US Shale Gas Reserve and Production Forecasts and Implications for Shale Oil

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

Bureau of Economic Geology
Jackson School of Geosciences, The University of Texas at Austin
Outline

- U.S. Shale Gas Reserves and Production Forecasts
- The Impact of Shale on US and Global Gas and Oil Markets
- Above Ground Challenges and Implications
BEG 3-Year Study
Shale Gas Reserve & Production Forecasting

Goal: 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
- 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

Lower 48 states shale plays

Source: Energy Information Administration based on data from various published studies.
Updated: May 9, 2011
Barnett
DPhi * H
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 4x4 mile block is colored based on the*...
Economics by Tier (Bcf)

Breakeven Economics
10% IRR

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

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

Tinker, 2014
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

Parameters Considered

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic Well Life Limit (mmcf/d)</td>
<td>Processing Fee</td>
</tr>
<tr>
<td>Basis to Henry Hub ($/mmbtu)</td>
<td>Lease Cost/acre</td>
</tr>
<tr>
<td>Royalty Rate (%)</td>
<td>Spacing (ac)</td>
</tr>
<tr>
<td>Severance Tax Rate (%)</td>
<td>Depletion Cost</td>
</tr>
<tr>
<td>Marginal Tax Rate (%)</td>
<td>Abandonment Cost</td>
</tr>
<tr>
<td>Inflation Rate (%)</td>
<td>Basis to Henry Hub</td>
</tr>
<tr>
<td>Drilling Cost (CAPEX)</td>
<td>WTI Price</td>
</tr>
<tr>
<td>Related CAPEX Factor (%)</td>
<td>GPL/WTI Ratio</td>
</tr>
<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>
</tr>
<tr>
<td>Water Cut (bbl/mcf)</td>
<td>Annual Technology Improvement</td>
</tr>
<tr>
<td>Water Disposal Cost</td>
<td>Annual Well Cost Improvement</td>
</tr>
<tr>
<td>Oil Yield</td>
<td>Minimum Completions in a Year</td>
</tr>
<tr>
<td>GPL Yield</td>
<td>Attrition</td>
</tr>
<tr>
<td>Gas Shrinkage</td>
<td></td>
</tr>
</tbody>
</table>
Barnett
Production Outlook

Model forecast was accurate for 2011-2012

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

Production (MMcf/d)
0  600  1,200  1,800  2,400  3,000  3,600  4,200  4,800  5,400  6,000

Completions Per Year
0  300  600  900  1,200  1,500  1,800  2,100  2,400  2,700  3,000

Tinker, 2014

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

Tinker, 2014
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
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).

0.07 - 1.00
1.01 - 1.50
1.51 - 2.00
2.01 - 2.50
2.51 - 3.00
3.01 - 6.58
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

Tcf per year

2005 2010 2015 2020 2025 2030

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

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

More people live inside the circle than outside...
Global Energy Mix and Demand

Source: United States basins from U.S. Energy Information Administration and United States Geological Survey; other basins from ARI based on data from various published studies.
Global Natural Gas Production

Source: BP Statistical Review 2012
Natural Gas Supply

Resources and Cost

U.S. Natural Gas

Production and Reserves

Marketed Production (Tcf)

End-of-Year U.S. Proved Reserves

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

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

Model: Rice University, Medlock, 2012

Source: U.S. Energy Information Administration

The graph illustrates the dry shale gas production from various shale formations across different years, with actual production data shown. The data is sourced from the U.S. Energy Information Administration.
Options to “Fracking” for Power

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

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

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

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

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

VI. Geothermal
   - Affordable where concentrated, no emissions
   - Geology
Source: Lawrence Livermore National Laboratory and U.S. DOE based on Annual Energy Review, 2008 (EIA, 2009)

(U.S. Energy Flows)

Energy services 42.15

- Residential 11.48
- Commercial 8.58
- Industrial 23.94
- Transportation 27.86

Natural gas 23.84

- Residential 11.48
- Commercial 8.58
- Industrial 23.94
- Transportation 27.86

Petroleum 37.13

- Residential 11.48
- Commercial 8.58
- Industrial 23.94
- Transportation 27.86

Coal 22.42

- Residential 11.48
- Commercial 8.58
- Industrial 23.94
- Transportation 27.86

Biomass 3.88

- Residential 11.48
- Commercial 8.58
- Industrial 23.94
- Transportation 27.86

Geothermal 0.35

- Residential 11.48
- Commercial 8.58
- Industrial 23.94
- Transportation 27.86

Wind 0.51

- Residential 11.48
- Commercial 8.58
- Industrial 23.94
- Transportation 27.86

Hydro 2.45

- Residential 11.48
- Commercial 8.58
- Industrial 23.94
- Transportation 27.86

Nuclear 8.45

- Residential 11.48
- Commercial 8.58
- Industrial 23.94
- Transportation 27.86

Solar 0.09

- Residential 11.48
- Commercial 8.58
- Industrial 23.94
- Transportation 27.86

Electrification generation 39.97

- Residential 11.48
- Commercial 8.58
- Industrial 23.94
- Transportation 27.86

Energy services 42.15

- Residential 11.48
- Commercial 8.58
- Industrial 23.94
- Transportation 27.86

Net electricity imports 0.11

- Residential 11.48
- Commercial 8.58
- Industrial 23.94
- Transportation 27.86

Electricity generation 39.97

- Residential 11.48
- Commercial 8.58
- Industrial 23.94
- Transportation 27.86

Source: Lawrence Livermore National Laboratory and U.S. DOE based on Annual Energy Review, 2008 (EIA, 2009)
The Future Transportation Mix

Millions of oil-equivalent barrels per day

North America
- Gasoline
- Ethanol
- Diesel
- Jet fuel
- Fuel oil
- Natural gas
- Other

Europe
- Gasoline
- Ethanol
- Diesel
- Jet fuel
- Fuel oil
- Natural gas
- Other

Asia Pacific
- Gasoline
- Ethanol
- Diesel
- Jet fuel
- Fuel oil
- Natural gas
- Other

Global Oil Production

Source: BP Statistical Review 2012

30.5 BBY
Long-Term Oil Supply

Resources and Cost

Annual US Oil Production

2010 U.S. SHALE LIQUIDS PROJECTION

3.8 mmbd by 2022...

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


1.4 Bby shale oil by 2022
Outline

- U.S. Shale Gas Reserves and Production Forecasts
- The Impact of Shale on US and Global Gas and Oil Markets
- Above Ground Challenges and Implications
Unconventional Reservoirs

Marcellus Mapped Frac Treatments/TVD

Depth (ft)

Frac stages (sorted on Perf Midpoint)
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
Unconventional Reservoirs

Implications

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

• Regulation and Planning
  ✓ Infrastructure
  ✓ Resources
  ✓ Permitting

• Emissions

• Energy Security
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!