Workshop Agenda

SCHEDULE:

9:00 am  Introduction – Joseph Cavarretta, Executive Director, American Academy of Environmental Engineers
9:15 am  General Introduction to Shale O&G Development and Environmental Challenges – C. Hunter Nolen, Pres., Industrial Service Group, CDM Smith
9:45 am  Well Completion and Hydraulic Fracturing Methodology Explained – Kevin Rice, Baker Hughes Corporation
10:15 am BREAK
10:30 am Protection of Groundwater During Natural Gas Development – David Yoxtheimer, P.G., Penn State Marcellus Center for Outreach and Research
12:00 pm LUNCH
1:00 pm  An Operator’s Perspective on Successful Development of Appalachian Shale O&G – Andrew Place, EQT Corporation
1:45 pm  Industry Participation in EPA’s Hydraulic Fracturing Study – Chris Hill, Chesapeake Energy Corporation
2:30 pm BREAK
2:45 pm  Natural Gas Development in the Delaware River Basin – Carol Collier, Executive Director, Delaware River Basin Commission
3:30 pm  Natural Gas Development and the NYC Water Supply – Kathryn Garcia, Chief Operating Officer, NYC Environmental Protection
4:00 pm  Water Treatment Technologies and Key Considerations in Shale O&G Development – Bob Kimball, Technical Director Produced Water Treatment, CDM Smith
4:30 pm ADJOURN

BREAKEFAST SESSION: May 15th, 7:00-8:15 a.m. - Managing the Water Resource Impacts of Shale Gas – Tom Beauduy, Deputy Executive Directory and Council, Susquehanna River Basin Commission

MODERATORS:
– Joseph Cavarretta, CAE, Executive Director, American Academy of Environmental Engineers
– C. Hunter Nolen, P.E., BCEE, President, Industrial Services Group, CDM Smith
Presentation Outline

1) Summary of Shale Resource
2) Economic / Geopolitical Implications
3) Environmental Concerns
4) Water Management / Treatment
5) Energy Choices
World Energy Consumption

World Energy Consumption, 1990-2035 (quadrillion Btu)  

World Energy Consumption by Fuel, 1990-2035 (quadrillion Btu)

Net Imports and Domestic Petroleum as Shares of U.S. Demand, 2010

U.S. Petroleum 51%

Net Imports 49%

Source: U.S. Energy Information Administration, Monthly Energy Review, Table 3.3a (April 2011), preliminary data.
It’s Not Going To Get Any Easier
(e.g., *Chinese Oil Production and Consumption*)

Source: EIA and BP Statistical Review
Oil Migration & Entrapment, Conventional Model

Oil is trapped where reservoir rocks occur in trapping configuration.

Oil migrates upward.

About 1.5 to 3 miles down...

Source rocks generate oil.

Reservoir rock

Seal

Earth’s surface

Source: University of Texas at Austin, Bureau of Economic Geology, Annual Report, 2011
Horizontal Drilling and Hydraulic Fracturing

Release of Natural Gas from Shale Rock

Marcellus Shale Outcrop
History of Fracturing

**Late 1800’s** Explosive fracturing

**1940’s** First hydraulic fractures

**1988** Common practice
(1 million performed to date)

**2006** Advent of multistage fracturing of horizontal well

**2011** 60% - 80% of all O&G wells are hydraulically fractured
(35,000 per year and 2.5 million to date)

*Source: Baker Hughes*
Shale gas has grown to over 15% of U.S. gas production and is expected to grow to 45% by 2035.
U.S. Shale and Tight Gas Basins

Source: EIA based on data from various published studies.
Natural Gas U.S. Reserves Estimates

Source: Power Magazine 2011
Currently Known Global Shale Resources

Legend:
- Red: Assessed basins with resource estimate
- Yellow: Assessed basins without resource estimate
- Countries within scope of report
- Gray: Countries outside scope of report

[Map showing global shale resources with countries and regions highlighted in red and yellow]
Marcellus Shale and Other Appalachian Formations

500 – 1,500 trillion cubic feet (tcf) in place (50 - 500 tcf recoverable) in the Marcellus.

First gas well in U.S. – 1821, Devonian Shale, Fredonia, NY.
Magnitude of Supply

• A trillion cubic feet is enough gas to:
  – Heat 15 million homes for 1 year
  – Generate 100 billion kilowatt-hours of electricity
  – Fuel 12 million natural gas vehicles for one year
  – Marcellus alone ≈ 50 – 500 tcf

• 120 year supply in U.S.

• Lots of oil too (Utica, Eagle Ford, Bakken, etc.)

Source: EIA
ECONOMIC / GEOPOLITICAL IMPLICATIONS
Libya’s Civil War
A GRAVE SCANDAL AT ARLINGTON

ENVIRONMENT SPECIAL

THIS ROCK
COULD
POWER
THE
WORLD

WHY SHALE CAN SOLVE
THE ENERGY CRISIS

BY BRYAN WALSH

Source: Time Magazine Science,
“Could Shale Gas Power the World”, Bryan Walsh
Natural Gas Characteristics

- We have **lots of it**.
- **Cleanest combustion fuel available** (half the CO$_2$ of coal). But fugitive loss of CH$_4$ is 25xCO$_2$ potency for GHG.
- “**Bridge**” fuel for transition to renewables, and “**leveling**” fuel for wind and solar.
- **Extensive transmission / distribution network** already in place.
- Underutilized gas power generation capacity can achieve **20 percent CO$_2$ emissions reduction** rapidly.
- Current **supply far exceeds demand**.
Blueprint for a Secure Energy Future

White House, March 30, 2011

- Three-point plan
  - Develop and secure America’s energy supplies
  - Energy reduction
  - Innovate clean energy

“Natural gas and oil from shale formations...will play a critical role in domestic energy production in the coming decades.”
Supply > Demand so Natural Gas is Affordable

- 1 barrel of oil = $97.23 (May 10, 2012)
- 1 MMBtu of gas = $2.56 (May 10, 2012)
- 1 barrel of oil equivalent (BOE) = 5.8 MMBTU
- Price of 1 BOE of natural gas = $14.85
Sources and Use of Primary Energy in the U.S. with Natural Gas Highlighted (quadrillion Btu), 2009

- **Petroleum**: 35.3 quadrillion Btu, 72% of supply, 94% of transportation, 3% of demand
- **Natural Gas**: 23.4 quadrillion Btu, 32% of supply, 40% of industrial, 18% of demand
- **Coal**: 19.7 quadrillion Btu, 93% of supply, 7% of residential & commercial, 1% of demand
- **Renewables**: 7.7 quadrillion Btu, 53% of supply, 9% of electric power, 1% of demand
- **Nuclear**: 8.3 quadrillion Btu, 100% of supply, 22% of electric power, 1% of demand

**Total Supply**: 94.6 quadrillion Btu

**Total Demand**
- **Transportation**: 27.0 quadrillion Btu
- **Industrial**: 18.8 quadrillion Btu
- **Residential & Commercial**: 10.6 quadrillion Btu
- **Electric Power**: 38.6 quadrillion Btu

Source: EIA, Annual Energy Outlook, 2009
Central Area Transit Authority, State College, PA
Natural Gas Transit Facility

Many similar current and future projects in U.S. and abroad
Recent History Natural Gas In U.S. Power Generation

- **1970**: Oil crisis created natural gas demand spike.
- **1980**: Primarily coal and nuclear plants constructed.
- **1990**: Deregulation and offshore gas development drove combined cycle gas turbine construction.
- **2000**: Fear of shortages and prior instability created liquefied natural gas (LNG) demand and nuclear renewal.
- **2010**: Tremendous opportunity and motivation for use of underutilized gas-fired capacity (20% CO₂ reduction) and construction of new gas plants.
Looking for Some Cheap Windmills?

T. Boone Pickens is Selling...

“You can’t do wind because natural gas is too cheap.”

T. Boone Pickens, May 2011

$2B, 667 windmill property in Texas panhandle

“The need to spend enormous sums to build new long-distance transmission lines to move power from generating sites favorable for wind and sun to local centers may diminish with readily available low-cost gas

Maize et al, Power Magazine, Sept 2011
Exxon Declares Gas King
Abundant Fuel Expected to Dethrone Coal as Top U.S. Power Generator by 2025

By TOM FOWLER

Natural gas will replace coal as the leading fuel for generating electricity in the U.S. by 2025, when it will also become the world's No. 2 overall fuel source thanks to its abundance and a drive for cleaner-burning energy, according to the latest long-term outlook from Exxon Mobil Corp.
• U.S. Reliance on Foreign O&G Equates to $500 Billion in Wealth Transfer Annually
• Barnett Shale Economic Impact Report estimated $11 billion and 111,000 jobs annually contributed to DFW area, plus $275 million annually in state severance taxes

• Marcellus peak drilling rate estimated at 3,000 wells annually for decades. The Manhattan Institute estimates a typical Marcellus well generates:
  – $5.5 million in purchases by company, supplier, worker, and landowner
  – $2 million in tax revenues
  – 62 jobs
Jobs / Taxes (continued)

“The end to the moratorium on fracturing in New York could spur over $11.4B in economic output and create 15,000-18,000 jobs in the state’s southern tier and western New York alone”

*Manhattan Institute, 2011*

Over 600,000 jobs created to date from the shale gas development industry

*Wall Street Journal, 2011*
Projections for Chemical Industry Economic Boost from Shale Gas (Natural Gas and Ethane)

- **17,000** new knowledge-intensive jobs
- **395,000** additional jobs – suppliers and construction
- **$4.4B** more in federal, state, and local tax revenue annually (**$43.9 billion** over 10 years)
- **$16.2B** in capital investment for new capacity
- **$132B** in U.S. economic output (production, suppliers, and capital)

*Source: American Chemical Council, March 2011*
Big Oil Heads Back Home

Energy companies are shifting their focus away from the Middle East and toward the West—with profound implications for the companies, global politics and consumers

By GUY CHAZAN

Big Oil is redrawing the energy map.

For decades, its main stomping grounds were in the developing world—exotic locales like the Persian Gulf and the desert sands of North Africa, the Niger Delta and the Caspian Sea. But in recent years, that geographical focus has undergone a radical shift that could have profound implications for the companies, global politics and consumers.

A Shift in the Energy Landscape

The Middle East still has most of the leaders in proven oil reserves (2010, in billions of barrels)

- Saudi Arabia: 262.4
- Canada: 179.2
- Iran: 137.6
- Iraq: 113.0
- Kuwait: 104.0
- Venezuela: 99.4
- United Arab Emirates: 97.6
- Russia: 60.0
- Libya: 44.3
- Nigeria: 17.2

But many of the biggest increases in oil and natural-gas reserves over the past decade have come outside the Middle East as unconventional technologies make more deposits accessible. Percentage changes for selected countries, 2000 to 2010 (except as noted):

- Australia: +15%
- Brazil: +74%
- Canada: +62%
- Kuwait: +8%
- U.S.: +2%
- Iran: +53%
- Iraq: +29%
- Saudi Arabia: +29%
- U.A.E.: +1%

*1999-2009 data, the latest available  Source: Energy Information Administration, Department of Energy
Shale Gas and U.S. National Security
Baker Institute Policy Report, October 2011

**ALTERNATIVE 1**
Extensive U.S. Development
- U.S. energy security
- Improved CO₂ footprint (power and transportation conversion)
- Seriously diminished Russian, Venezuelan, and Iranian geopolitical power
- U.S. economic enhancement
  - Employment
  - Currency stability (Less wealth transfer)
  - Lower energy cost

**ALTERNATIVE 2**
No Further Development
- Opposite of Alternative 1

**ALTERNATIVE 3**
No Northeast U.S. Development
- Generally diminishes Alternative 1
- Higher energy cost in northeast U.S.
- Lesser and shorter diminishment of Russian, Venezuelan, and Iranian geopolitical power
ENVIRONMENTAL CONCERNS
# Environmental Concerns

## SURFACE
- Air Emissions
- Water Resources / Quality
- Land Impacts
  - Drilling Locations
    - Pit Construction; Chemical Storage; Erosion Control
  - Infrastructure
    - Roads; Compressors; Pipelines; Water Treatment Facilities
  - Truck Traffic and Road Damage

## SUBSURFACE
- Protecting Underground Water Resources
- Seismic Events

Source: Southwestern Energy
Onshore Exploration and Production Regulatory Framework

FEDERAL
- U.S. EPA – CWA, SDWA, CAA, NEPA, and OPA
- 2011 U.S. EPA National Enforcement Initiative (NEI) for energy extraction activities
- Bureau of Land Mgmt. (BLM) – BLM lands
- U.S. Forest Service (USFS) – USFS lands
- Hydraulic fracturing not regulated at federal level “regulated at state and local level”

STATE
- Permitting agencies
- Environmental regulatory agencies
- Many have “primacy” for federal regulations
- Much variation between states

LOCAL / REGIONAL
- Cities, counties, tribes, and regional water authorities

INDEPENDENTS
- Ground Water Protection Council (VIC implementation review)
- Interstate Oil and Gas Compact Commission (IOGCC)
- State Review of Oil and Natural Gas Environmental Regulations (STRONGER)

REGULATIONS IN FLUX
WATER MANAGEMENT / TREATMENT
Hydraulic Fracturing
The Shale Development Solution and Environmental Controversy

- Frac Water Volume: 2 to 6 million gallons per well
- Additional components include biocides, corrosion inhibitors, O₂ scavengers, proppant, etc.
- 20-40% frac “flow back” water recovery requires collection, handling, and disposal / treatment / reuse

Shale Development and Water

- Source it
- Transport it
- Store it
- Treat it
- Re-use it
- Dispose of it
- Protect it (quality and quantity)
  - Surface water
  - Ground water

**PLAN IT**
Shale Gas Water Use Requirements

Estimated Marcellus water use at expected peak drilling rate (3,000 wells per year)

Source: USGS Pennsylvania Water Consumption
Shale Gas:
Water Use Efficiency vs. Other Energy Sources

Source: GSI Environmental, Houston, Texas, 2010
Groundwater and Surface Water Concerns

Surface Activities

Well Completion

Fracturing?
Shale O&G Water Treatment

- Treatment for Deep Well Injection
- Treatment for Reuse in Fracturing
- Treatment for Surface Discharge
As frac water spends an increasing amount of time in the ground it transitions from fresh water to salty brine, dissolving salt compounds in the earth. Over time, volume decreases and TDS increases.

Source: Siemens AG 2009
Other Major Treatment Challenges

- Water balance changes over life of a field
- Water quality variations
  - Geography
  - Temporally
- Mobile vs. centralized treatment planning / decision
## Treatment Technologies – Treatment Options

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Notes: X indicates the technology is effective for the respective parameter.
O&G / Water Knowledge Convergence

**Community**
- Jobs
- Energy Needs
- Environmental Concerns
- Limited Technical Expertise

**Oil & Gas Companies**
- Exploration and Production Expertise
- Limited Water Expertise

**Environmentally Sound Energy Development**

**Regulators**
- Environmental Management Responsibility
- New Challenges
- Stretched Resources

**Engineering and Science Community**
- Water / Environmental Expertise
- Limited Oil & Gas Exploration & Production Expertise
- Infrastructure Design-Build Resources
Energy by Source

- Oil: 33.5%
- Coal: 26.8%
- Gas: 20.9%
- Nuclear: 5.8%
- Others: 0.2%
- Renewables: 10.6%
- Hydro: 2.2%
“There are very few energy resources large enough to cope with modern global energy demand. Any technologies able to satisfy these demands will unavoidably interfere with natural dynamic systems. A scenario in which available energy resources fail to provide a basis for the energy infrastructure will be a scenario with drastic reductions in economic output and one in which living standards will fall back to much lower levels.”

Klaus Lackner, Issues in Environmental Science and Technology, Royal Society of Chemistry 2010
## Tone of Shale Gas Media Coverage

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<td>7%</td>
</tr>
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“The great enemy of the truth is very often not a lie – deliberate, contrived, and dishonest – but the myth – persistent, persuasive, and unrealistic.”

*John F. Kennedy*
No-Development Case – France 
*(Ban on Hydraulic Fracturing)*

France wants gas, they just want it to come from somebody else’s backyard.

**IS THIS WHAT WE WANT TOO?**

*Source: U.S. EIA (market) and Oil & Gas Journal, Dec. 6, 2010*
“The road to the future is paved in the middle. Too far to the left or too far to the right is in the gutter.”

Dwight D. Eisenhower
Questions and Answers

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