Shale Gas: Where, Why and How?

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ConocoPhillips
Program Co-Chair

JOURNEY INTO UNCHARTED TERRITORIES
PLENARY SESSION 3

REPOSITIONING THE PROJECTS BUSINESS IN A WORLD WITH CHANGING BOUNDARIES
Shale Gas is a game changer for the capital projects business.

1. Agree 59%
2. Neutral 22%
3. Disagree 6%
4. I don’t know 13%
Shale Gas: Where, Why and How?

LAURA ATKINS
Director of Petroleum Research, Hart Energy

JOURNEY INTO UNCHARTED TERRITORIES
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Shale Gas: Unfamiliar to Unknown Territory

• Shale Gas Production is a Recent Phenomenon in North America –
  - Barnett Shale reached 1 bcf/d in 2005, 5 bcf/d in 2010
  - Learning curve is steep
  - Intensive capital$ and manpower

• Outside of North America we are heading into uncharted territory
Gas has been produced from shales for a long time (but quantities were small until recently)

<table>
<thead>
<tr>
<th>Fractured Dunkirk Shale</th>
<th>Shale gas wells drilled</th>
<th>Antrim Shale</th>
<th>Speckled Shale</th>
<th>US Gov initiates shale gas research</th>
<th>9000 Wells in the Antrim</th>
</tr>
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<tbody>
<tr>
<td>NY gas production</td>
<td>Appalachia</td>
<td>Michigan</td>
<td>Alberta</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1850</td>
<td>1920</td>
<td>1948</td>
<td>1950</td>
<td>1960</td>
<td>1980</td>
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<thead>
<tr>
<th>George Mitchell</th>
<th>1st Barnett hydraulic frac</th>
<th>Barnett massive fracs in vertical wells</th>
<th>Multistage Fracs in Horizontal wells</th>
<th>Haynesville /other shale gas plays begin</th>
<th>Barnett Shale production 5 BCF/D</th>
</tr>
</thead>
</table>

**Shale Gas Production Begins to Take Off**
North American Shale Plays

Source: Hart Energy Data and Mapping Service
Unconventional Gas vs. Conventional Gas

- Known
  - Conventional structural gas accumulation
  - Coal-bed gas
  - Conventional stratigraphic gas accumulation

- Unfamiliar to Unknown
  - Continuous-gas accumulation

- Known
  - Conventional structural oil accumulation

EXPLANATION
- Red: Gas
- Green: Oil
- Blue: Water

Tens of miles (kilometers)

Source: USGS
What is Shale?

**Marcellus Shale Outcrop**

Source: Geoexpro.com

**Shale under an Electron Microscope**

Source: Bureau of Economic Geology

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**Diagram of Shale Composition**

- Shale Matrix
- Non-clay Minerals
- Organic Matter
- Clay Minerals
- Clay Bound Water
- Mobile & Capillary Bound Water
- Hydrocarbons

Effective Pore Space

Total Pore Space
Evaluating & Developing a Shale Gas Play

1 Meter = 1 Million Yrs.

Data

Lateral Variations

Rocks!

Drilling and Fracturing

Continuous Learning

High Rate Low Cost Wells

43rd ANNUAL EOG CONVENTION
A Horizontal Well

Typical Hydraulic Fracture:

• 4 - 11 million gallons water
• 100 to 5,500 tons sand
• ~2% chemical additives
• 10 to 30 stages

Hydraulic Fracturing - Shale Natural Gas Extraction

Shale Video YouTube Link

http://www.youtube.com/watch?v=IB3FOJjpy7s
The Logistics Are Complex and the Scale Enormous

Frac trucks laden with compressors, water lines, and other equipment are essential for completing a well in the Barnett (photo from Devon Energy, source: OGJ)

Halliburton assembled 34 pump trucks for the Barnett shale frac job in 2004 (Source: Halliburton)

Eagle Ford Rig Count

Source: Hart Energy/Rystad Energy
North American Shale Quarterly

Frac trucks laden with compressors, water lines, and other equipment are essential for completing a well in the Barnett (photo from Devon Energy, source: OGJ)
The Barnett Shale has over 14,000 Wells

Source: Texas Railroad Commission
Why So Many Wells are Necessary

Source: Hart Energy
Shale Gas Wells Can Produce for a Long Time

- Power Law Decline
- Barnett Horizontal Well

21 years
29,000 ft³/day

Source: Hart Energy
North American Shale Gas 35 BCF/D by 2020

28.5 BCF/D ➔ 40% of US supply in 2020

Source: Hart Energy/Rystad North American Shale Quarterly
North American Gas Infrastructure is Extensive
(But More is Required)
Eagle Ford Shale Infrastructure

Source: Hart Energy Data and Mapping Service
Southern Union To Build Processing Plant For Avalon, Bone Spring Plays - Aug. 23 2011
DCP Midstream To Build Eagle Ford, Permian Pipeline - Aug. 19 2011
Key Energy Services Finalizes Acquisition Of Midstream Cos. - Aug. 8 2011
NuStar, EOG Team Up For Shale-Focused Terminal Project - Aug. 5 2011
Dominion Details Major Marcellus/Utica Midstream Project - Aug. 4 2011
Peregrine Given Green-Light For Uinta Storage Facility - Aug. 3 2011
Pembina To Expand Cutbank Processing Complex - Aug. 3 2011
Monroe Gas Initiates Open Season For Storage Facility- Aug. 1 2011
El Paso Places Rockies-Focused Ruby Pipeline In Service- Jul. 28 2011
Crosstex To Grow Texas, Louisiana Midstream Infrastructure- Jul. 26 2011
Enterprise To Build Sixth Mont Belvieu NGL Fractionator - Jun. 27 2011
El Paso, Spectra Hold Open Season For Marcellus Ethane Pipeline - Jun. 27 2011
Shale Gas is a Game Changer in the US Power Sector

EIA 2006 Outlook for New Power Generation

EIA 2011 Outlook for New Power Generation
Price Disparity between Oil and Natural Gas Continues

Source: EIA AEO 2011 Reference Case

US$ per mmBtu ($2009)

- Light Crude Cushing OK
- Natural Gas Henry Hub Price

Source: EIA AEO 2011 Reference Case
Levelized Costs for Power Generation in 2020

- Natural gas combined cycle
- Nuclear
- Coal

2009 Cents per Kilowatt-Hour

Source: EAI AEO 2011
Long Term Low Cost Gas Supply: Opportunities in Petrochemicals

- Ethane production up by 25%
- Ethane cost lower
- Margins stronger for ethylene and derivatives
- Incremental near-term capacity growth
  - Debottlenecking of existing light-feed capacity
  - Conversion of heavy-feed crackers
- Examples
  - Dow Chemical re-starting ethane cracker in Louisiana and adding ethane feedstock flexibility in Louisiana and Texas
  - Westlake Chemical expanding ethane cracking capacity in Louisiana
Shell new ethane cracker for Marcellus Shale
- 60,000 to 80,000 barrels per day capacity
- Cost ~ US$ 1 billion

Dow Chemical new ethylene plant US Gulf Coast by 2017
Dow Chemical new propylene production facility, Texas, 2015

Other Opportunities

**LNG Exports**

- Kitimat, BC
  - 700 mmcf/d 5 million tons/year
  - Construction start 2010
- Sabine Pass Liquefaction LLC
  - Up to 2.2 bcf/d
  - Approval received from DOE

**Natural Gas vehicles**

- Fueling infrastructure would have to be built
- May be more appropriate for fleets
Will Shale Gas be Developed Outside N. America?

• Huge potential in high quality formations
• Compelling reasons to increase domestic supplies
  - Growing gas demand
  - Imports from high cost and/or unstable countries
  - Conventional gas declining or inaccessible
• Huge Challenges
  - Land access
  - Required scale of operations unavailable
  - Lack of infrastructure
  - Unfavorable fiscal terms
  - Public opposition
Shale Gas is Evenly Distributed Compared to Conventional Gas

Sources: EIA, IEA, OPEC
Poland

- Highly dependent on Russian gas
- Huge shale gas resource – 700 TFC
- Most Activity in Europe today
- Most of the acreage has been leased but farm ins are being done
- Challenges
  - Control over drilling rigs by NOC
  - Land Use and Environmental Concerns

Source of Data: http://maps.nationmaster.com/country/pl/1
Vibrator trucks (for seismic) owned by Geofizyka Krakow in a farmer’s field west of Gdansk

Source: Hart Oil and Gas Investor
Argentina

- Great rocks - Early exploration results are encouraging
- Gas infrastructure in place
- Major challenges with political and economic instability, uncertain fiscal terms, high inflation and powerful labor unions
- But, they really need the gas:

<table>
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<th>Year</th>
<th>Imports</th>
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<tr>
<td>2010</td>
<td>300 mmcf/d</td>
</tr>
<tr>
<td>2011</td>
<td>780 mmcf/d</td>
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**Gas Prices**

Source: Ruben Etchevery presentation to Congreso de Producción del Bicentenario 21 Mayo 2010
Australia

- Large conventional gas reserves, but most are offshore Northwest Shelf
- No infrastructure to serve internal markets
- Three separate markets favor shale gas and coal bed methane
Uncharted - India

- LNG imports increasing every year
- Government wants to reduce coal usage
- Schlumberger hired for feasibility study
- Challenges:
  - Little gas infrastructure
  - Poor fiscal terms for IOCs
  - Low gas price except for LNG
Coming Attractions

• China
  – Shale gas blocks were awarded to Chinese companies
  – IOCs can come in later under a PSA but economics of shale gas are difficult with this fiscal structure

• Saudi Arabia
  – Huge conventional gas reserves but it is associated gas and not available

• Turkey
  – Most energy is imported
  – Potential 15 TCF but mostly untested
Western Europe - Public Resistance to Shale Gas

- **UK:** 1 Well Drilled Despite Protests
- **Sweden:** Acreage Leased but no Activity
- **France:** Law Banning Hydraulic Fracking
- **Ukraine:** New Contracts
- **Bulgaria:** New Contract
- **Germany:** Acreage Leased - no Drilling Yet
Will it be This?

Or This?

GO FRACK YOURSELF!!
What the Public Thinks

Groundwater

Source: Robert Wagner campaign for Vermont Senator 2012
The Reality of Shale Fracturing

Source: Chesapeake Energy
Environmental Impacts Related to Hydraulic Fracturing

• Water requirements – 4 to 11 million gallons required per frac job!
  - 500 or more wells drilled in each play every year
  - 3.5 billion gallons per year or average 9.5 million gallons per day
  - Withdrawals from surface waters in New York State are 9 to 10 billion gallons per day for all uses.
  - Within the Delaware River Basin, 150 million gallons/day for power generation

• Produced water
  - Disposal or reuse

• Traffic and Noise

Photo by Laura Atkins
Not All Environmental Impacts are Caused by Fracturing

• Surface water contamination
  - Poor handling of produced water, i.e. dumping it into a river
  - Storing produced water in an open pit

• Ground water contamination
  - Could result from poor cement job around surface casing (not unique to shale gas wells)
  - Leaking water storage pit
  - Methane in a coal seam or shallow organic-rich layer is most likely source of methane in well water

• Air pollution near shale gas sites
  - Vapor venting from storage tanks or pipelines
  - Volatile compounds evaporating from produced water storage pits

• Greenhouse gas emissions
  - Methane leaking from pipelines and surface facilities
The road to shale is paved with good intentions!

- Environmental issues are not going away
- Industry PR efforts are met with skepticism – viewed as more “Big Oil” propaganda
- Is confrontation the only way to deal with the issues?
  - Environmental concerns are legitimate
  - Properly designed regulations level the playing field
- Some Encouraging Signs
  - State of Texas new law requiring fracture fluid disclosure is supported by industry
  - Range Resources sampling water wells in vicinity of Marcellus Shale drilling location
  - US DOE Shale Gas Subcommittee Report
    - Industry and policy experts appointed to the committee
    - American Natural Gas Association tentatively endorsed it
Shale Gas Subcommittee Recommendations

**Government**
- Establish ground water database
- Improve communications between State & Federal Agencies
- Undertake basic research

**Industry**
- Develop best practices, help code them as regulations
- Measure and reduce air emissions
- Treat and/or reuse produced water
- Disclose fracture fluid composition

**Benefits**
- For the industry, better efficiency
- For regulators, sharing data will help craft sound policies
- For the public, higher level of confidence with regulatory oversight
The Journey Can Succeed!

• Shale gas is indeed a game changer in North America
  - Production will continue to grow
  - Opportunities for companies involved in all aspects of shale gas – upstream, midstream and downstream

• Other countries will benefit from North American shale gas experience
  - Potential is huge
  - Challenges can be overcome
  - Opportunities are great for first movers and those with a longer term view

• Environmental issues must be addressed
  - Public concerns are legitimate
  - Industry should develop best practices and cooperate with regulators
Have your views on Shale Gas developments on the capital project business changed?

1. Yes 52%
2. No 37%
3. Not at all 11%
JOURNEY INTO UNCHARTED TERRITORIES

How are owners, contractors and suppliers adapting to successfully execute projects and reposition their businesses in the ever evolving project environment?

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