Williston Basin Petroleum Conference
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The Role of Unconventionals in the Global Energy Future

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Global Population and Energy

Population (millions)

Quads

Population
Primary Energy (Q)

http://www.eia.gov/iea/wecbtu.html
OECD Energy Demand

Non-OECD Energy Demand

U. S. Energy Flows

(2008 Quads)

U. S. Energy Consumption

Petroleum/NGL Produced, 15
Petroleum/NGL Imported, 19
Natural Gas Produced, 24
Natural Gas Imported, 2
Coal, 22
Hydropower, 3
Nuclear (Uranium), 8
Biomass, 4
Other Renewables, 2
Other, 1

Source: EIA, 2012
Transportation

U. S. Energy Flows

Source: Lawrence Livermore National Laboratory and U.S. DOE based on Annual Energy Review, 2008 (EIA, 2009)
From National Academies Press, America’s Energy Future, 2009
BP Statistical Review of World Energy, CIA World Factbook, Census Bureaus, Marc Faber Limited, RJ Estimates
From Raymond James and Associates, Inc., August 2, 2010
Transportation Demand by Region

North America
- Marine
- Aviation
- Rail
- Heavy duty
- Light duty

Europe

Asia Pacific

Global Demand

US and China Vehicle Sales

U.S. Bureau of Transportation Statistics, RJ Estimates, China Association of Automobile Manufacturers
From Raymond James and Associates, Inc., August 2, 2010
Change in Oil Demand 2000-2010

Long-Term Oil Supply

Resources and Production

Source: IEA World Energy Outlook 2009
Long-Term Oil Supply

Resources and Production

Source: IEA World Energy Outlook 2009
Shale Oil

North Dakota
Bakken
Bakken

Source: BEXP Wells
Conventional Stratigraphy

Maverick Basin and San Marcos Arch  East Texas Basin

<table>
<thead>
<tr>
<th>Upper Cretaceous</th>
<th>Austin Chalk</th>
<th>Austin Group</th>
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<tbody>
<tr>
<td>Coniacian, Santonian, Campanian</td>
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<td>Turonian</td>
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<td>Cenomanian</td>
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<td>Buda Limestone</td>
<td>Eagle Ford Group</td>
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<td>Eagle Ford Shale</td>
<td>Pepper Shale</td>
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<td>Maness Shale</td>
<td>Woodbine Group</td>
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<td>Del Rio Shale</td>
<td>Buda Limestone</td>
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<td>Georgetown Ls.</td>
<td>Del Rio (Grayson) Sh.</td>
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Childs et al. (AAPG COSUNA Project, 1988)
Cretaceous Paleogeography

Levin, Earth Through Time, 7th Edition
Eagle Ford outcrop
Lozier Canyon
West of Langtry
Most wells are drilled in this lower zone
Outcrop areas

Eagle Ford gets deeper towards the coast

Eagle Ford Shale Play, Western Gulf Basin, South Texas

Eagle Ford Producing Wells (HPDI)
- OIL
- GAS

Eagle Ford Petroleum Windows (Petrohawk, EOG, DI)
- Oil
- Wet Gas/Condensate
- Dry Gas

Top Eagle Ford Subsea Depth Structure, Ft (Petrohawk)

Eagle Ford Shale Thickness, Ft (EOG)

Eagle Ford Shale-Austin Chalk Outcrops (TNRIS)
(NW limit of Eagle Ford-Austin Chalk presence)
Currently Drilling Wells
Eagle Ford

Baker Hughes Rig Count for October 14, 2011
Gates Ranch is our largest asset totaling roughly 26,500 net acres ...

Rosetta Resources Gates Ranch development, Webb County
40 wells drilled so far

Slide from Rosetta Resources, Oct 2011
Originally planned for 100 ac spacing
= 250 wells
Experiments now suggest closer spacing
May end up at 55 ac spacing, 340 wells
U.S. SHALE LIQUIDS PROJECTIONS

3.8 Mbpd growth potential by 2020

From Morse et al., 2012, Energy 2020: North America, the new Middle East?; Citi GPS: Global Perspectives & Solutions, figure 14, p. 17.
Fort McMurray

Alberta

Oil Sands

Oil Challenges

• Conventional Production Plateau
• Limited Geographic Control
• Environmental Impact
• CO$_2$ Emissions
• Perception, Policy, Pipelines…
U. S. Energy Flows

Source: Lawrence Livermore National Laboratory and U.S. DOE based on Annual Energy Review, 2008 (EIA, 2009)
From National Academies Press, America’s Energy Future, 2009
Power Generation by Fuel

Quadrillion BTUs

North America

Europe

Asia Pacific

Natural Gas Supply - Resources and Production

Source: IEA World Energy Outlook 2009
Conventional Natural Gas

Qatar
North Field
U.S. Natural Gas
Production and Reserves

After Steve Harvey, EIA
U.S. Natural Gas Production

Annual Natural Gas Production (Tcf)

- Onshore unconventional
- Alaska
- Offshore
- Onshore conventional

After Steve Harvey, EIA
U.S. Natural Gas Production

EXHIBIT 8: UNITED STATES UNCONVENTIONAL GAS OUTLOOK (BCF/DAY)

Source: Modified from American Clean Skies, Summer 2008
After Steve Harvey, EIA
Coalbed Methane Plays

Alaska: 57

Other Rockies: 30

Black: Resource values in TcF from EIA (2007), PGC 2002
Red: Production, TcF, from EIA 2007

Map: EIA, 2009
Tight Gas Plays

Resource, Mean undiscovered values in Tcf from USGS, 1995 and later

EIA, 2009
North American shale plays (as of May 2011)

Potential Global Shale Gas Basins

Source: IHS CERA

Source: U.S. Energy Information Administration based on data from various published studies. Canada and Mexico plays from ARI. Updated: May 9, 2011
U.S. Gas Shale Production

Unconventional Gas

Practical Challenges

- Determining whether low-quality reservoirs covering large areas are continuous and can be developed as resource plays
- Finding the production “sweet spots”
- Developing advanced technologies for hydraulic fracturing and other primary stimulation approaches
- Secondary and tertiary recovery strategies
- Realistic EUR and production forecasts
- Addressing adverse environmental effects required to produce low quality reserves – surface disturbance, compressor noise, water disposal, earthquakes, methane emissions, etc.
Ar-ion-beam milling produces a flat area with no artifacts related to differential hardness or plucking.

From Ruppel and Loucks, 2008

Image by Rob Reed
Ar-ion-beam milling produces a flat area with no artifacts related to differential hardness or plucking.

From Ruppel and Loucks, 2008

Image by Rob Reed
Sample Preparation

Polished thin section

Ar-ion milled stub

Image by Rob Reed

From Ruppel and Loucks, 2008
Barnett Shale

Nanopores in Organics

Orange dots are 20 nm in diameter

Human Hair

50 µm

T.P. Sims #2; 7625'

After Reed, BEG
Pore System in Barnett Shale

Pores found mostly in organic matter
Smaller pores

Require thermal maturation to form
Gas productive

From Ruppel and Loucks, 2008

Image by Rob Reed
Pore System in Eagle Ford Shale

- Associated with higher porosity and permeability
- Larger pores
- Oil and gas productive

From Ruppel and Loucks, 2008
Innovation driven by necessity

Barnett drilling location
University of Texas at Arlington
From XTO annual report
Step 3: Divide Reservoir Into Tiers

- 1 Section Grid Blocks
- 3300+ blocks with at least 1 well
- Many blocks have 20+ wells
- Identify best rock quality
- Sort into 10 tiers ~330 blocks/tier
- Resembles industry sweet spot maps
- White spaces are undrilled blocks
Step 5: Determine Recovery Factor and Drainage Areas

- Drainage areas were calculated based on EUR for every well in the Barnett
- Vertical wells were oriented at 50 degrees matching the natural fracture orientation
- Horizontal wells assumed to drain evenly along well path
- Wells showing overlap are typically confirmed to interfere
- Any area of Barnett can easily be inspected for drained and un-drained acreage
Step 12: Develop Barnett supply model

- The chart shows the production outlook for the Barnett assuming:
  - $4.00 Henry Hub
  - 90% of proven acreage
  - 20% of untested acreage

- The model EUR is 72 TCF with 40,000 wells drilled.

- The annual production grows to ___ by 2020.

- The well count steadily declines in the $4.00 price environment impacted by fewer higher tier prospects.
Step 13: Develop Model Sensitivities

- Impact of natural gas price on Barnett production forecast
- Higher gas price accelerates development of tiers 3 through 6
- Higher tiers are not developed in any case and the lowest tiers are fully developed even at low gas prices
U.S. Shale Gas

Implications

- Environmental
  - Water (-)
  - Traffic (-)
  - Noise/light (-)
  - Land Use (-)
  - NORM (-)
  - Carbon (+/-)
- Energy Security (+)
- Fuel Diversity (+)
Woodford Shale Frac Depth

Woodford Shale (OK) Mapped Frac Treatments/TVDs

- Deepest Aquifer Depth
- Frac Top
- Perf Top
- Perf Mid
- Perf Btm
- Frac Btm

Depths (ft)

1 11 21 31 41 51

Frac Wells (sorted on Perf Midpoints)

- Atoka
- Blaine
- Canadian
- Carter
- Cleveland
- Coal
- Garfield
- Hughes
- Johnston
- Pittsburg

Tinker, 2012
Woodford Shale Frac Depth

Marcellus Mapped Frac Treatments/TVD

Frac stages (sorted on Perf Midpoint)
Natural Gas Challenges

- Deliverability
- Access
- Competition with Coal
- Public Perception
Not all basins are created equal; geology matters

Sweet spots may be more spotty and less regional than we think

Technology matters and impacts EUR
Oil and gas will play a major role in the future energy mix, and...

Shale will be a vital part oil and gas production and reserves, but...

Above ground challenges are real, thus...

Rigorous operational practices and transparency are key, so that...
A Look at the Global Future

Petroleum Consumption
Coal Consumption
Natural Gas Consumption
Nuclear Electric Power Consumption
Hydroelectric Power Consumption
Biomass, Geothermal, Solar & Wind Consumption

Tinker Forecast
A Look at the Global Future

Tinker, 2012
A Look at the Global Future

Tinker Forecast

Petroleum Consumption
Coal Consumption
Natural Gas Consumption
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Hydroelectric Power Consumption
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