Critical Issues Forum

America’s Increasing Reliance on Natural Gas: Benefits and Risks of a Methane Economy

Wifi network: FWC Wireless
Password: (no password needed)
Session 1: Outlook for natural gas supply
John B. Curtis
Colorado School of Mines
U.S. Natural Gas Supply: A View from the Potential Gas Committee

John B. Curtis
Potential Gas Agency
Colorado School of Mines
November 19, 2014
Potential Gas Agency

Proved Reserves vs Resources

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

- Discovered
- Undiscovered
- Effects of technology

Colorado School of Mines
Figure 10. U.S. wet natural gas proved reserves, 1982-2012

Figure 3. Proved reserves of the top five U.S. gas reserve states, 2007-12

Note: Includes natural gas plant liquids.
Figure 13. Proved shale gas reserves of the top six U.S. shale gas states, 2007-12

Classic Shale-Gas Systems of the US: Where Significant Production Began

Fredonia, New York

Monument at Fredonia New York

“The Site of the First Gas Well in the United States. Lighted in Honor of General Lafayette’s Visit, June 4, 1825”

Modified from Hill and Nelson, 2000
Potential Supply of Natural Gas in the United States

Report of the Potential Gas Committee (December 31, 2012)

Washington, D.C.
April 9, 2013
Potential Gas Committee:
100 Volunteer Geoscientists & Petroleum Engineers
Biennial Assessment - since 1964 – of
the Technically Recoverable U. S. Natural Gas Endowment

PGC + EIA Proved Reserves = Potential Future Supply
# Natural Gas Resource Assessment of the Potential Gas Committee, 2013 (mean values)

<table>
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<tr>
<th>Gas Resource</th>
<th>Quantity</th>
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<tr>
<td>Traditional Gas Resources</td>
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<tr>
<td>Coalbed Gas Resources</td>
<td>158.2 Tcf</td>
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<tr>
<td>Total U.S. Gas Resources</td>
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<td>Proved Reserves (EIA)*</td>
<td>322.7 Tcf</td>
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<tr>
<td>Future Gas Supply</td>
<td>2,706.6 Tcf</td>
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Totals are subject to rounding.  
* Latest available value (wet gas), year-end 2012
PGC Resource Assessments, 1990-2012

Total Potential Gas Resources (Mean Values)

Data source: Potential Gas Committee (2013)
Some Elements of a Successful Shale Gas Play

- Productivity
- Organic Richness
- Maturation
- Gas-In-Place
- Permeability
- Pore Pressure
- Brittleness
- Mineralogy
- Thickness
Regional Resource Assessment

Data source: Potential Gas Committee (2013)

* Separately aggregated from all province data.

- U.S. Traditional (mean)*: 2,252.6 Tcf
- U.S. Coalbed (mean)*: 158.2 Tcf
- Grand Total U.S. (mean): 2,383.9 Tcf

Map showing regional gas resources:
- Rocky Mountain: 421.3 Tcf (51.9)
- Pacific: 54.4 Tcf (2.6)
- North Central: 20.8 Tcf (11.6)
- Atlantic: 741.3 Tcf (17.3)
- Mid-Continent: 269.5 Tcf (8.0)
- Gulf Coast: 521.0 Tcf (3.4)
- Alaska: 193.8 Tcf (57.0)

- 20.8
  Traditional Gas Resources, mean value
- 11.6
  Coalbed Gas Resources, “most likely” value; Area mean values not computed
PGC Resource Assessment 2012

Total Traditional Resources (mean values) by category

Data source: Potential Gas Committee (2013)
PGC Resource Assessment 2012

Total Traditional Resources (mean values) by category

- Probable (existing fields): 708.5 Tcf
- Possible (new fields): 952.3 Tcf
- Speculative (frontier): 558.7 Tcf
- Total*: 2,225.6 Tcf

* Separately aggregated value.

Data source: Potential Gas Committee (2013)
PGC Resource Assessment 2012

Total Coalbed Gas Resources (mean values) by category

Data source: Potential Gas Committee (2013)
Total Coalbed Gas Resources (mean values) by category

Probable (existing fields) 14.2 Tcf
Possible (new fields) 48.3 Tcf
Speculative (frontier) 95.8 Tcf
Total* 158.2 Tcf

* Separately aggregated value.

Data source: Potential Gas Committee (2013)
Influences on Future Gas Supply

- Resource Base
- Environmental Issues
- Skilled Workforce
- Technology
- Gas Price
- Regulatory & Land Issues
- Pipeline Capacity
- Rig Availability

Sufficient Supply to Meet Demand
Richard Nehring
Nehring Associates
Fig. 1. Natural Gas Production by Type in the Contiguous U.S., 1960-2006

Sources: Nehring Associates, EIA

- Conventional
- Unconventional
- Transitional
Fig. 2. Natural Gas Production by Type in the Contiguous U.S., 1960-2012

Sources: Nehring Associates, EIA
THE PROMISE

• New technologies have proved their potential

• Increasing production occurring despite plummeting prices

• Therefore [*trumpet flourish]*: 100 years or more of gas supply

• Cornucopia of benefits
THE REALITY

- Geologic constraints – majority of new gas areas are low productivity
- Costs count – recent production increases limited to a few low cost areas
- Low cost areas are geographically limited

- The promise of a 100 years of gas supply is thus a classic overpromote – a myth (in the pejorative sense)
Intelligent Foundations: The Resource Pyramid

Conventional

Unconventional

Source: Steve Holditch, SPE
The U.S. Gas Resource Pyramid
View 1) Reservoir Rock Volume (12:1 Ratio)
The U.S. Gas Resource Pyramid
View 2) Porous Reservoir Rock Volume
(3:1 Ratio)
The U.S. Gas Resource Pyramid

View 3) Recoverable Gas (1:1 Ratio)
HOW MUCH GAS DO WE NEED TO PROVIDE 100 YEARS OF SUPPLY?

- 2500 – 3000 trillion cubic feet (TCF)
- 26.2 TCF (2013 U.S. consumption)
- 2-2.5 X 1200 TCF (US cumulative gas production thru 2013)
- 4-5X 604 TCF (US gas production, 1980-2012)
MASSIVE GAS RESOURCES REQUIRE MASSIVE GAS PLAYS

- Monster Mega (400+ TCF) 1 600 TCF
- Super Mega (100-400 TCF) 3 750
- Large Mega (60-100 TCF) 5 400
- Small Mega (30-60 TCF) 10 450

- Large Major (15-30 TCF) 15 300
- Small Major (3-15 TCF) 20 200

- Total – 2700 TCF (54 plays)
## U.S. MASSIVE GAS PLAY POTENTIAL

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<thead>
<tr>
<th>Category</th>
<th>Count</th>
<th>TCF</th>
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<td>Large Mega (60-100 TCF)</td>
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<td>Small Mega (30-60 TCF)</td>
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<td>Large Major (15-30 TCF)</td>
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<tr>
<td>Small Major (3-15 TCF)</td>
<td>15-20</td>
<td>150-200</td>
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<td><strong>Total:</strong> 700-750 TCF (26-31 plays)</td>
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GEOLOGIC LIMITS ON TECHNOLOGY

- Low porosity (low density)
- Low Total Organic Carbon (TOC)
- Immature or overmature
- High ductility (shales)
- Low pressure (CBM)
KEY LESSONS LEARNED

• Variability within plays and the ability to map, explain, and predict this variability
• Salience of well density and completion practices
• Importance of cost of production
  – Supply curve instead of technically recoverable resources

• Development of assessment methods that incorporate these lessons
SHALE GAS

• Largest of new resources (includes tight oil)
• Not enough mega plays
  – Marcellus: only super mega play
  – Only four other mega plays: Barnett, Eagleford, Haynesville, and Utica
• Only a few other major plays
• Cumulative (thru 2012): 67 TCF
• Ultimate potential: 460-760 TCF
TIGHT SANDSTONES/CARBONATES

• Mostly major plays – at least 24
  – Only two (barely) possible mega plays

• Leading source of unconventional production thru 2010

• Mostly mature – majority of plays developed and peaked between 1995 and 2005

• Cumulative (thru 2012): 140 TCF

• Ultimate Potential: 270-340 TCF
COALBED METHANE

• Most disappointing unconventional resource
• Only one mega play (Fruitland CBM)
• Four small major plays
• Most remaining potential is high cost
• Cumulative (thru 2012): 31 TCF
• Ultimate Potential: 56-70 TCF
TRANSITIONAL RESOURCES

• Limited – major geological constraints
  – Deepwater – low thermal gradient
  – Deep/Ultra Deep - poor reservoir quality and thermal destruction
• All have peaked (Deep in 1970s!)
• Cumulative (thru 2012): 55 TCF
• Ultimate Potential: 77-100 TCF
CONVENTIONAL RESOURCES

• Great resource, but highly mature

• Few sizeable discoveries in the past 25 years

• Cumulative (thru 2012): 882 TCF

• Ultimate Potential: 975-1050 TCF
REMAINING US GAS RESOURCES BY BROAD TYPE

- Conventional: 93-168 TCF
- Transitional: 22-45 TCF
- Unconventional: 549-926 TCF
- Total: 664-1139 TCF

(27-46 years @ 25 TCF/year)
IMPLICATIONS: PRODUCTION AND PRICES

- Production likely to plateau by 2020
- Production greater than 25 TCF/year likely to be maintained only to 2025-2040
- Low cost (<$4/Mcf) resources will be largely developed by 2020; gas development from 2020 to 2030 will need $5-8/Mcf prices
- Because post-2020 wells will have lower productivity, maintaining production will require more rigs drilling for natural gas
IMPLICATIONS: DEMAND

- Expanding markets for natural gas is an idea whose time has gone.
- Increasing use for transportation would require displacing traditional uses.
- Gas supply insufficient and too expensive to displace coal and nuclear for generation.
- Other than pipeline exports to eastern Canada and Mexico, exports (specifically LNG) are not good for domestic consumers.
CONCLUSIONS

• Expanded domestic gas resources are not a game-changer; they only provide us with a long extra-period

• A natural gas economy for the United States is not a possibility if it is to be based primarily on domestic gas resources
L. Renee Orr
Bureau of Ocean Energy Management
American Geosciences Institute
America’s Increasing Reliance on Natural Gas: Benefits and Risks of a Methane Economy

Renee Orr
Chief, Office of Strategic Resources
Bureau of Ocean Energy Management
U.S. Department of the Interior

November 19-20, 2014
“(T)he outer Continental Shelf is a vital national resource reserve held by the Federal Government for the public, which should be made available for expeditious and orderly development, subject to environmental safeguards, in a manner which is consistent with the maintenance of competition and other national needs” [emphasis added]

Outer Continental Shelf Lands Act
Sec. 3.(3)
The Bureau of Ocean Energy Management (BOEM) promotes energy independence, environmental protection, and economic development through responsible, science-based management of offshore conventional and renewable energy resources.
BOEM’s Expertise & Scope

- Over 50 years’ experience in regulating offshore oil and gas operations
- Responsible for 1.7 billion acres on the Outer Continental Shelf (OCS)
- Administers 33 million leased acres; 6,200 active leases
- Approximately 3,200 production structures with over 34,000 wells
- Over 161 different companies operating on the Federal OCS
Use of Resource Estimates

- **Pre-lease**
  - Identification of favorable areas
  - Forecasting OCS activity levels
  - Estimation of revenue
  - Environmental analysis
  - Energy policy planning

- **Post-lease**
  - Assure fair value in public/private transactions
  - Estimation of revenue
  - Estimation of reserves
Undiscovered Technically and Economically Recoverable Gas on the OCS
Natural Gas Production: Federal Offshore and Total U.S.

<table>
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<th>Year</th>
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<td>5.3%</td>
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</table>
Natural Gas Production: Federal Offshore and Total U.S.
• Advanced subsea technology and innovative extended architecture systems can enable more cost-effective development and production of natural gas in new frontier regions located in deep water and in deeper reservoirs.

• Innovative seismic technologies continue to improve subsurface imaging on the OCS and are pivotal to the discovery of additional hydrocarbon resources.

• Beginning in 2020 and up to 2050, natural gas production on the OCS has the potential to increase significantly as future deep water Gulf of Mexico Lower Tertiary discoveries are developed and access to OCS areas currently unavailable are considered for leasing.

• BOEM has also completed an assessment of natural gas hydrate resources on the OCS in anticipation of hydrates becoming a potential resource in the long term.
Other

- Engagements with academic institutions including UT, SIO, LSU, Ohio State U., Oregon State U., Columbia, Rice, etc.
- Consortium for Ocean Leadership (June, 2013) – steering committee for Field Research Plan
- June, 2014 – Co-Op project with Scripps Inst. of Oceanography to study methane hydrate offshore southern California using Electromagnetic technologies
- GOM JIP Leg II Science Party and Exec Board
- Spring, 2013 – BOEM co-sponsors Multi-component and High-Res data acquisition at sites in deepwater GOM
Methane Hydrate – natural gas hosted in an ice-like lattice structure in high pressure / low temperature environments on the US OCS

- Likely several hundred thousand TCF in-place globally
- BOEM participates in the larger Federal effort to coordinate our R&D and Resource Assessment
- Commercial production from offshore methane hydrate reservoirs is likely 10 – 20 years out
- Japanese gov’t has proven production technologies from marine methane hydrate reservoirs
  - >700,000 ft3/day (short term test)
  - $122,000,000 budget for 2014
- BOEM has Int’l involvement with several foreign entities, including Indian Government (DGH) through formal MOU
Assessment of In-Place Gas Hydrate Resources of the Lower 48 United States Outer Continental Shelf

Natural gas hydrates are ice-like crystalline substances occurring in nature where a solid-water lattice accommodates gas molecules (primarily methane, the major component of natural gas) in a cage-like structure known as a clathrate.

Using a mass balance assessment methodology, the Bureau of Ocean Energy Management estimated a mean of 51.3 trillion cubic feet of in-place gas hydrate resources in the Federal Outer Continental Shelf of the Lower 48 United States.

Introduction

This report summarizes the results of the Bureau of Ocean Energy Management (BOEM) assessment of the undiscovered in-place gas hydrate resources for those areas of the U.S. Outer Continental Shelf (OCS) adjacent to the Lower 48 states and within the limits of the 200 nautical mile U.S. Exclusive Economic Zone (EEZ). Figures 1a, 1b, 1c. Gas hydrate resources on the U.S. OCS adjacent to Alaska have not yet been assessed in this effort. The OCS comprises that portion of the subseafloor seabed whose mineral existence is subject to Federal jurisdiction. This assessment represents a comprehensive appraisal of relevant data and information available from a variety of proprietary and non-proprietary data sources.

Gas hydrate resources are assessed in in-place volumes and reported as the amount of natural gas that resides in the form of gas hydrate in any reservoir in the subsurface of the OCS, without regard to technical recoverability. This differs from BOEM's assessments of conventional oil and gas resources (e.g., BOEM Fact Sheet RS2-2011-01), where undiscovered oil and gas resources are reported as technically recoverable and economically recoverable volumes. BOEM does not report the larger in-place volume of undiscovered conventional oil and gas resources. Gas hydrate resources on the OCS are assessed using a spatially resolved mass balance model that incorporates uncertainty at various levels of model component input. The stochastic nature of the assessment approach provides a range of resources at the model cell level and at levels aggregated to greater geographic extent. More detailed information about the methodology and assessment methodology will be made available in separate national and regional assessment reports.

Figures 1a and 1b. In-place gas hydrate volume distribution for the Atlantic (top) and Pacific OCS (bottom). Red colors indicate maximum accumulations; blue colors indicate minimal accumulations.
David Pursell
Tudor, Pickering, Holt & Co.
Natural Gas Thoughts

November 19, 2014

*Disclosures begin on page 8
2014 Injections +3.5bcfd vs Norms

- Consistent top of the range injections through majority of injection season reflect a market over-supplied by 3.5bcfd
- These extraordinary inventory builds are allowing absolute storage levels to rebound from Polar Vortex induced record draws last winter

![Total Natural Gas Injections Graph]

Source: EIA, TPH Research
Drop to Long-term $4.00 Price on Improving Well Economics

Note: every $10/bbl increase in NGL pricing lowers gas break-evens by 50c

Source: TPH Research
## TPH Gas Production Forecast - Grouped

### Graph

![Graph showing gas production forecast grouped by regions](image)

### Table

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### Source

EIA, TPH Research

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## TPH Gas Production Forecast - Grouped

### Gas Production (Bcf/d)

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### Y/Y Change (Bcf/d)

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<td>(0.5)</td>
<td>(0.4)</td>
<td>(0.1)</td>
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<td>(0.2)</td>
<td>(0.2)</td>
<td>(0.3)</td>
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### Gas Price

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Source: EIA, TPH Research
TPH Gas Production Forecast

Production Growth (2013 vs. 2020)

Source: EIA, TPH Research
# TPH Gas Production Forecast

## Production Growth (2013 vs. 2020)

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<td>1,805</td>
<td>1,805</td>
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<td>3,193</td>
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TPH Forecast: 60,765 62,785 67,441 70,672 71,279 75,447 78,541 80,906 84,947 89,373 93,622 97,176 25,897

Source: EIA, TPH Research
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