U.S. Shale

Reserves and Production

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Bureau of Economic Geology
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Outline

- The Role of Shale
- Reserves and Production Forecasting
- Implications and Considerations
U.S. Energy Mix (%)

Source: EIA, 2012
U.S. Energy Mix (%)

Source: EIA, 2012
Long-Term Oil Supply

Resources and Cost

2010 U.S. SHALE LIQUIDS PROJECTION

3.8 mmbpd by 2022...

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

IRR Source: Rystad Energy
US Shale and Tight Oil Production

Right on Pace...

Source: U.S. Energy Information Administration
Annual US Oil Production

1.4 Bby shale oil by 2022

Natural Gas Supply

Resources and Cost

U.S. Natural Gas
Production and Reserves

Marketed Production (Tcf)

U.S. Proved Reserves (Tcf)

End-of-Year U.S. Proved Reserves

Annual U.S. Production

Data: BP World Energy 2012
U.S. Natural Gas Production (TcF)

- Shale gas
- Coalbed methane
- Tight gas
- Non-associated offshore
- Alaska
- Associated with oil
- Non-associated onshore

http://www.eia.gov/energy_in_brief/about_shale_gas.cfm
From a 2004 Tinker Talk to the IPAA
US Natural Gas 2004 forecast

An Anticipated Evolution

2013 Dry Shale Gas Production

- Rest of US
- Bakken (ND)
- Eagle Ford (TX)
- Haynesville (LA and TX)
- Woodford (OK)
- Fayetteville (AR)
- Barnett (TX)
- Antrim (MI, IM, and OH)

Billion cubic feet per day

TcF/Year

2007 2009 2011 2013

Source: U.S. Energy Information Administration
2013 Dry Shale Gas Production

Model: Rice University, Medlock, 2012

Actual
2013 Dry Shale Gas Production

2010 forecast is low to actual. Why?

In spite of continued popular prognostications about the poor economics of shale, the reality is that parts of several basins are economic, and technology and price allow for continued drilling and production.

Rigorous, integrated, bottom-up geologic, engineering and economic studies provide a realistic look at the future.
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Reserves and Production Forecasting

Bureau of Economic Geology Program

Goal: Contribute to the objective understanding of the capability of U.S. shale gas to contribute to natural gas supply for the next 20 years

- 3-year project, funded by the Alfred P. Sloan Foundation
- Multidisciplinary team of geoscientists, engineers, and economists.
- Four plays: Barnett, Fayetteville, Haynesville, Marcellus
- Rapidly developing, some mature, others just starting
- Uncertainties about well performance and drivers
- Low price environment
Framing Questions

- What is the resource base in place?
- What portion of that resource is recoverable?
- What pace of drilling activity will be necessary to sustain production at various levels?
- How achievable is this activity level, given advances in technology and prices?
- What impact will these levels of production have on infrastructure, roads, water, regulation, jobs, taxes...
U.S. Shale Gas Plays

Lower 48 states shale plays

Source: Energy Information Administration based on data from various published studies.
Updated: May 9, 2011
Barnett Shale
Nanopores in Organics

Orange dots are 20 nm in diameter

T.P. Sims #2; 7625'

After Reed, BEG
30-Year Natural Gas Productivity
Extrapolated
Barnett Shale, TX*
Tiers 1-10

*Each sq. mile block is colored based on the estimated productivity of the average 4,000 ft. horizontal well in that block.
30-year production projection (Bcf).
For further details, see Ikonnikova et al. (2013).

Barnett Production Outlook

Barnett Production Outlook - Base Case

~15,000 wells  ~3,000 wells  ~11,000 wells

Model forecast was accurate for 2011-2012

Browning, J. et al. 2013. SPE Econ & Mgmt
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Unconventional Reservoirs

After Nicot and Wolaver, BEG, 2013
Unconventional Reservoirs

1000’s of Feet of Rock

After Nicot and Wolaver, BEG, 2013
Unconventional Reservoirs

Marcellus Mapped Frac Treatments/TVD

- Deepest Aquifer Depth
- fracTOP
- perfTOP
- Perf Midpoint
- perfSTM
- OH
- PA
- WV

Frac stages (sorted on Perf Midpoint)
Emissions Considerations

- Infrared cameras and Organic/Toxic Vapor Analyzer to detect leaks
- Electric or CNG motors
- “Green completions”
- Well pad location to account for wind
- Capture gas and limit flaring/venting

After Nicot and Wolaver, BEG, 2013
Water Considerations

- Harvest rain water (impoundments)
- Re-use and recycle brackish, flowback and formation water
- Chemicals that perform with high TDS
- Biodegradable chemicals
- “Dry” fracturing

After Nicot and Wolaver, BEG, 2013
Surface Considerations

- Location selection
- Noise control/sound barriers
- Mobile water tanks and centralized impoundments instead of pits
- Use of waste heat/stranded natural gas
- Well pad footprint
- Re-vegetate pad to limit erosion
- Multi-well pads

After Nicot and Wolaver, BEG, 2013
Subsurface Considerations

- Cement all gas producing zones
- Subsurface characterization for disposal
- Disclosure of all chemicals
- Baseline data ahead of drilling
  - Thermal
  - Chemical
  - Conductive
  - Hydro
  - Seismic

After Nicot and Wolaver, BEG, 2013
Unconventional Summary
“Trade Offs”

- **Environmental** Risks and Impacts
  - Traffic/noise/light
  - Surface
  - Groundwater
  - Quakes
  - Local and atmospheric emissions

- **Energy Security** and Economic Benefits
  - Available
  - Affordable
  - Reliable
  - Atmospheric emissions
  - Jobs and Taxes

*These are not mutually exclusive!*
Unconventional Reservoirs

Implications

• Balance of Trade
  ✓ Exports: Natural gas, liquids, products
  ✓ Imports: Oil

• Regulation and Planning
  ✓ Infrastructure
  ✓ Resources
  ✓ Permitting

• Emissions

• Energy Security