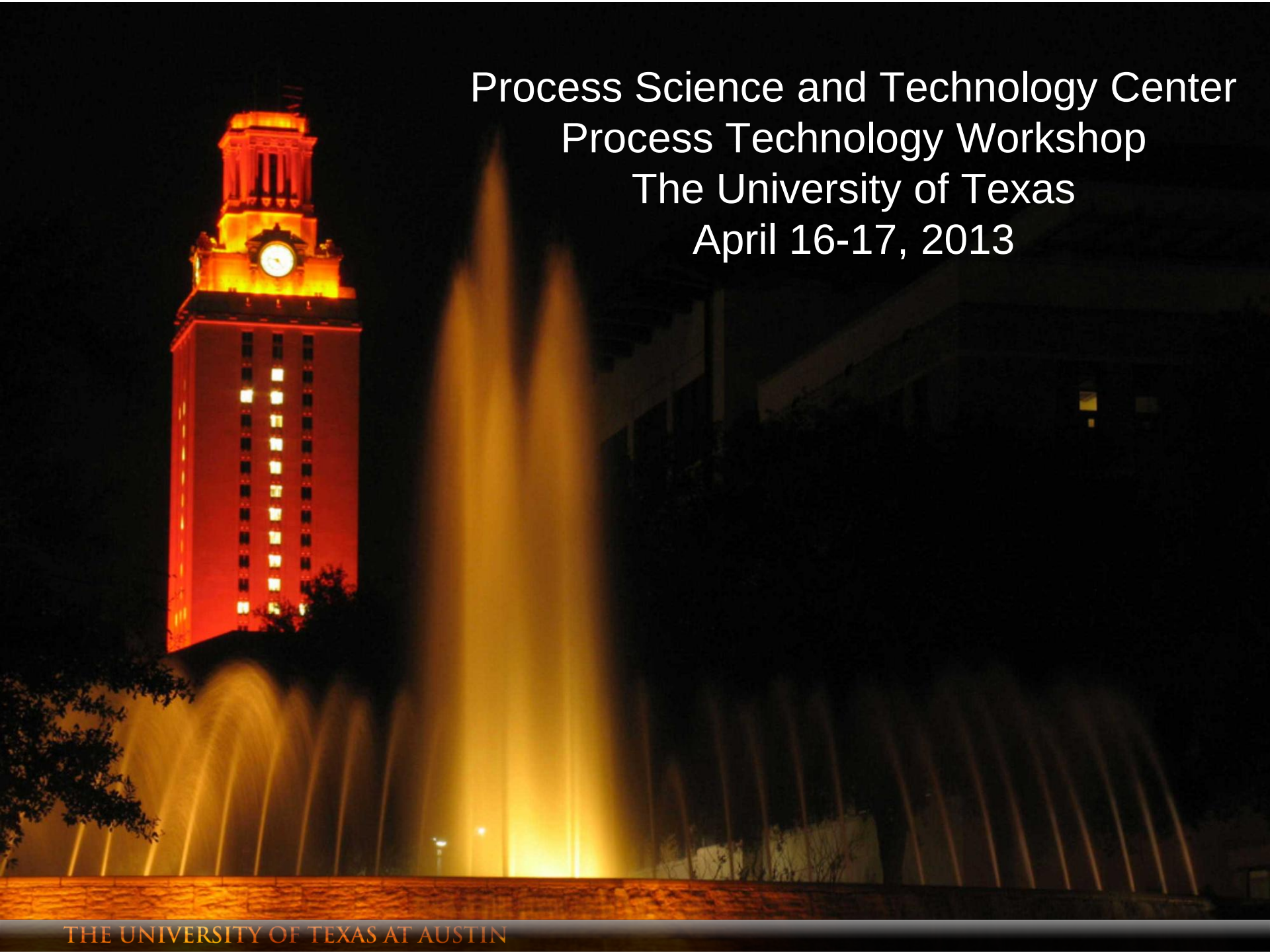
Source: PriceWaterhouseCoopers

Challenges for getting unconventional natural gas from the wellhead to the end user

- Significant water is used in the recovery of unconventional natural gas
- Some predict increased greenhouse gas emissions from shale gas recovery
- Unconventional gas is often not located near natural gas pipelines or refineries







Process Science and Technology Center
Process Technology Workshop
The University of Texas
April 16-17, 2013

JAMES R. FAIR PROCESS SCIENCE & TECHNOLOGY CENTER

Workshop Objectives

- Outline critical needs for research in traditional process technologies.
- Outline manpower needs for addressing process technology development.
- Inform academic community and funding organizations of needs.
- Propose a path forward for addressing needs including research funding mechanisms.

Technology Areas

General

Process Control

Separations Technology

Modeling / Simulation / Process Optimization

Reaction Engineering / Catalyst Development

Summary of Workshop Recommendations

"Opportunities to Support the Manufacturing Renaissance Created by New US Shale Gas Supplies"

Dr. Sharon Robinson

May 2013

State of the Industry

Global Renaissance – Challenges and Opportunities

Russell Heinen, Senior Director
Technology and Analytics
April 16, 2013
PSTC Process Workshop
Austin, Texas

Workforce Demographics Challenge

- **Workforce demographic changes are a key concern in the industry now**
  - **Retirements are resulting in significant knowledge loss**
  - **Lack of middle career engineers mean there are limited replacement options**
  - **Knowledge management is becoming a critical issue**

Process Development Issues

- Process developments are being impacted by the globalization
  - China - in coal based technology
  - Brazil – ethanol based chemicals and biomass utilization
- Developments in other scientific areas provide opportunities
  - Nanotech – catalyst, new materials
  - Biotech – alternate feedstocks, harnessing biomechanics
  - Modeling/Computer technology
  - Others
- Relative feedstock costs also impact R&D focus due to shifts in process economics

Areas for Future Research

- **Better molecular level understanding of processes**
  - **Improves process optimization and process control**
- **Biocatalyst technology, as a part of a broader "chemical biotechnology," is increasingly important as a tool for chemical synthesis.**

ICCA/IEA Top Catalyst/process Development Needs

- Feedstock Production Efficiencies – Direct methane conversion to ethylene and methanol
- Alternative Fuels - GTL process improvements and small scale plant developments provide opportunities to monetize flared natural gas
- Biomass Feedstock - saccharification of lignocellulose for fermentation, depolymerization of lignin to aromatics
- Alternative hydrogen production – Optimization of electrolysis process and development of low-cost catalytic electrode materials

ExxonMobil
Research and Engineering

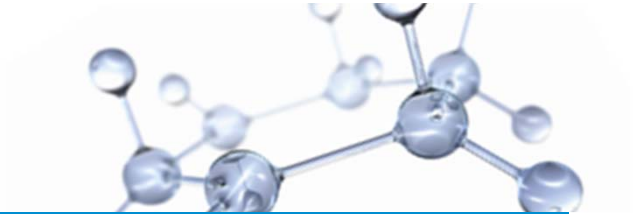
Challenges in the Refining Sector – the Decade Ahead

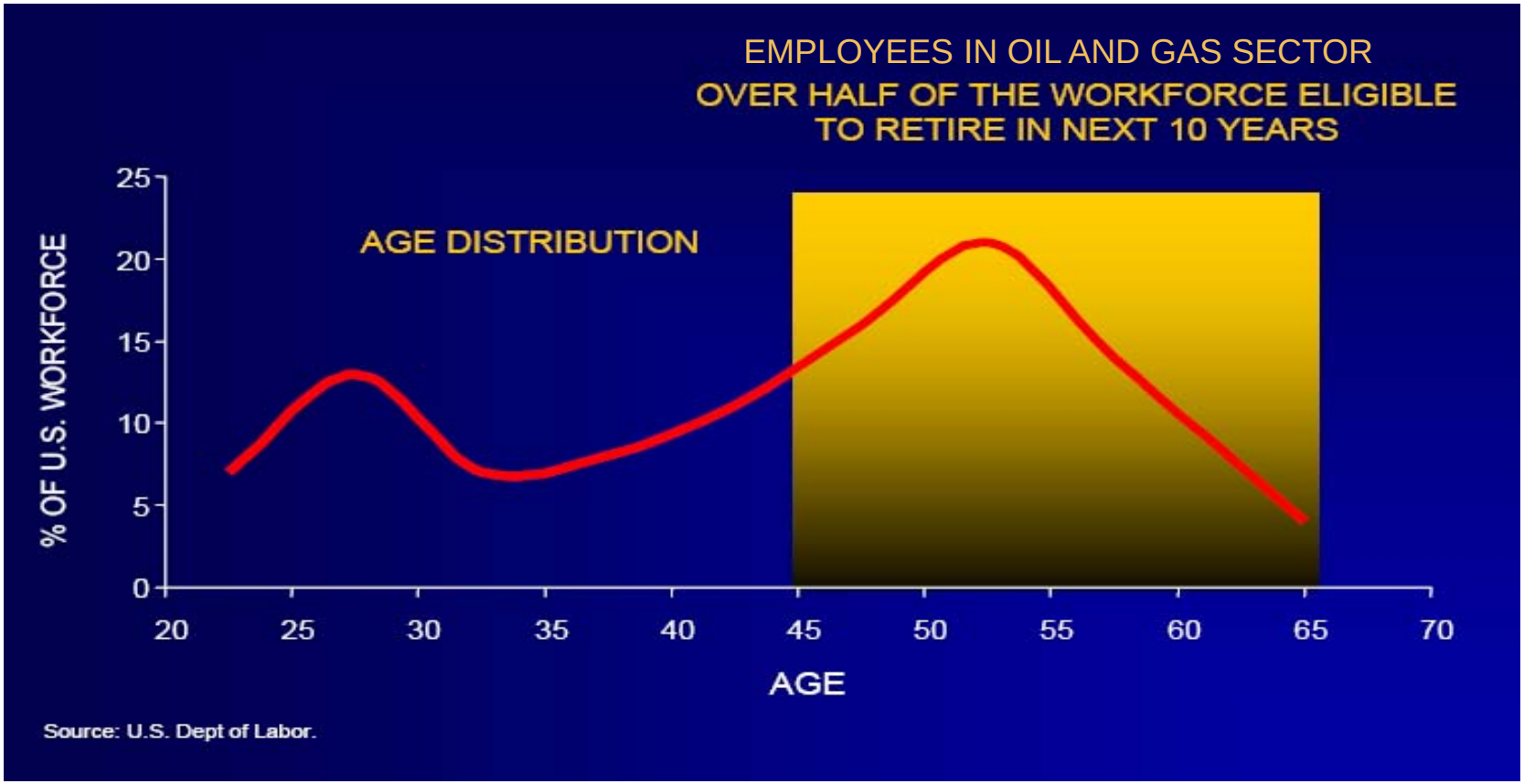
2013 Process Science and Technology Center Symposium

Thomas F. Degnan, Jr.
ExxonMobil Research and Engineering Company
Tuesday, April 16th
Austin, TX

This presentation includes forward-looking statements. Actual future conditions (including economic conditions, energy demand, and energy supply) could differ materially due to changes in technology, the development of new supply sources, political events, demographic changes, and other factors discussed herein (and in Item 1 of ExxonMobil's latest report on Form 10-K). This material is not to be reproduced without the permission of Exxon Mobil Corporation.

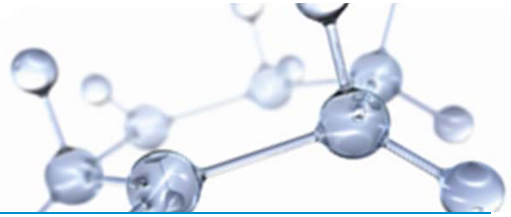
Demographics Remain Challenging





ExxonMobil Research and Engineering

National Research Council Report – April 2013



EMERGING WORKFORCE TRENDS IN THE U.S. ENERGY AND MINING INDUSTRIES: A CALL TO ACTION

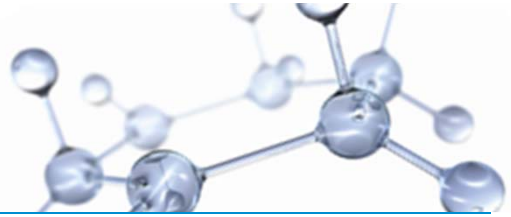
PREPUBLICATION

Committee on Emerging Workforce Trends in the U.S. Energy and Mining Industries
Committee on Earth Resources
Board on Earth Sciences and Resources
Division on Earth and Life Studies
in Collaboration with
Board on Higher Education and Workforce
Policy and Global Affairs Division

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu

Conclusions



- The Refining Sector will continue to provide many important challenges where chemical engineering skills are critical.
- The major Sector drivers are:
  - Changing feedstock composition
  - Evolving product shifts
  - Improved energy efficiency
  - Tighter emissions standards
- There is concern that we not be able to adequately resource the talent and expertise required to meet these challenges

Process Technology Challenges

Alan Nelson, Research Director

John G. Pendergast, Separations Fellow

The Dow Chemical Company

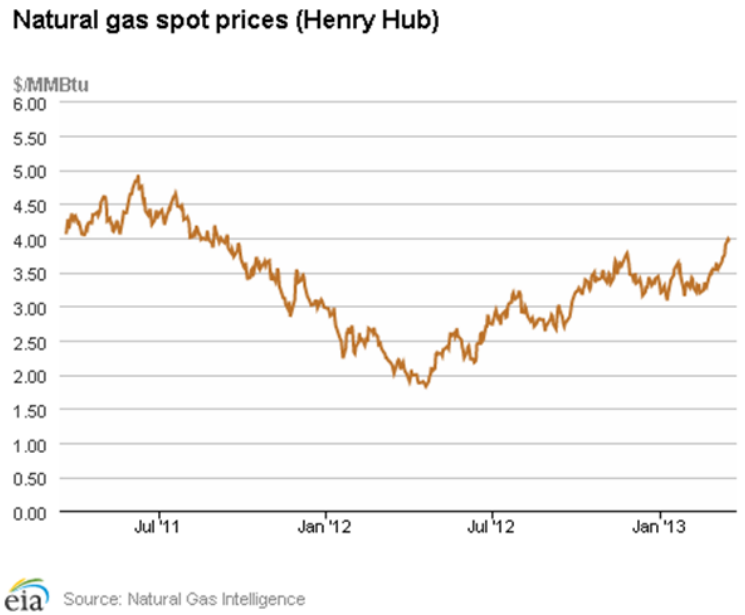
April 2013

Key Skills and Elements of Success

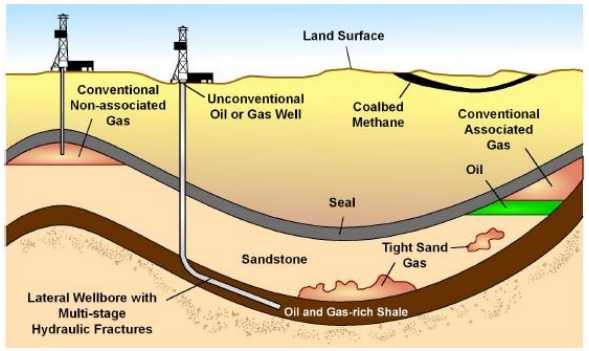
- **Fundamentals!**
  - Thermodynamics
    - » Chemical Engineering Thermodynamics
    - » Mechanical Engineering Thermodynamics++
  - Kinetics
  - Fluid Mechanics
  - Mass Transfer
    - » Vapor Liquid Equilibrium
  - Chemistry
    - » Basic principles
    - » Basic Engineering Economics
- **Critical Thinking**
- **Articulation of ideas**
  - Verbal and written
- **Continuous Learning**
  - What is important to <u>your area</u>

Summarizing our Opportunities

- Shale gas renaissance has opened a window of opportunity for U.S. Chemical Manufacturing
  - Lower energy costs
  - Ethane and propane feedstock
    - » New facilities announced by Dow and others
    - » Ethylene, Propylene-on-Purpose, Methanol …
- How do we take advantage?
  - Limitations on capital, manpower
    - » New facilities
    - » How do we upgrade existing facilities
    - » Develop new technology



1) Hydraulic Fracturing Technology



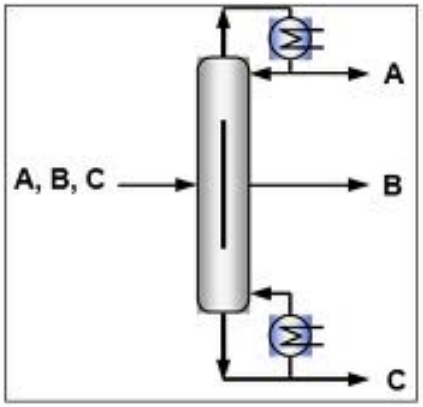
Fracking Fluids

- Optimization/minimization of usage
- Alternative fluids – gas/liquid
- Study the impact of each chemical on environment
- High-pressure mass transfer fundamentals

Treatment and Recovery

- Separations (oil/water, gas components)
- Wastewater treatment – molecular separations
- Reusability

2) Complex Column Arrangements



Divided Wall Columns
- Process control
- Reliable design

Pilot plant operations → database
Detailed design procedures
Dynamic simulations
Metric for when divided wall columns provide benefits over traditional sequences (including lab-scale investigation)
Modeling

Column internals
- Packings/trays
- Distributors
  - Wall treatments
  - Mobilization/modularity/energy & infrastructure challenges

3) Plant Energy Efficiency

Improved Distillation Column Efficiency
Heat integration within/between columns
Low-level heat recovery
Higher efficiency internals
Distillation column pre-flooding condition detection by using data analytics
Energy reduction & waste heat utilization
Evaluation of current state of the art / determination of opportunity areas
Aim for innovative / unconventional solutions
Conceptual design of plants and modular units, process intensification
Algorithms for stochastic optimization / design under uncertainty
Start-up aided by control system / optimization during start-up

4) Natural Gas to Products

Direct Methane to Products without Need for Syngas Production
- Olefins
- Catalysis

Conversion of Natural Gas to Higher Value Products
- Olefins, LNG, petrochemical feedstocks, refinery feedstocks, Benzene/Xylene/Toluene
- Power – steam, electricity

Stranded Natural Gas Monetization

5) Carbon Dioxide

Carbon Collection/ Capture/ Transportation Technology
Secondary environmental impact of amine scrubbing
CO_2 Sequestration / Utilization
Conversion methods
    Biological (algae), chemical, solar
Direct Usage
    Solvents
    Hydraulic fracturing
Impacts of Impurities/Contaminants
    Membrane-based separations
CO_2 Removal from Natural Gas