From Fears of Shortages to Expectations of Plenty: The Paradigm Shift in Natural Gas Supplies

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Unconventional Resources • Enhanced Recovery • Carbon Sequestration
The “Paradigm Shift”

Driven by a new understanding of the size and availability of gas shales and unconventional gas, a “paradigm shift” is underway on natural gas supplies. This “paradigm shift” began a decade ago in the U.S. with only modest fanfare.

- Low cost coalbed methane in the San Juan Basin of Colorado and New Mexico led the way.
- Next was the introduction of highly productive tight gas development at the Jonah and Pinedale fields in western Wyoming.
- Third was the emergence of the Barnett and now the other North American gas shales.
From “Fears of Shortages” to “Expectations of Plenty”

This “paradigm shift” has changed the outlook for U.S. natural gas from “fears of impending shortages” to “expectations of plenty”.

- Instead of declining, U.S. natural gas production increased, from 53 Bcf/d in 2000 to 59 Bcf/d this year.
- Gains in unconventional gas of 20 Bcf/d more than countered declines in onshore and offshore conventional gas.
- Gas shales provide 12 Bcf/d today (20% of domestic natural gas production) account for much of the 20 Bcf/d of the growth.
- Today, unconventional gas provides over 60% of U.S. natural gas production.
Unconventional Gas Is Now the Dominant Source of U.S. Natural Gas Production

The 20 Bcfd growth in unconventional gas production, has more than replaced declines in U.S. conventional onshore and offshore supplies.

*Includes onshore associated, non-associated and Alaska.
How Much Do Gas Shales Contribute Today?

Production of gas shales has grown by ten-fold and is expected to exceed 12 Bcf/d, equal to 20% of U.S. natural gas production this year.

<table>
<thead>
<tr>
<th></th>
<th>2000 (bcf/d)</th>
<th>2009 (p) (bcf/d)</th>
<th>2010 (e) (bcf/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haynesville</td>
<td>0.0</td>
<td>1.0</td>
<td>2.4</td>
</tr>
<tr>
<td>Marcellus</td>
<td>0.0</td>
<td>0.4</td>
<td>1.0</td>
</tr>
<tr>
<td>Woodford</td>
<td>0.0</td>
<td>0.7</td>
<td>0.9</td>
</tr>
<tr>
<td>Fayetteville</td>
<td>0.0</td>
<td>1.4</td>
<td>1.9</td>
</tr>
<tr>
<td>Barnett</td>
<td>0.2</td>
<td>4.8</td>
<td>5.1</td>
</tr>
<tr>
<td>Other</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td><strong>Sub-Total</strong></td>
<td><strong>1.1</strong></td>
<td><strong>9.2</strong></td>
<td><strong>12.2</strong></td>
</tr>
</tbody>
</table>

Source: Advanced Resources International (2010)
What Is Unconventional Gas?

Three natural gas sources comprise today’s unconventional gas. Methane hydrates, a fourth candidate, is not yet ready for “prime time”.

- **TIGHT GAS SANDS**
  - Continuous Deposition
  - Low Permeability
  - Both Traditional and “Basin-Center” Settings

- **COALBED METHANE**
  - Self-Sourcing Reservoir
  - Gas Adsorbed in Coal
  - Requires Depressuring and Usually Dewatering

- **GAS SHALES**
  - Self-Sourcing Plus Traditional Porosity Reservoirs
  - Gas Adsorbed in Organic Matter
  - Requires Pervasive Natural or Created Fracture Network
Addressing the Fundamental Questions

Understanding the future role of gas shales and unconventional gas requires that we address a series of questions:

- How large is the unconventional gas resource base?
- Is it large enough to enable unconventional gas to become a major climate change solution and support exports via LNG?
- How much of it can be converted to productive capacity at affordable prices?
- How much would progress in technology impact the economically affordable resource base?
- Can the resource be developed in an environmentally sound way?
One of the Many Benefits of Bountiful Unconventional Gas Supplies

If abundant and affordable, unconventional gas can provide a major climate change mitigation option for power generation, reducing CO₂ emissions by 70%.

**CO₂/SO₂ Emissions by Fuel Type (lbs of CO₂ & SO₂/BBtu)**

- **Coal**
  - CO₂: 250,000
  - SO₂: 3,000
- **Natural Gas**
  - CO₂: 150,000
  - SO₂: 1,000

**CO₂ Emissions for Electricity (lbs/kwh)**

- **Older, Inefficient Coal Power Plant (@ 30% Efficiency)**
  - 1.09 lbs/kwh
- **New, Efficient Natural Gas Power Plant (@ 55% Efficiency)**
  - 0.33 lbs/kwh

Source: EnCana 2009
How Large is the Gas Shale and Unconventional Gas Resource?

Our in-depth assessments of U.S. gas shale, tight gas sand and coalbed methane basins shows nearly 1,400 Tcf of recoverable resources.

<table>
<thead>
<tr>
<th>Sources</th>
<th>Recoverable Resource*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tcf</td>
</tr>
<tr>
<td>Gas Shales</td>
<td>700</td>
</tr>
<tr>
<td>Tight Gas Sands</td>
<td>567</td>
</tr>
<tr>
<td>CBM</td>
<td>106</td>
</tr>
</tbody>
</table>

*Includes 39 Tcf of gas shales proved reserves, 96 Tcf of tight gas sands proved reserves and 21 Tcf of coalbed methane proved reserves.

In addition, the U.S. recoverable conventional gas resource base (including Alaska) is in excess of 1,200 Tcf.
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U.S. Gas Shale Basins

Eastern U.S. Gas Shale Basins
Mid-2010 Production Rate

- Anadarko – Woodford: 0.1 Bcf/d
- Arkoma – Woodford: 0.8 Bcf/d
- Barnett Shale: 5.1 Bcf/d
- Haynesville Shale: 2.4 Bcf/d
- Fayetteville Shale: 1.9 Bcf/d
- Marcellus Shale: 1.0 Bcf/d
- Utica Shale
- New Albany Shale: 0.3 Bcf/d
- Conasauga Shale
- Lower Huron Shale: 0.4 Bcf/d

Legend:
- Established
- Emerging

Source: Advanced Resources International
Canada’s Horn River and Montney are two of the “Magnificent Seven” gas shale plays.

<table>
<thead>
<tr>
<th></th>
<th>Resource Endowment (Tcf)</th>
<th>Prospective Recoverable Resource (Tcf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horn River</td>
<td>760</td>
<td>130</td>
</tr>
<tr>
<td>Montney*</td>
<td>620</td>
<td>110</td>
</tr>
<tr>
<td>Total</td>
<td>1,380</td>
<td>240</td>
</tr>
</tbody>
</table>

Additional resources exist in the other shale basins of Canada.

Source: Advanced Resources International, 2009
Unconventional gas (particularly the higher quality gas shales) is today the low cost portion of the natural gas price/supply curve.

Prior Perception

New Understanding

Gas Prices

Gas Prices

Gas Resources

Gas Resources
Role of Policies, R&D and Technology

Progress in technology can help unconventional gas remain an affordable resource. Gas shales and unconventional gas are a R&D and policy success story:

- The DOE/NETL helped build the essential resource and science knowledge base.
- The Gas Research Institute and industry launched the early technology demos.
- Section 29 tax credits (now expired) helped attract capital and build economies of scale.

However, we are still in the early, emerging stages of having an optimum set of technologies for the large lower quality portion of the resource.
What Changed the Game?

Horizontal Well with Multi-Stage Fracturing

Natural gas production from shallow, fractured shale formations in the Appalachian and Michigan basins of the U.S. has been underway for decades.

What “changed the game” was the recognition that one could “create a permeable reservoir” and high rates of gas production by using intensively stimulated horizontal wells.
What Changed the Game?

This break-through in knowledge and technology enabled the numerous deep, low permeability gas shale formations to become productive, making the Barnett Shale “the largest natural gas field in Texas”.

Meanwhile, horizontal well lengths and intensity of stimulation continue to evolve.
Case Study of Using Technology to Improve Well Performance and Lower Costs

With emphasis on “learning” and technology, Southwestern Energy has improved the performance of its Fayetteville Shale well by nearly three fold.

<table>
<thead>
<tr>
<th>Time Frame</th>
<th>Wells on Production</th>
<th>Average IP Rate (Mcf/d)</th>
<th>30th Day Rate</th>
<th>60th Day Rate</th>
<th>Average Lateral Length</th>
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<tbody>
<tr>
<td>1st Qtr 2007</td>
<td>58</td>
<td>1,260</td>
<td>1,070</td>
<td>960</td>
<td>2,100</td>
</tr>
<tr>
<td>2nd/3rd/4th Qtr 2007</td>
<td>197</td>
<td>1,770</td>
<td>1,490</td>
<td>1,290</td>
<td>2,500-3,190</td>
</tr>
<tr>
<td>1st Qtr 2008</td>
<td>75</td>
<td>2,340</td>
<td>2,150</td>
<td>1,940</td>
<td>3,300</td>
</tr>
<tr>
<td>2nd/3rd/4th Qtr 2008</td>
<td>254</td>
<td>2,920</td>
<td>2,480</td>
<td>2,200</td>
<td>3,560-3,850</td>
</tr>
<tr>
<td>1st Qtr 2009</td>
<td>120</td>
<td>3,000</td>
<td>2,370</td>
<td>1,880</td>
<td>3,870</td>
</tr>
<tr>
<td>2nd/3rd/4th Qtr 2009</td>
<td>326</td>
<td>3,650</td>
<td>2,710</td>
<td>2,400</td>
<td>4,180</td>
</tr>
<tr>
<td>2nd Qtr 2010</td>
<td>143</td>
<td>3,450</td>
<td>2,610</td>
<td>2,430</td>
<td>4,530</td>
</tr>
</tbody>
</table>
Can These New Natural Gas Resources Be Developed In An Environmentally Sound Way?

As drilling increases and production grows, a harsher spotlight will fall on natural gas. “Green natural gas development” will help put a more environmentally friendly face on this activity.

- Reducing Surface Impacts
- Capturing Methane Emissions
- Assuring Environmentally Safe Wells and Hydraulic Fractures
“Green” Unconventional Gas Development

Reducing Land Use Impacts with Multi-Well Pads and Horizontal Wells

Source: Canadian Association of Petroleum Producers, 2010
Voluntarily Reducing Methane Emissions

• Since 1990, Natural Gas Star partners have eliminated over 500 Bcf of methane emissions from the oil and gas production sector.

• Williams reports 24 Bcf of methane emissions captured with costs of $17 million and revenues of $159 million.

Source: U.S. Environmental Protection Agency (www.epa.gov/gasstar/accomplish.htm)
Protecting the Environment  
(Properly Designing the Well and Monitoring the Frac)

- The well is designed with steel casing and cement to protect groundwater aquifers.
- The shale interval is 5,000 to 10,000 feet below the water table, protected by unfractured strata.
- Real-time micro-seismic monitoring reveals that the fractures remain in the shales, deep underground.
- Disclosure and less environmentally impactful chemicals are increasingly being used.
The Gas Shale Transformation

For more information, please see the recent three-part series on gas shales written by the staff of Advanced Resources International and published in the *Oil and Gas Journal*.

- Article 1 – *Magnificent Seven Shales* (September 28, 2009).
- Article 2 – *Technology; Lessons Learned* (October 5, 2009).
- Article 3 – *Emerging Shales; Environment* (October 19, 2009).
Concluding Remarks

Our work to date shows that the U.S. (and potentially the world) has large supplies of gas shales and unconventional gas. Progress in technology can help make or keep these resources affordable.

With “green development practices”, these resources can be developed in an environmentally sound way.

Bountiful supplies from gas shales and unconventional sources can provide many benefits:

• Promote progress on climate change by substituting natural gas for coal in old, inefficient power plants.
• Increase domestic energy security by replacing imported petroleum for transportation with CNG and low emission power for electric cars.
• Improve the domestic economy from lower energy costs, more domestic jobs and an improved trade balance.