The Impact of Shale on North American and Global Gas Markets

Scott W. Tinker

John Browning, Svetlana Ikonnikova, Gürcan Gülen, Eric Potter, Frank Male, Qilong Fu, Katie Smye, Susan Horvath, Tad Patzek, Ken Medlock, Forrest Roberts and William Fisher
Outline

- U.S. Shale Gas Reserves and Production Forecasts
- The Impact of Shale on US and Global Gas Markets
Reserves and Production Forecasting

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

- Led by Bureau of Economic Geology
- 3-year project, funded by the Alfred P. Sloan Foundation
- Four plays: Barnett, Fayetteville, Haynesville, Marcellus
- Multidisciplinary team of geoscientists, engineers, and economists.
Framing Questions

- What is the *original resource base* in place?
- What portion of the resource is *technically recoverable*?
- What portion of the technically recoverable resource is *economically recoverable*?
- What impact will these levels of production have on infrastructure, roads, water, regulation, jobs, taxes...
U.S. Shale Gas Plays

Source: Energy Information Administration based on data from various published studies.
Updated: May 9, 2011
Log and microseismic data

Production history data and directional surveys

Geologic Characterization
Structure, porosity, net pay-zone maps

Production Decline
Production rate estimate, EURs

Econometric Analysis
Validate Decline Curve; Test Geologic and Other parameters; Describe “typical well”

Well Spacing
Well Recovery, Drainage Areas, Infill drilling locations (by tier) => Technically Recoverable Resources

Well Economics
• Average well profile by tier,
  • Incremental economics

Production Outlook
• Pace of drilling as a function of historical pattern, economics, attrition, logistics
  • Cum. production under different scenarios

Data Sources
IHS, DrillingInfo, USGS, TexasNRIS, Arkansas GS, Carrizo, ExxonMobil, Devon, SWN, XTO, Chesapeake, MJ Systems, Cimarex.

1. AAPG Bulletin
2. AAPG Bulletin
3. In preparation
4. SPE Reservoir Evaluation
5. Energy Journal
6. SPE Economics and Management
7. Oil and Gas Journal
Estimated Original Free Gas in Place
Barnett Shale Play, TX

Barnett
OGIP Free
30-Year Natural Gas Productivity

*Extrapolated*

Barnett Shale, TX*

Tier 1

*Each 1x1 mile block is colored based on the*
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).

Tier 10

Drainage areas of the existing wells

"Bottom Up" Well Recovery Drainage Areas Infill Drilling Potential


Barnett:
• Variable leases
• Multiple operators
• Wide range of completion types
<table>
<thead>
<tr>
<th>Parameters Considered</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Economic Well Life Limit (mmcf/d)</td>
<td>Processing Fee</td>
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<tr>
<td>Basis to Henry Hub ($/mmbtu)</td>
<td>Lease Cost/acre</td>
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<tr>
<td>Royalty Rate (%)</td>
<td>Spacing (ac)</td>
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<tr>
<td>Severance Tax Rate (%)</td>
<td>Depletion Cost</td>
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<td>Marginal Tax Rate (%)</td>
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<td>Inflation Rate (%)</td>
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<td>Drilling Cost (CAPEX)</td>
<td>WTI Price</td>
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<td>Related CAPEX Factor (%)</td>
<td>GPL/WTI Ratio</td>
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<tr>
<td>Expense/Well/Year</td>
<td>Developable Acreage Ceiling</td>
</tr>
<tr>
<td>Gathering, Compression, Treatment</td>
<td>• Partly Drained</td>
</tr>
<tr>
<td>NGL Transport Cost</td>
<td>• Undrilled</td>
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<tr>
<td>Water Cut (bbl/mcf)</td>
<td>Annual Technology Improvement</td>
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<tr>
<td>Water Disposal Cost</td>
<td>Annual Well Cost Improvement</td>
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<tr>
<td>Oil Yield</td>
<td>Minimum Completions in a Year</td>
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<td>GPL Yield</td>
<td>Attrition</td>
</tr>
<tr>
<td>Gas Shrinkage</td>
<td></td>
</tr>
</tbody>
</table>
Barnett
Production Outlook

Barnett Production Outlook - Base Case

Model forecast was accurate for 2011-2012

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

Browning, J. et al. 2013. SPE Econ & Mgmt
Barnett
Production Forecast

Tcf per Year
(Base Case Sensitivity to Price)

- Tcf @ $10 HH
- Tcf @ $6 HH
- Tcf @ $4 HH
- Tcf @ $3 HH
- Henry Hub $2010

Production Forecast

[Graph showing Barnett production forecast with Tcf per Year on the y-axis and years from 1995 to 2030 on the x-axis. Different colored lines represent Tcf production at different price points ($10, $6, $4, $3 HH) against Henry Hub $2010.]
Economic Production Distribution

Monte Carlo

0.000 0.005 0.010 0.015 0.020 0.025 0.030 0.035 0.040 0.045 0.050

29 34 39 44 49 55 60 65 70

Relative Frequency

Cumulative Production (Tcf)

Barnett

35 Tcf

45 Tcf

56 Tcf

Browning, J. et al. 2013. SPE Econ & Mgmt
Original Free Gas in Place
Fayetteville Shale Play, Arkansas

Sources
Arkansas Public Land Survey System data acquired from AGIO. Well data provided by IHS; well raster logs provided by MJ Systems. Compiled in ESRI ArcMap 10.2.
NAD 1927 State Plane Arkansas North

Original Free Gas in Place (Bcf) values determined for each PLSS section in the Fayetteville pay zone
Fayetteville Tiers

30-Year Natural Gas Productivity
*Extrapolated*
Fayetteville Shale Play, Arkansas Tiers 1 - 6

Each Arkansas PLSS Section is colored based on the estimated productivity of the average 4,400 ft. horizontal well in that section. 30-year production projection (Bcf).
Fayetteville
Production Forecast

Tcf per Year
(Base Case Sensitivity to Price)

- Tcf @ $10 HH
- Tcf @ $6 HH
- Tcf @ $4 HH
- Tcf @ $3 HH
- HH $2010

Henry Hub $2010

- $10
- $9
- $8
- $7
- $6
- $5
- $4
- $3
- $2
- $1
- $0

2005 2010 2015 2020 2025 2030
Economics by Tier (Bcf)

Breakeven Economics
10% IRR

- Barnett Low Btu
- Barnett High Btu
- Fayetteville Shallow
- Fayetteville Medium
- Fayetteville Deep
- Haynesville

Tier 1 Tier 2 Tier 3 Tier 4 Tier 5 Tier 6 Tier 7 Tier 8 Tier 9 Tier 10
Unconventional Summary

“Trade Offs”

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

- Energy Security and Economic Benefits
  - Available
  - Affordable
  - Reliable
  - Jobs and Taxes

*These are not mutually exclusive!
Environmental Issues

Regulatory Considerations

I. Mandatory baseline data
II. Cement all gas producing zones
III. Minimize fresh water use on the front end
IV. Full disclosure and adaptation of chemicals
V. Handle flowback and produced water
   a. Treat and reuse
   b. Induced seismicity
VI. Minimize methane emissions
VII. Minimize surface impact

after Rao, 2012
Reducing Surface Disruption

Barnett drilling location
University of Texas at Arlington
From XTO annual report
Outline

- U.S. Shale Gas Reserves and Production Forecasts
- The Impact of Shale on US and Global Gas Markets
Population
~1 billion people per color

More people live inside the circle than outside...
Global Natural Gas Production

- **Total North America**
- **Total S. & Cent. America**
- **Total Europe & Eurasia**
- **Total Middle East**
- **Total Africa**
- **Total Asia Pacific**

Source: BP Statistical Review 2012

**115 Tcfy**
Natural Gas Supply

Resources and Cost

U.S. Natural Gas

Production and Reserves

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

- Shale gas: 23 TcF
- Coalbed methane: 14 TcF
- Tight gas: 9 TcF
- Non-associated offshore: 5 TcF
- Associated with oil: 4 TcF
- Non-associated onshore: 2 TcF

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!


http://www.eia.gov/energy_in_brief/about_shale_gas.cfm
2013 Dry Shale Gas Production

Model: Rice University, Medlock, 2012
2013 Dry Shale Gas Production

Model: Rice University, Medlock, 2012

Source: U.S. Energy Information Administration
Global Shale Gas

Global shale gas basins, top reserve holders

Assessed basins
- With resource estimate
- Without resource estimate

Source: EIA based on Advanced Resource International Inc data, BP

Reuters graphic/Catherine Trevethan
Options to “Fracking” for Power

I. Coal
   o Available, affordable to generate, reliable
   o Dirty, expensive to build

II. Nuclear
   o Efficient, no emissions, affordable generation
   o Expensive to build, waste, safety

III. Wind
   o Simple, affordable, no emissions
   o Intermittent, land and visual, transmission

IV. Solar
   o Simple, no emissions, local
   o Expensive, intermittent, land

V. Hydro
   o Efficient, affordable to generate, no emissions
   o Water, land, drought

VI. Geothermal
   o Affordable where concentrated, no emissions
   o Geology
Unconventional Reservoirs

Implications

• Balance of Trade
  ✓ Exports: Natural gas, liquids, products
  ✓ Imports: Oil
• Regulation and Planning
  ✓ Infrastructure
  ✓ Resources
  ✓ Permitting
• Emissions
• Energy Security
Leaving our Corners

Government

Compromise

Academia/NGO

Industry
Leaving our Corners

Government

The Radical Middle

Academia/NGO

Industry
Global Context

- Shale will be a big part of the future and “above ground” challenges must be addressed.
- Diverse energy portfolios are inevitable, and for the most part desirable; efficiency is part of the energy portfolio.
- Energy security — affordable, available, reliable, sustainable — drives energy mix.
- The global energy transition will take time; let’s come out of our corners to The Radical Middle, where things get done.
Thanks!