Abstract

Projections by the United States government indicate that annual U.S. gas demand could increase from the current 22 Tcf (trillion cubic feet) to 26 Tcf by the year 2030. This would occur during a period of declining Canadian gas imports and increasing U.S. reliance on LNG imports, a commodity only available in a highly competitive market. The robustness of the North American gas resource base, particularly shale gas, coalbed methane, and tight sands gas needs to be quantified.

Shale gas production, which dates from 1821 in the United States, is now rapidly increasing, accounting for approximately 5% of annual production. The U. S. Energy Information Administration estimates that shale gas production will overtake coalbed methane production by 2025, and will grow from the current 1 Tcf to 2.3 Tcf annually by 2030.

Shale gas is also an increasingly large component of future, technically recoverable resources. Both of these trends are due to improvements in exploration, completion, and production technologies, aided by wellhead price increases.

The latest Potential Gas Committee biennial assessment, (September, 2007), shows an overall increase of 18% (200 Tcf) for total U.S. gas resources. The bulk of this increase is for shale gas resources assessed in the Appalachian, Anadarko, Arkoma, Ft. Worth, and Permian basins. This paper analyses shale gas future potential in light of past production, current proved reserves, and the geological and economic realities of current and emerging Lower-48 U. S. plays.
U.S. Shale Gas Resources: Classic and Emerging Plays, the Resource Pyramid and a Perspective on Future E&P

John B. Curtis, CSM
David G. Hill, EnCana
Paul G. Lillis, USGS
Major U.S. Basins and Shale Plays
Lower-48 Shale Gas Resource Base

264 Tcf Total Producible Shale Gas Resource Base

- Produced ~ 8.5 Tcf
- Proved Reserves ~10.5 Tcf
- Economic Recoverable 53-114 Tcf
- Undiscovered 131.3 Tcf
- Gas-In-Place > 600 Tcf

Increasing development costs, technology needs, and uncertainty.

Modified and Updated from Hill and Nelson, 2000
U.S. Shale Gas Annual Production from Five Principal (Classic) Plays

Modified and updated from Hill and Nelson, 2000
Ausable 9-34 Antrim Shale Natural Gas Production

Cumulative Production = 1.68 Bcf

Data Source: Pi/Dwights Production Database Version 1.7
Shale Gas Annual Production and Energy Information Administration (EIA) Forecast

![Graph showing shale gas annual production and forecast](image-url)
Barnett Shale Annual Natural Gas Production, Fort Worth Basin (Data Source: IHS)
Barnett Shale Annual Producing Well Count, Fort Worth Basin (Data Source: IHS)
Fayetteville Shale Average Daily Production and Producing Well Count (Data Source: IHS)
Fayetteville Shale Monthly Producing Well Count by Type (Data Source: IHS)
Woodford Shale Average Daily Production and Producing Well Count, Arkoma Basin
(Data Source: IHS)
Woodford Shale Monthly Producing Well Count by Type, Arkoma Basin (Data Source: IHS)
Caney Shale Average Daily Production and Producing Well Count, Arkoma Basin (Data Sources: IHS; Cardott, 2007)
Caney Shale Monthly Producing Well Count by Type, Arkoma Basin (Data Source: IHS)
Baxter Shale Average Daily Production and Producing Well Count, Vermillion Basin
(Data Source: IHS)
Average Drill Depth to Selected U.S. Shale-Gas Plays

- Antrim, New Albany
- Lewis, Ohio
- Barnett
- Fayetteville, Caney
- Woodford
- Baxter
- Utica, Floyd, Conasauga, Bend, Pearshall, Gothic Creek
- Barnett, Wolfcamp, Cane
- Mancos, Hiliard

Drilling Depth, Feet
Geochemical Properties of Gas Shales (Modified from Hill and Nelson, 2000)
Hydrogeology of New Albany Shale
(Walters et al., 2000)
Evolution of Antrim Shale Gas (Curtis, 2002)

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### PETROLEUM SYSTEM EVENT
- Source rock
- Reservoir rock
- Seal rock
- Overburden
- Trap formation
- Generation-migration-accumulation
- Preservation time
- Critical moment

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**PALEOZOIC**
- **C**
- **O**
- **S**
- **D**
- **M**
- **P**
- **P**

**MESOZOIC**
- **T**
- **J**
- **K**
- **E**
- **M**

**CENOZOIC**
- **E**
- **M**

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- Deposition
- Fracturing due to HC maturation & regional loading/unloading
- Thermogenic gas
- (Microbial gas)

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**TIME (Ma)**
- 500
- 400
- 300
- 200
- 100
- 0
Elements of a Successful Shale Gas Play

- Organic Richness
- Maturation
- Thickness
- Gas-In-Place
- Mineralogy
- Permeability
- Britteness
- Pore Pressure
- Productivity
Potential Gas Agency
Potential Supply of Natural Gas in the United States

Report of the Potential Gas Committee (December 31, 2006)
Highlights of the 2006 PGC Report

- Historical gas production trends
- Gas shale geology and resource potential
- Realities of developing offshore gas resources
- Canadian resource assessment and E&P
- LNG, methane hydrates and deep gas
- Comparison with NPC and EIA assessments
Proved Reserves vs. Resources

- Known gas reservoirs
- Existing economic conditions
- Existing operating conditions

- Discovered
- Undiscovered
- Effects of technology
- Effects of economics
## Natural Gas Resource Estimates of the PGC, 2006 (mean values)

<table>
<thead>
<tr>
<th>Resource Type</th>
<th>Estimate (Tcf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional Resources</td>
<td>1,154.8</td>
</tr>
<tr>
<td>Coalbed Gas Resources</td>
<td>166.1</td>
</tr>
<tr>
<td>Total U.S. Resources</td>
<td>1,320.9</td>
</tr>
<tr>
<td>Proved Reserves (EIA)</td>
<td>204.4</td>
</tr>
<tr>
<td>Future Supply</td>
<td>1,525.3</td>
</tr>
</tbody>
</table>
Total Traditional Resources (mean values) by category

- Probable (existing fields): 270.1 Tcf
- Possible (new fields): 426.4 Tcf
- Speculative (frontier): 460.7 Tcf
- Total: 1,154.8 Tcf
PGC Resource Assessment 2006

Total Coalbed Gas Resources (mean values) by category

<table>
<thead>
<tr>
<th>Category</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probable (existing fields)</td>
<td>15.5 Tcf</td>
</tr>
<tr>
<td>Possible (new fields)</td>
<td>50.9 Tcf</td>
</tr>
<tr>
<td>Speculative (frontier)</td>
<td>98.9 Tcf</td>
</tr>
<tr>
<td>Total</td>
<td>166.1 Tcf</td>
</tr>
</tbody>
</table>
Regional Resource Comparison

![Bar charts showing potential resources for different regions as of Year-End 2006: Gulf Coast, Rocky Mountain, Mid-Continent, Alaska, Atlantic, Pacific, North Central.](image)

Data source: Potential Gas Committee (2007)

* No resources or negligible quantity estimated.
### Regional Resource Assessment Summary

<table>
<thead>
<tr>
<th>PGC Area</th>
<th>Traditional Resources (Mean, Tcf)</th>
<th>Coalbed Gas Resources (M.L., Tcf)</th>
<th>Total Resources (Tcf)</th>
<th>Region’s Proportion of Total L48</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gulf Coast</td>
<td>329.6</td>
<td>3.4</td>
<td>332.9</td>
<td>31.2%</td>
</tr>
<tr>
<td>Rocky Mountain</td>
<td>233.6</td>
<td>53.6</td>
<td>287.1</td>
<td>26.9%</td>
</tr>
<tr>
<td>Mid-Continent</td>
<td>232.2</td>
<td>7.5</td>
<td>239.7</td>
<td>22.5%</td>
</tr>
<tr>
<td>Atlantic</td>
<td>91.7</td>
<td>17.3</td>
<td>109.0</td>
<td>10.2%</td>
</tr>
<tr>
<td>Pacific</td>
<td>55.5</td>
<td>2.6</td>
<td>58.1</td>
<td>5.5%</td>
</tr>
<tr>
<td>North Central</td>
<td>22.1</td>
<td>16.6</td>
<td>38.6</td>
<td>3.6%</td>
</tr>
<tr>
<td><strong>Total Lower 48</strong></td>
<td><strong>965.6</strong></td>
<td><strong>100.9</strong></td>
<td><strong>1,065.5</strong></td>
<td></td>
</tr>
<tr>
<td>Alaska</td>
<td>193.8</td>
<td>57.0</td>
<td>250.8</td>
<td></td>
</tr>
<tr>
<td><strong>Total U.S. (means)</strong></td>
<td><strong>1,154.8</strong></td>
<td><strong>166.1</strong></td>
<td><strong>1,320.9</strong></td>
<td></td>
</tr>
</tbody>
</table>

Data source: Potential Gas Committee (2007)
References

