Natural Gas Resource Assessments

Bureau of Economic Geology
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Technically Recoverable Resource Estimates

Grown significantly over time.

Source: Based on a widely used chart produced by Gas Technology Institute (GTI).
Shale Gas Mostly Responsible for Increased Estimates but...

- Shale gas resource estimates cover a wide range
- Some are for TRR; others are for ERR
- Assumptions & approach not always transparent

BEG’s Integrated Approach: Barnett, Fayetteville, Haynesville, Marcellus

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

**Log and seismic data**

**Production history data and directional surveys**

**Geologic Analysis:**
Structure, porosity, net pay-zone maps

**Panel Data Analysis:**
Validate Decline Curve; Test Geologic and Other parameters; Describe “typical well”

**Decline Analysis:**
Production rate estimate, EURs

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

**Well Economics:**
Attrition rate, Breakeven prices, Representative well profiles (by tier)

**Production Outlook:**
Pace of drilling and ultimate recovery w.r.t. Prices, Technology, and Time

Funded by Alfred P. Sloan Foundation
• We estimate the content of natural gas in the formation for each 1 mi² of the Barnett Shale Play:
  - OGIPfree of the entire Barnett: ~444 Tcf;
  - OGIPfree of the “developed” area: ~280 Tcf

Red blocks have the highest OGIPfree; blue blocks - the lowest.
Decline Analysis

• Rather than apply a standard exponential or harmonic decline approach, we derive the decline function (REI) based on physical properties.

• We confirm it to be statistically valid by testing the function against the data for more than 16,000 wells drilled in the Barnett Shale.

• We use the results, to estimate ultimate recovery (EUR) for all the existing wells and assess EUR of future wells.

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Well Economics

- We evaluate economics of wells across 10 tiers, using DCF analysis along with sensitivity tests and stochastic simulation.
- Dry gas and high Btu (wet) areas are analyzed separately to account for liquids value.

Worst tiers not viable at any reasonable price.

Only best tiers viable at low prices.
Total expected production for 15,144 wells drilled through 2010 is ~18.8 Tcf; Cumulative production through 2010 is 8.4 Tcf.
# Barnett Shale: Base Case

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Base case</th>
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<tbody>
<tr>
<td>- Henry Hub price for natural gas</td>
<td>$4.00/MMBtu</td>
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<tr>
<td>- Partly drained acreage developable ceiling</td>
<td>80%</td>
</tr>
<tr>
<td>- Undrilled acreage developable ceiling</td>
<td>15%</td>
</tr>
<tr>
<td>- WTI price</td>
<td>$80/bbl</td>
</tr>
<tr>
<td>- GPL/WTI price ratio</td>
<td>45%</td>
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<tr>
<td>- Annual technology improvement</td>
<td>0.39%</td>
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<tr>
<td>- Annual well-cost improvement</td>
<td>0.24%</td>
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<tr>
<td>- Economic limit for shutting-in a well (low Btu)</td>
<td>0.05 MMcf/d</td>
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<tr>
<td>- Economic limit for shuttling-in a well (high Btu)</td>
<td>0.029 MMcf/d</td>
</tr>
<tr>
<td>- Minimum completions in a year (low Btu)</td>
<td>20 (Tiers 1-4) 2 (Tiers 5-10)</td>
</tr>
<tr>
<td>- Minimum completions in a year (high Btu)</td>
<td>25 (Tiers 2-5) 10 (Tiers 1, 6-10)</td>
</tr>
</tbody>
</table>
Barnett Shale: Base Case

Tcf per Year
(Base Case Sensitivity to Price)

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

Henry Hub $2010

Base Case @ $4 HH
45 Tcf Cumulative Production
Fayetteville Production

Cum Prod 2050 (Tcf)

- $3: 16
- $4: 18.2
- $6: 20
- $10: 21.2