Tulsa Chapter SPEE Presentation
Estimating Reserves for Unconventional Shale Resource Plays

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Disclaimer

The materials contained in this presentation are intended to show general information regarding various shale plays. Actual estimates of reserves and resources and other technical and economic factors require specific information about the properties being evaluated and technical expertise in the field of petroleum property evaluations.
Discussion Outline

• What is the big deal about the shale plays?
• Estimating Reserves – Critical Issues
  ▪ Early development - Reserves techniques
  ▪ Maturing Plays – Determining Ultimate Well Spacing
• Overview of Selected Plays
  ▪ Barnett
  ▪ Fayetteville
  ▪ Haynesville
  ▪ Marcellus
## Summary by Shale Play

<table>
<thead>
<tr>
<th>Shale Basin</th>
<th>Barnett</th>
<th>Fayetteville</th>
<th>Woodford</th>
<th>Haynesville</th>
<th>Marcellus</th>
<th>Eagle Ford</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Acres ('000's)</td>
<td>2,549</td>
<td>2,009</td>
<td>749</td>
<td>3,334</td>
<td>6,600</td>
<td>1,633</td>
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<tr>
<td>Depth (Ft)</td>
<td>6,500-8,500</td>
<td>1,000-7,000</td>
<td>6,000-11,000</td>
<td>10,500-13,500</td>
<td>4,000-8,500</td>
<td>9,000-13,000</td>
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<tr>
<td>Thickness (Ft)</td>
<td>100-600</td>
<td>20-200</td>
<td>120-220</td>
<td>200-300</td>
<td>50-200</td>
<td>100-300</td>
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<tr>
<td>OGIP (TCF)</td>
<td>700</td>
<td>200</td>
<td>90</td>
<td>900</td>
<td>1,000+</td>
<td>250</td>
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<tr>
<td>Est. Rec. Resources (TCF)</td>
<td>64</td>
<td>37</td>
<td>16</td>
<td>109</td>
<td>96</td>
<td>21</td>
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<tr>
<td>Cum Prod (TCF)</td>
<td>9.0</td>
<td>1.7</td>
<td>0.8</td>
<td>1.2</td>
<td>?</td>
<td>0.1</td>
</tr>
<tr>
<td>No. of Wells</td>
<td>14,000</td>
<td>3,000</td>
<td>1,200</td>
<td>800</td>
<td>600+</td>
<td>120</td>
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<tr>
<td>EUR/well (BCF)</td>
<td>2.4</td>
<td>2.6</td>
<td>4.3</td>
<td>6.2</td>
<td>4.2</td>
<td>5.1</td>
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<tr>
<td>30-day IP (MMCFD)</td>
<td>2.1</td>
<td>2.5</td>
<td>4.0</td>
<td>9.5</td>
<td>4.5</td>
<td>6.0</td>
</tr>
<tr>
<td>Avg Well Cost ($MM)</td>
<td>2.6</td>
<td>2.8</td>
<td>5.0</td>
<td>8.0</td>
<td>3.9</td>
<td>5.5</td>
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<tr>
<td>Break-Even ($/MCF)</td>
<td>4.95</td>
<td>4.06</td>
<td>5.15</td>
<td>4.81</td>
<td>4.17</td>
<td>4.57</td>
</tr>
</tbody>
</table>

Source: BMO Capital Markets – Unconventional Gas (Oct-09), NSAI
Productive Shale Supply Implications

- **US Gas production**
  - ~57 BCF/DAY
- **US Shale Gas**
  - ~14+ BCF/DAY
- **20,000 HZ Wells**

**Tier 1**
- 15,819 wells
- 75 miles

**Tier 2**
- 770 wells

**Tier 3**
- 5 BCF/DAY
- 15 MBO/DAY

Core
- 5 BCF/DAY
- 220 MBO/DAY

- 35 wells to date > 10 Bcf
- 26 are HK operated

- 6-7 Bcf
- 10+ Bcf

- 4 Bcf contour

- 800 miles

**2 BCF/DAY**
- 2,631 wells

- 300 miles

- ~500 wells

**0.3 BCF/DAY**
- 357 wells
- 30 MBO/DAY
- ~57 BCF/DAY

**1.5 BCF/DAY**
- 2,631 wells

- 75 miles

**US Gas production**
- 357 wells

**20,000 HZ Wells**
- 770 wells

**5 BCF/DAY**
- 75 miles

**15,819 wells**

**5 BCF/DAY**
- 220 MBO/DAY

**220 miles**

- 350,000 gross acres

**PXD Eagle Ford acreage**

**Fayetteville Shale Gas Play Central Map**

**First Marcellus Prod. in NE PA**

**COG Test #8V**

**High Pressure**

**Low Pressure**

**Discover**

**Wet Gas**

**Dry Gas**

**Condensate Window**

**Oil Window**

**Dry Gas Window**

**Condensate Window**

**Oil Window**

**Active Rigs**

**50 Miles**

**75 miles**

**300 miles**

**~500 wells**

**300 miles**

**~500 wells**
Recent Acquisitions and Joint Ventures (JVs)
13 Transactions $33 Billion Dollars

Upstream JV Deals (Chronologically):

- **Total – Chesapeake, Barnett:** January 2010 – 25% interest in 270,000 acres, $2.25 billion total split into $800 million cash + $1.45 billion carry of Chesapeake’s share of drilling and completion costs. **Price ~$33,330/acre**

- **Mitsui – Anadarko, Marcellus:** February 2010 – 32.5% interest in approximately 300,000 acres, $1.4 billion total with all money being used to carry Anadarko over the next 3 years. This deal allows Mitsui the rights to participate and purchase up to 32.5% in future leaseholds with Anadarko. **Price ~$14,360/acre**

- **Reliance – Atlas, Marcellus:** April 2010 – 40% interest in approximately 300,000 acres, $1.699 billion total split into $339 million cash + $1.36 billion carry of Atlas’s share of capital costs. **Price ~$14,160/acre.** This JV has since acquired an additional ~42,000 acres (at $4,532/acre).

- **Reliance – Pioneer, Eagle Ford:** June 2010 – 45% interest in approximately 263,000 acres, $1.315 billion total split into $263 million cash + $1.052 billion carry of Pioneer’s share of capital costs and some midstream assets. **Price ~$11,110/acre**

- **Statoil – Talisman, Eagle Ford:** August 2010 – 50% interest in approximately 134,000 acres $1.325 billion total $180 million from Statoil to buy into Talisman’s previous approximately 37,000 acres with the rest buying approximately 97,000 acres from Enduring Resources. **Price ~$19,780/acre**

- **CNOOC – Chesapeake, Eagle Ford:** November 2010 – 33% Interest in 600,000 acres for $2.16 billion split $1.08 billion in cash + $1.08 billion carry of Chesapeake’s share of drilling and completion costs. This deal allows CNOOC the rights to participate and purchase up to 33.3% in future leaseholds with Chesapeake. **Price ~$10,800/acre**

- **Sasol – Talisman, Montney:** December 2010 – 50% interest in approximately 57,200 acres for C$1.25 billion total C$262.5 million cash + C$787.5 million in drilling and completion costs. **Price ~C$36,710/acre**

- **PetroChina – Encana, Montney:** February 2011 – 50% interest in approximately 635,000 acres, 255 MMCFED of production, 700MMCFD of processing capability, 3,400 km of pipeline, and the Hythe natural gas storage facility for C$5.4 billion total. **Price ~C$17,010/acre**

- **KNOC – Anadarko, Eagle Ford:** March 2011 – 33.3% interest in approximately 240,000 acres of Eagle Ford shale and an additional 48,000 acres of Pearsall shale for $1.55 billion by funding capital costs. **Price ~$16,150/acre**

Upstream Acquisitions:

- **Shell– East Resources, Marcellus:** May 2010 – Interest in ~650,000 Marcellus acres and 60 MMcfe/d for $4.7 billion in cash. **Price ~$7,230/acre**

- **Hess – TRZ Energy, Bakken:** November 2010 – 167,000 acres for $1.05 billion in cash. **Price ~$6,290/acre**

- **Chevron/Reliance – Atlas, Marcellus, Utica:** November 2010 – 486,000 acres of Marcellus, 623,000 acres of Utica, and 49% interest in Laurel Mountain Midstream for $4.3 billion total split 3.2 billion cash and 1.1 billion debt. **Price ~$3,880/acre**

- **BHP Billiton – Chesapeake, Fayetteville:** February 2011 – 487,000 acres and over 400 MMCFD for $4.75 billion in cash. **Price ~$9,750/acre**
Early Development Techniques

• Analogy to other Shale Plays
  ▪ Use type curves from another shale plays (hyperbolic exponents ranges 0.8 to 1.8)
  ▪ Volumetric analysis – Drainage areas 40 to 160 acres and recovery factors 5 to 30 percent
  ▪ Estimating horizontal well recovery based on multiple of vertical well completions (Generally 3 to 6 times)
  ▪ EUR Distributions from analogous plays (i.e. Tier I Barnett shale area P75-P25 1.0 – 3.0 Bcf)
# General Shale Forecast Parameters

## Projection Parameters

<table>
<thead>
<tr>
<th></th>
<th>Marcellus Horizontal*</th>
<th>Barnett</th>
<th>Fayetteville</th>
<th>Woodford</th>
<th>Haynesville</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP (MCF/Mo)</td>
<td>80,000 – 150,000</td>
<td>80,000 – 90,000</td>
<td>50,000 – 80,000</td>
<td>60,000 – 120,000</td>
<td>300,000 – 700,000</td>
</tr>
<tr>
<td>De (%) (instantaneous)</td>
<td>95 - 99</td>
<td>90 – 95</td>
<td>80 – 85</td>
<td>90 – 99</td>
<td>99 – 99.9</td>
</tr>
<tr>
<td>N</td>
<td>1.0 – 1.5</td>
<td>1.5 – 1.75</td>
<td>1.0 – 1.3</td>
<td>1.0 – 1.3</td>
<td>0.8 – 1.2</td>
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<tr>
<td>Df (%)</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>EUR (BCF) – Tier I**</td>
<td>1.5 – 5.0</td>
<td>1.0 – 3.0</td>
<td>1.5 – 4.0</td>
<td>1.5 – 4.0</td>
<td>2.5 – 7.0</td>
</tr>
<tr>
<td>EUR (BCF) – Tier II**</td>
<td>0.5 – 1.5</td>
<td>0.5 – 1.5</td>
<td>0.5 – 2.5</td>
<td>0.5 – 2.0</td>
<td>1.0 – 4.0</td>
</tr>
</tbody>
</table>

* Based on limited data  
** P75 – P25 EURs  
This is a generalized interpretation - individual reserves calls require judgment based on specific data.
Methodology Life Cycle

- Reserves Estimate Methods
- Estimated Ultimate Recovery Range
- Production Curve
- Depletion Stage

- ANALOGY
- VOLUMETRICS
- MATERIAL BALANCE
- DECLINE CURVE

High
Low

Exploration  Delineation  Development  Early Production  Mature Production
Performance Variability

Free gas in the natural and induced fracture system & high perm matrix porosity contribution

Gas from siliceous shale micro porosity

Release of adsorbed gas on organic material (TOC) with low perm matrix porosity contribution
Actual Well Performance Variability

Barnett Shale
Northeast Wise County

- Wide range of performance trends for wells in close proximity
- EURs range from 0.3 to 3.6 BCF
  - Average EUR is 1.5 BCF
- There may not be a 'typical' well

Average of 107 wells
Projection of Average Production
Well Count
Haynesville Shale Production Variability

From Petrohawk Energy investor presentation
Decline Curve Analysis
How much data is needed?

~100 Days of Production

<table>
<thead>
<tr>
<th>n (Hyp exp)</th>
<th>50-year EUR (BCF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2</td>
<td>3.3</td>
</tr>
<tr>
<td>1.5</td>
<td>4.4</td>
</tr>
<tr>
<td>1.8</td>
<td>5.5</td>
</tr>
</tbody>
</table>

~900 Days of Production

<table>
<thead>
<tr>
<th>n (Hyp exp)</th>
<th>Df (%/year)</th>
<th>50-year EUR (BCF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>4</td>
<td>5.0</td>
</tr>
<tr>
<td>1.5</td>
<td>6</td>
<td>4.4</td>
</tr>
<tr>
<td>1.5</td>
<td>8</td>
<td>3.8</td>
</tr>
</tbody>
</table>
• Early Development would limit Proved Undeveloped locations to direct parallel offsets
Maturing Plays – Critical Issues

- Regional Overview
- Geological Aspects
  - OGIP
  - Contributing Rock Volume
- Recovery Factor
- Ultimate Well Spacing
- Defining Proved Areas – Reliable Technology
Regional Overview

- **Barnett Shale**
  - Projected ~12,000 wells
  - Analyzed ~100+ logs & 5+ cores

- **Fayetteville Shale**
  - Projected ~3,000 wells
  - Analyzed ~50 logs & ~10+ cores

- **Haynesville Shale**
  - Projected ~800 wells
  - Analyzed ~100 logs & ~10+ cores

- **Eagle Ford Shale**
  - Projected ~200 wells
  - Analyzed ~100 logs & ~10+ cores
Haynesville Initial Potential Map (2008)
OGIP - Does not tell the whole story

Texas Louisiana

Thick – Lower Quality
Thick - Poor Quality
Target Thickness Versus Gas-in-Place

- 200 BCF/mi² Gas-in-Place
  - 200 Feet Thick
  - 2,000 Feet Thick

- 200 BCF/mi² Gas-in-Place
  - 1 BCF/foot
  - 0.1 BCF/foot
Contributing Rock Volume

d\text{y} = \text{Lateral Length (3,000' to 5,000')} 
d\text{x} = \text{Well Spacing or Effective Frac Distance (500' to 1,500')} 
d\text{z} = \text{Net Shale Thickness or Effective Frac Height (50' to 300')} 

\[ d\text{x} \times d\text{y} \times d\text{z} = \text{Contributing Rock Volume} \]
Shale Performance Analysis
Moving Average Methodology

• **Premise 1**: OGIP, per-well EUR, well spacing, and recovery factor are interrelated.

• **Premise 2**: The statistical nature of shale plays requires aggregation of data in a meaningful way.

• **Premise 3**: Aggregation of data over a square mile is meaningful.
Moving Average Mapping

Search Radius
- 3,000 feet
- 648 acres

Each Grid Node
- Well Count
- Total EUR
- Average EUR
- OGIP

Moving Average
Grid 1,000 ft x 1,000 ft
Example: Well Count Contour Map

Production data posting location (midpoint of perforation data)
Influenced by individual well EURs and number of wells per $m^2$

This is a generalized interpretation - individual reserves calls require judgment based on specific data.
Calculated Recovery Factor Map

NSAI Total EUR (BCF/mi²) / NSAI Screening Total OGIP (BCF/mi²)

This is a generalized interpretation - individual reserves calls require judgment based on specific data.
Recovery Factor Versus Well Count

This is a generalized interpretation - individual reserves calls require judgment based on specific data.
The moving average allows for wells to be statistically aggregated by proximity. This addresses interference and local geologic variations. Isolated wells are sampled numerous times with the moving average method.

This is a generalized interpretation - individual reserves calls require judgment based on specific data.
Total Gas Ultimate

Contours are BCF of estimated ultimate gas recovery per square mile

The second most densely drilled area of the Barnett Shale (39,000 acres, 1,076 wells)

The most densely drilled area of the Barnett Shale (41,500 acres, 1,150 wells)

Successful horizontal development area of the Barnett Shale (1,100 acres, 12 horizontal wells)

Successful horizontal development area of the Barnett Shale (450 acres, 8 horizontal wells)

This map was created by taking a moving average sum of all individual well EURs in a 1-square-mile area at a ½-mile grid increment.

This is a generalized interpretation - individual reserves calls require judgment based on specific data
Reservoir Permeability versus Recovery Factor

- **Unconventional Tight Gas**: Recovery Factors 30 to 50%
- **Conventional Gas**: Recovery Factors 50 to 95%
- **Shale Gas**: Recovery Factors 5 to 30%
- **Conventional Depletion Oil**: Recovery Factors 15 to 30%
- **Tight Depletion Oil**: Recovery Factors 5 to 15%
- **Unconventional Tight Gas**: Recovery Factors 30 to 50%
- **Shale Oil**: Recovery Factors 1 to 10%

Porosity vs. Reservoir Permeability (md) chart.
### Barnett Shale Volumetric Analysis

#### 160 BCF OGIP Recovery Factor Well Spacing Analysis

<table>
<thead>
<tr>
<th>EUR per Well Array (BCF)</th>
<th>Recovery Factor (percent)</th>
<th>40%</th>
<th>30%</th>
<th>20%</th>
<th>10%</th>
<th>5%</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>160</td>
<td>12</td>
<td>8</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>120</td>
<td>12</td>
<td>9</td>
<td>6</td>
<td>3</td>
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<td></td>
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<td>40</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
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</table>

This is a generalized interpretation - individual reserves calls require judgment based on specific data.

### Barnett Shale Decline Curve Performance Analysis

<table>
<thead>
<tr>
<th>Year</th>
<th>Gas EUR (MMCF)</th>
<th>Avg. Lateral Length (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P25</td>
<td>Mean</td>
</tr>
<tr>
<td>2010</td>
<td>4,600</td>
<td>3,700</td>
</tr>
</tbody>
</table>

This is a generalized interpretation - individual reserves calls require judgment based on specific data.
Critical Considerations for Proved Area

- Enough production data to make reasonably certain EUR projections ★★★
  Minimal (months), Sufficient (year), Optimal (years)

- Enough well EUR data to be statistically significant ★★★
  Minimal (<10), Sufficient (~40), Optimal (>100)

- Level of EUR relative to economic (PW10) ★★
  Minimal (P50), Sufficient (P75), Optimal (P90)

- EUR versus demonstrated well spacing ★★★
  Minimal (pilot down spacing), Sufficient (statistically significant developed areas), Optimal (all wells drilled on constant spacing)

- Data supporting hydrocarbons-in-place ★
  Minimal (logs), Sufficient (+ production), Optimal (+ core)

- Data supporting geologic consistency ★
  Minimal (regional mapping), Sufficient (+ local log analysis), Optimal (+ seismically defined structure)

- Data supporting leasehold and certainty of locations being drilled in timely manner ★
  Minimal (say they will), Sufficient (history of drilling), Optimal (corporate level plan)

- Individual reserves calls require judgment based on specific data

★★ Engineering ★★ Geology ★☆ Company
Resources Plays
Example of Leverage with Horizontal Wells

1. Property maturity       Early       Moderate       Mature
2. Data rich/poor          Poor        Good Well Control       Rich
3. Consistency             ?           Good                       Very Good
4. Geologic understanding  Low         Still Learning     High
5. Analogy to other areas  Low         Good               Good
6. Economic robustness     Marginal    Strong (most wells) Very Strong
7. Leverage effect         ?           ?                           ?

“...Evidence using Reliable Technology…”

This is a generalized interpretation - individual reserves calls require judgment based on specific data
Example area for Tiers 1, 2, and 3

This is a generalized interpretation - individual reserves calls require judgment based on specific data.
Significant Local and Regional Data

Enough EUR data to be statistically significant Minimal (4), Sufficient (20), Optimal (100s)

Purple line designates contiguous development areas. The overall Fayetteville trend area has 100s of wells leading to regionally optimal data set. We have some degree of confidence in the regional distribution of EURs.

Local contiguous development areas are defined by grey line areas.

Areas with statistically significant number of PDP wells (1-3 wells per section) would be considered candidates for Tier 1 areas based on the data concentrations only.

Lesser concentrations of data would be considered as Tier 2 and Tier 3 areas where there would be less leverage from a PDP-to-PUD ratio.

Toe-heel PUDs would be considered in Tier 1 and Tier 2 areas where the data are considerably certain.

This is a generalized interpretation - individual reserves calls require judgment based on specific data.
Quantity and Quality of Local Data

Assuming the EUR distribution in these local areas is **significantly** economic, the area within grey lines could be considered proved, and if the data are consistent, additional areas outside the grey but internal to the surrounding data could also be considered proved.

Not all external area between the grey and purple lines would be considered proved but not necessarily excluded from being proved.

This also assumes gas-in-place, geologic consistency, and leasehold and corporate plan are also documented and supported with a degree of certainty.

This is a generalized interpretation - individual reserves calls require judgment based on specific data.
Structure and isopach maps are important in determining the location of potential future wells.
### EXHIBIT 12: STRATIGRAPHY OF THE BARNETT SHALE

<table>
<thead>
<tr>
<th>Period</th>
<th>Group/Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permain</td>
<td></td>
</tr>
<tr>
<td>Leonardian</td>
<td>Clear Fork Grp</td>
</tr>
<tr>
<td></td>
<td>Wichita Grp</td>
</tr>
<tr>
<td>Wolfcampian</td>
<td>Cisco Grp</td>
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<tr>
<td></td>
<td>Strawn Grp</td>
</tr>
<tr>
<td>Virginian</td>
<td>Bend Grp</td>
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<tr>
<td>Missourian</td>
<td>Marble Falls Limestone</td>
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<tr>
<td>Desmoinesian</td>
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<td></td>
<td>Barnett Shale</td>
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<td>Atokan</td>
<td></td>
</tr>
<tr>
<td>Morrowan</td>
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<td></td>
<td>Chappel Limestone</td>
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<tr>
<td></td>
<td>Viola Limestone</td>
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<tr>
<td>Mississippian</td>
<td></td>
</tr>
<tr>
<td>Osagean</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Simpson Grp</td>
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<tr>
<td></td>
<td>Ellenburger Grp</td>
</tr>
<tr>
<td>Ordovician</td>
<td></td>
</tr>
</tbody>
</table>

**Source:** Hayden and Pursell, 2005
**AAPG, 1987**

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### EXHIBIT 13: BARNETT SHALE IN THE FORT WORTH BASIN

80 miles 134 km

**Source:** ALL Consulting, 2009
14,000 Producing wells
5.3 BCFD
9,000 BCF Cumulative Gas
Chronology of Barnett Shale Completion Techniques

Horizontal well (3 well simultaneously completed)
(newer light-sand based fracture stimulation)

Vertical well
(newer light-sand based fracture stimulation)

Vertical Well Refrac
(newer light-sand based fracture stimulation)

Horizontal well
(older gel-based fracture stimulation)

Vertical well
(older gel-based fracture stimulation)
Barnett Shale Type Curve

This is a generalized interpretation - individual reserves calls require judgment based on specific data.
Yearly Gas Ultimate Distribution

Barnett Shale Core Area

<table>
<thead>
<tr>
<th>Year</th>
<th>P10</th>
<th>P25</th>
<th>Mean</th>
<th>P50</th>
<th>P75</th>
<th>P90</th>
<th>Average Lateral Length (Feet)</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre 2007</td>
<td>4.2</td>
<td>3.0</td>
<td>2.3</td>
<td>2.0</td>
<td>1.2</td>
<td>0.6</td>
<td>3,167</td>
<td>1,116</td>
</tr>
<tr>
<td>2007</td>
<td>4.8</td>
<td>3.6</td>
<td>2.6</td>
<td>2.4</td>
<td>1.4</td>
<td>0.8</td>
<td>3,073</td>
<td>1,179</td>
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<td>2008</td>
<td>4.6</td>
<td>3.5</td>
<td>2.6</td>
<td>2.4</td>
<td>1.5</td>
<td>0.9</td>
<td>3,013</td>
<td>956</td>
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<tr>
<td>2009</td>
<td>5.8</td>
<td>4.3</td>
<td>3.3</td>
<td>3.0</td>
<td>1.9</td>
<td>1.2</td>
<td>3,248</td>
<td>477</td>
</tr>
<tr>
<td>2010</td>
<td>6.5</td>
<td>4.6</td>
<td>3.7</td>
<td>3.3</td>
<td>2.3</td>
<td>1.5</td>
<td>3,055</td>
<td>448</td>
</tr>
</tbody>
</table>

Gas EUR (BCF)

This is a generalized interpretation - individual reserves calls require judgment based on specific data
Completion Variability

Gas Ultimate vs. Avg. 3-Month Peak Rate of All Barnett Shale Wells

Peak Monthly Production (MCF/D)

Gas Estimated Ultimate Recovery (MMCF)

- Horizontal Wells
- Vertical Wells
Completion Variability

NSAI Estimates of Barnett Shale Wells

Vertical Wells
Deviated Wells
**Fayetteville Shale**

**EXHIBIT 14: STRATIGRAPHY OF THE FAYETTEVILLE SHALE**

<table>
<thead>
<tr>
<th>Period</th>
<th>Group/Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Atoka</td>
</tr>
<tr>
<td></td>
<td>Bloyd</td>
</tr>
<tr>
<td></td>
<td>Prairie</td>
</tr>
<tr>
<td></td>
<td>Grove</td>
</tr>
<tr>
<td></td>
<td>Cane Hill</td>
</tr>
<tr>
<td></td>
<td>(IMO)</td>
</tr>
<tr>
<td></td>
<td>Pitkin</td>
</tr>
<tr>
<td>Mississippian</td>
<td>Fayetteville</td>
</tr>
<tr>
<td></td>
<td>Batesville</td>
</tr>
<tr>
<td></td>
<td>Moorefield</td>
</tr>
<tr>
<td></td>
<td>Boone</td>
</tr>
</tbody>
</table>

**Source:** Hillwood, 2007

**EXHIBIT 15: FAYETTEVILLE SHALE IN THE ARKOMA BASIN**

**Source:** ALL Consulting, 2009
Fayetteville Production

- 3,000 Producing wells since 2004
- 2.5 BCFD
- 1,700 BCF Cumulative Gas
This is a generalized interpretation - individual reserves calls require judgment based on specific data.
Yearly Gas Ultimate Distribution

Fayetteville Shale Area

<table>
<thead>
<tr>
<th>Year</th>
<th>P10</th>
<th>P25</th>
<th>Mean</th>
<th>P50</th>
<th>P75</th>
<th>P90</th>
<th>Average Lateral Length (Feet)</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre 2006</td>
<td>0.6</td>
<td>0.2</td>
<td>0.2</td>
<td>0.1</td>
<td>0.0</td>
<td>0.0</td>
<td>606</td>
<td>59</td>
</tr>
<tr>
<td>2006</td>
<td>2.3</td>
<td>1.8</td>
<td>1.2</td>
<td>1.1</td>
<td>0.7</td>
<td>0.4</td>
<td>2,074</td>
<td>110</td>
</tr>
<tr>
<td>2007</td>
<td>2.8</td>
<td>2.1</td>
<td>1.5</td>
<td>1.4</td>
<td>0.8</td>
<td>0.4</td>
<td>2,422</td>
<td>411</td>
</tr>
<tr>
<td>2008</td>
<td>4.0</td>
<td>2.9</td>
<td>2.2</td>
<td>2.1</td>
<td>1.3</td>
<td>0.6</td>
<td>3,218</td>
<td>682</td>
</tr>
<tr>
<td>2009</td>
<td>4.5</td>
<td>3.4</td>
<td>2.6</td>
<td>2.4</td>
<td>1.5</td>
<td>0.9</td>
<td>3,938</td>
<td>834</td>
</tr>
<tr>
<td>2010</td>
<td>4.8</td>
<td>3.8</td>
<td>2.9</td>
<td>2.7</td>
<td>1.7</td>
<td>1.1</td>
<td>4,329</td>
<td>846</td>
</tr>
</tbody>
</table>

This is a generalized interpretation - individual reserves calls require judgment based on specific data.
Completion Variability

EUR Estimates of Fayetteville Shale Wells

Gas Estimated Ultimate Recovery (MMCF)

- Deviated Wells
- Vertical Wells

Completion Date

Jan-04 Jan-05 Jan-06 Jan-07 Jan-08 Jan-09 Jan-10
## EXHIBIT 16: STRATIGRAPHY OF THE HAYNESVILLE SHALE

<table>
<thead>
<tr>
<th>Period</th>
<th>Group/Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jurassic</td>
<td></td>
</tr>
<tr>
<td>Upper</td>
<td>Haynesville</td>
</tr>
<tr>
<td></td>
<td>Smackover</td>
</tr>
<tr>
<td></td>
<td>Norphlet</td>
</tr>
<tr>
<td>Middle</td>
<td>Louann</td>
</tr>
<tr>
<td>Lower</td>
<td>Werner</td>
</tr>
<tr>
<td>Triassic</td>
<td></td>
</tr>
<tr>
<td>Upper</td>
<td>Eagle Mills</td>
</tr>
</tbody>
</table>

### Source: Johnson et al., 2000

## EXHIBIT 17: HAYNESVILLE SHALE IN THE TEXAS & LOUISIANA BASIN

Source: ALL Consulting, 2009
Haynesville Shale Gas Play Limits

Source of Data
Base Map: Chesapeake 2008 Investor and Analyst Meeting; Haynesville limits by operator: company presentations
Haynesville Production

800 Producing wells since 2007
3 BCFD
1,200 BCF Cumulative Gas
This is a generalized interpretation - individual reserves calls require judgment based on specific data.
Yearly Gas Ultimate Distribution

Haynesville Shale Area

<table>
<thead>
<tr>
<th>Year</th>
<th>P10 (BCF)</th>
<th>P25 (BCF)</th>
<th>Mean (BCF)</th>
<th>P50 (BCF)</th>
<th>P75 (BCF)</th>
<th>P90 (BCF)</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre 2009</td>
<td>5.6</td>
<td>3.7</td>
<td>2.7</td>
<td>2.2</td>
<td>1.0</td>
<td>0.2</td>
<td>78</td>
</tr>
<tr>
<td>2009</td>
<td>8.1</td>
<td>6.4</td>
<td>5.0</td>
<td>4.5</td>
<td>3.1</td>
<td>2.1</td>
<td>343</td>
</tr>
<tr>
<td>2010</td>
<td>9.8</td>
<td>8.0</td>
<td>6.2</td>
<td>6.0</td>
<td>4.4</td>
<td>2.9</td>
<td>260</td>
</tr>
</tbody>
</table>

This is a generalized interpretation - individual reserves calls require judgment based on specific data.
### EXHIBIT 18: STRATIGRAPHY OF THE MARCELLUS SHALE

<table>
<thead>
<tr>
<th>Period</th>
<th>Group/Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penn</td>
<td>Pottsville</td>
</tr>
<tr>
<td>Miss</td>
<td>Pocono</td>
</tr>
<tr>
<td></td>
<td>Conewango</td>
</tr>
<tr>
<td></td>
<td>Conneaut</td>
</tr>
<tr>
<td></td>
<td>Canadaway</td>
</tr>
<tr>
<td></td>
<td>West Falls</td>
</tr>
<tr>
<td></td>
<td>Sonyea</td>
</tr>
<tr>
<td></td>
<td>Genesee</td>
</tr>
<tr>
<td></td>
<td>Tully</td>
</tr>
<tr>
<td></td>
<td>Hamilton Group</td>
</tr>
<tr>
<td></td>
<td>Moscow</td>
</tr>
<tr>
<td></td>
<td>Ludlowville</td>
</tr>
<tr>
<td></td>
<td>Skaneateles</td>
</tr>
<tr>
<td></td>
<td>Marcellus</td>
</tr>
<tr>
<td></td>
<td>Onandaga</td>
</tr>
<tr>
<td></td>
<td>Tristates</td>
</tr>
<tr>
<td></td>
<td>Heiderberg</td>
</tr>
</tbody>
</table>

Source: Arthur et al, 2008

### EXHIBIT 19: MARCELLUS SHALE IN THE APPALACHIAN BASIN

Source: ALL Consulting, 2009
Marcellus Shale
Range Resources EUR Estimates (January 2009)

Resources Plays – Are All Shale Plays the Same?

Analogy Type Curves – 5 MMCFD

Haynesville Profile
5 MMCFD IP → EUR = 1.7 BCF

Woodford Profile
5 MMCFD IP → EUR = 3.4 BCF

Fayetteville Profile
5 MMCFD IP → EUR = 5.4 BCF

Barnett Profile
5 MMCFD IP → EUR = 5.8 BCF

Marcellus Profile
5 MMCFD IP → EUR = ___ BCF

Note: Above EURs are not indicative of average EURs per resources play

Oldest horizontal production data in each play

Economic Production Limit

Daily Gas Rate (MMCFD)

Time (months)
Shale Gas is Easy?