Critical Issues Forum

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

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Session 1:

Outlook for natural gas supply

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John B. Curtis
Colorado School of Mines

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U.S. Natural Gas Supply: A View from the Potential Gas Committee

John B. Curtis
Potential Gas Agency
Colorado School of Mines

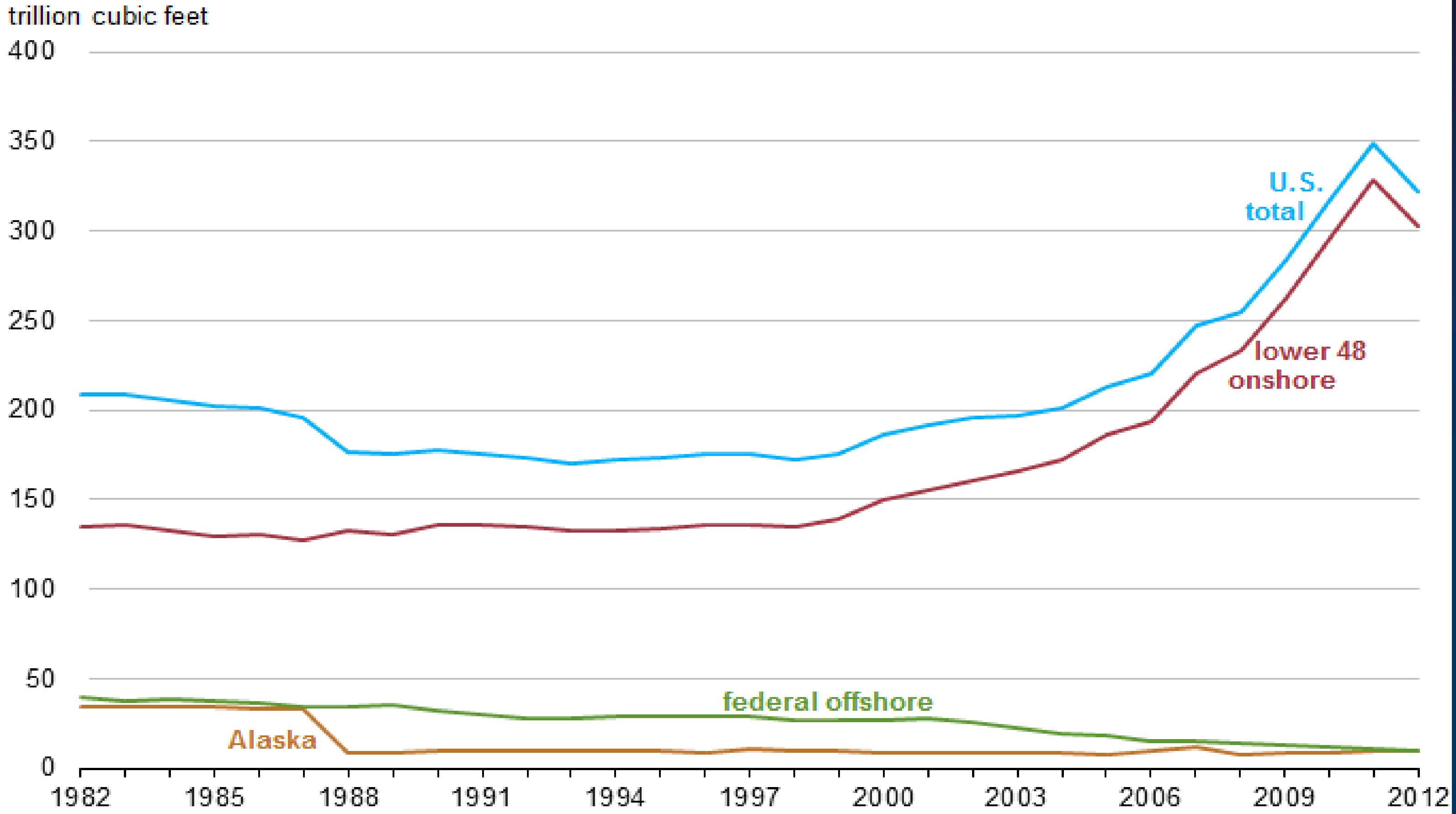
November 19, 2014

Proved Reserves vs Resources

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

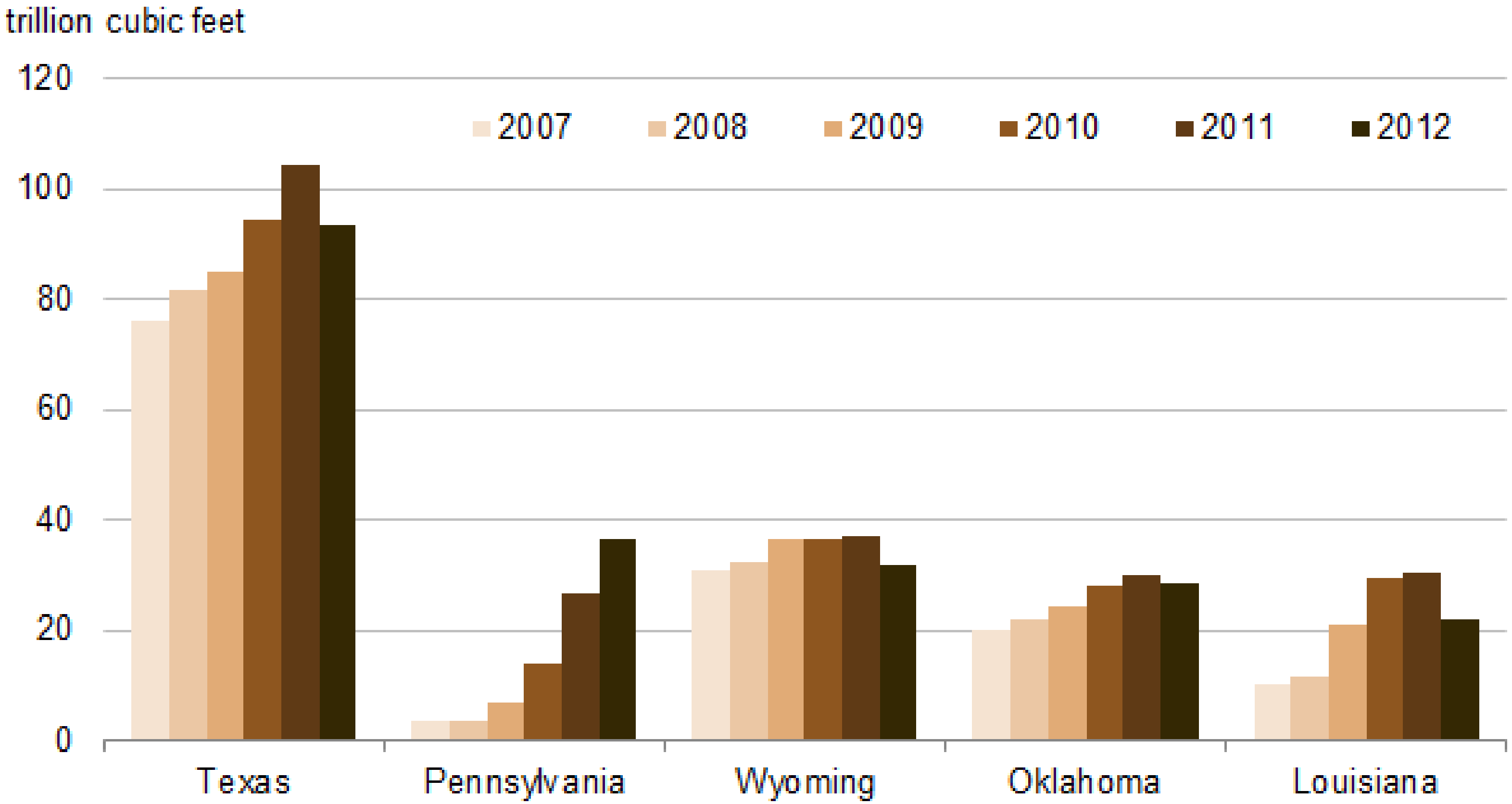
- Discovered
- Undiscovered
- Effects of technology

Figure 10. U.S. wet natural gas proved reserves, 1982-2012



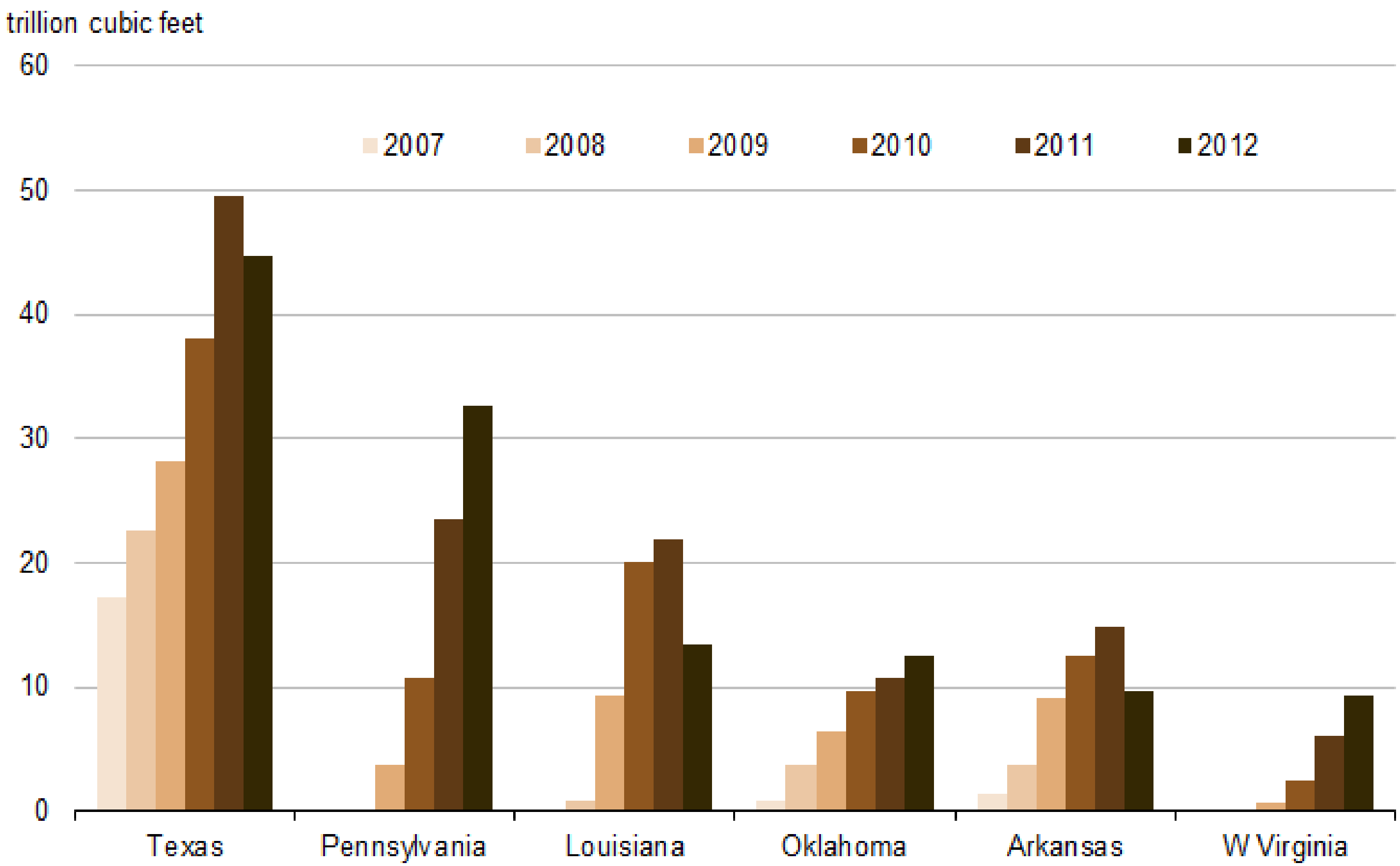
Source: U.S. Energy Information Administration, Form EIA-23, "Annual Survey of Domestic Oil and Gas Reserves," 1982-2012.

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



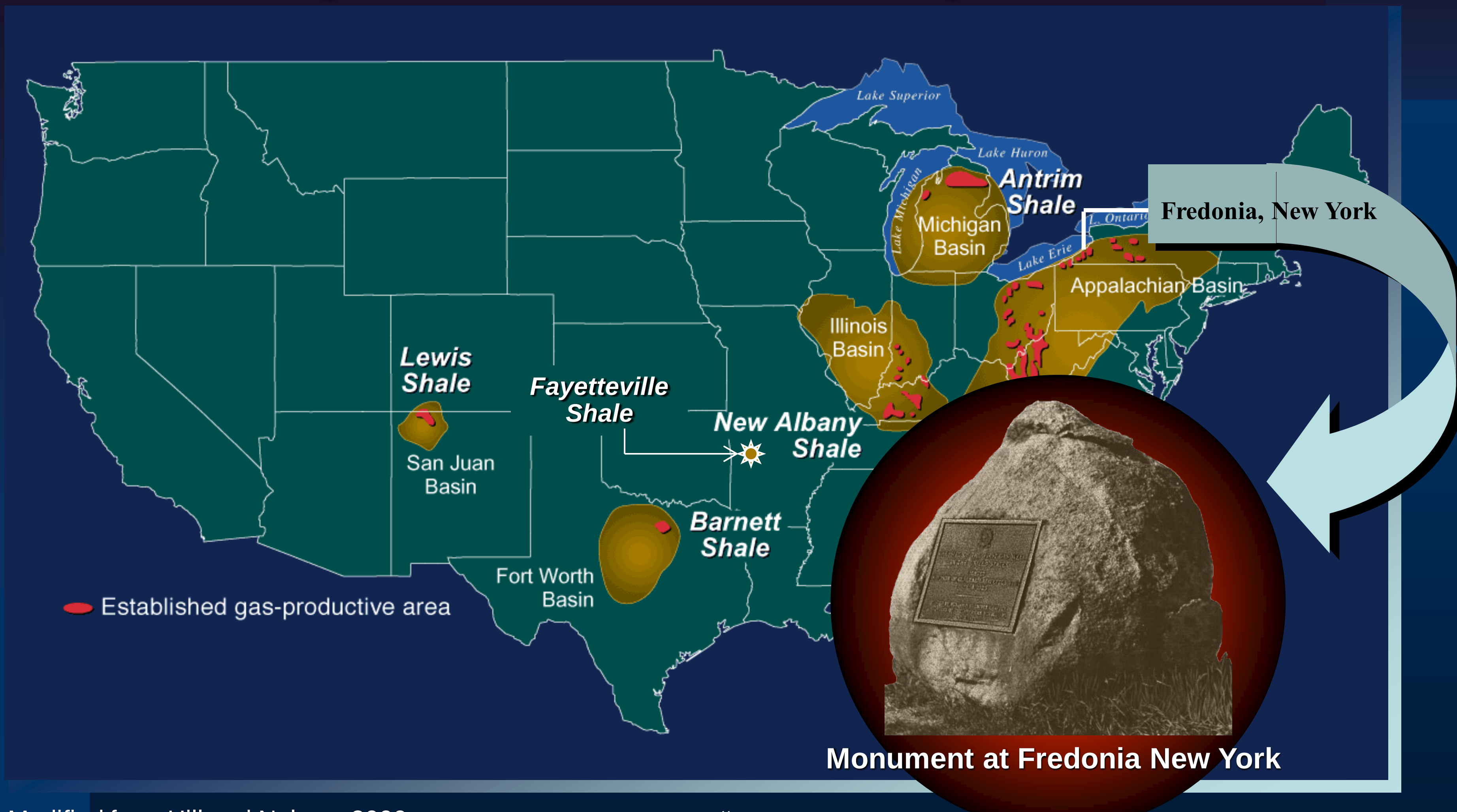
Note: Includes natural gas plant liquids.
Source: U.S. Energy Information Administration, Form EIA-23L, "Annual Survey of Domestic Oil and Gas Reserves," 2007-12.

Figure 13. Proved shale gas reserves of the top six U.S. shale gas states, 2007-12



Source: U.S. Energy Information Administration, Form EIA-23, "Annual Survey of Domestic Oil and Gas Reserves," 2007-12.

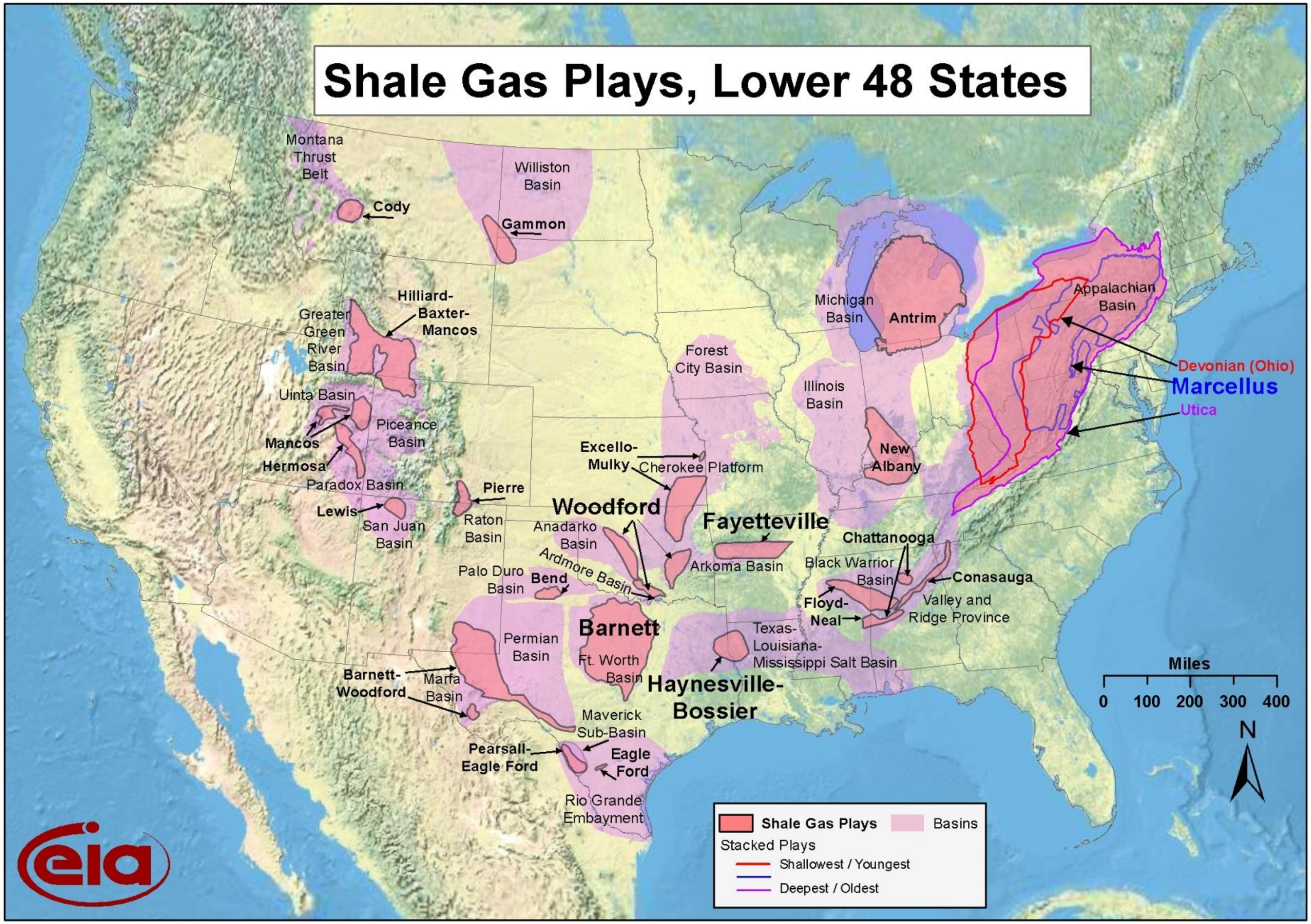
Classic Shale-Gas Systems of the US: Where Significant Production Began



Modified from Hill and Nelson, 2000

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

Location of U.S Shale Gas Plays



Source: Energy Information Administration based on data from various published studies.
Updated: March 10, 2010

U.S. Energy Information Agency, March 2010

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

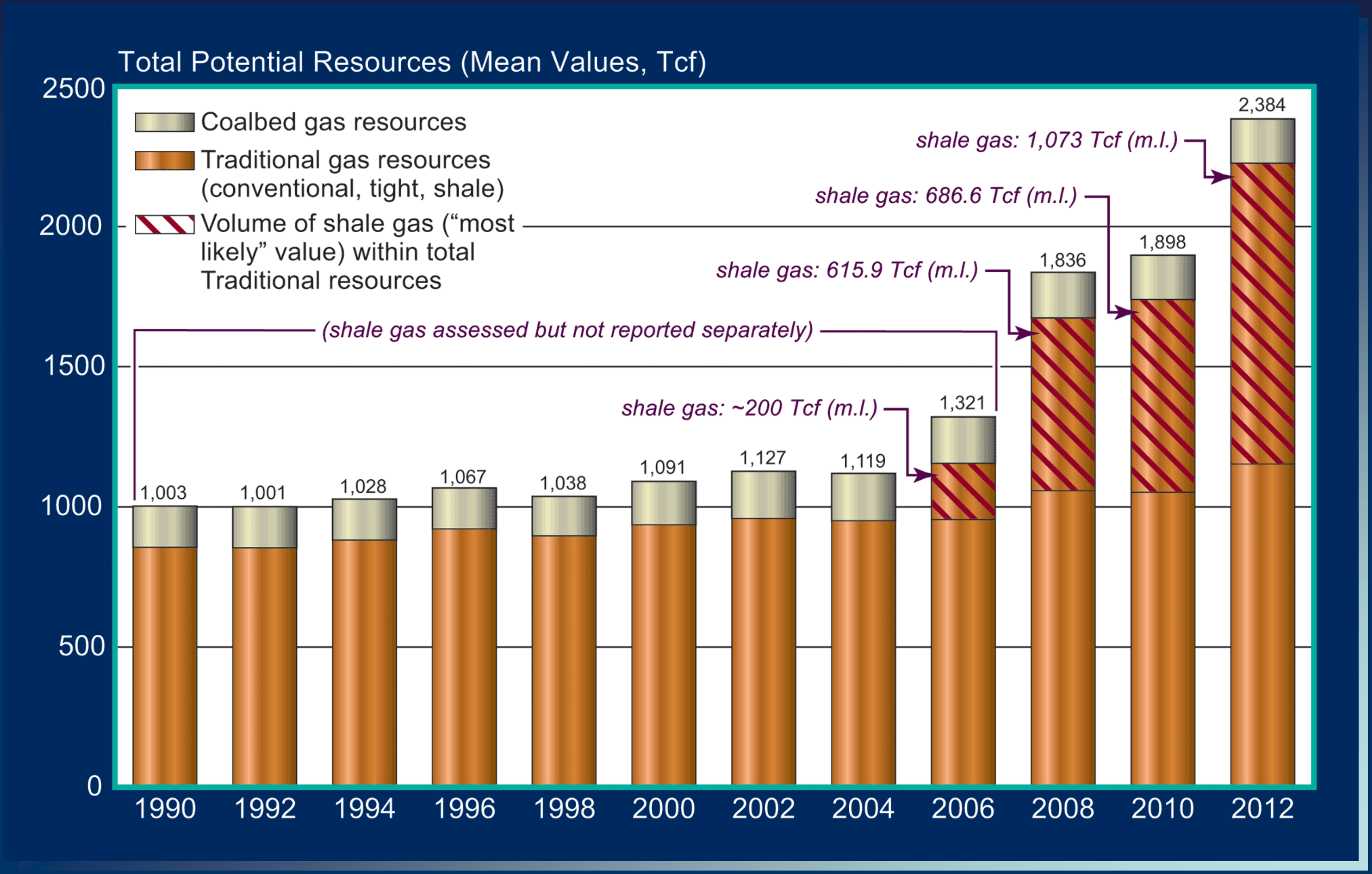
Natural Gas Resource Assessment of the Potential Gas Committee, 2013 (mean values)

Traditional Gas Resources	2,225.6 Tcf
Coalbed Gas Resources	158.2 Tcf
Total U.S. Gas Resources	2,383.9 Tcf
Proved Reserves (EIA)*	322.7 Tcf
Future Gas Supply	2,706.6 Tcf

Totals are subject to rounding.
* Latest available value (wet gas), year-end 2012

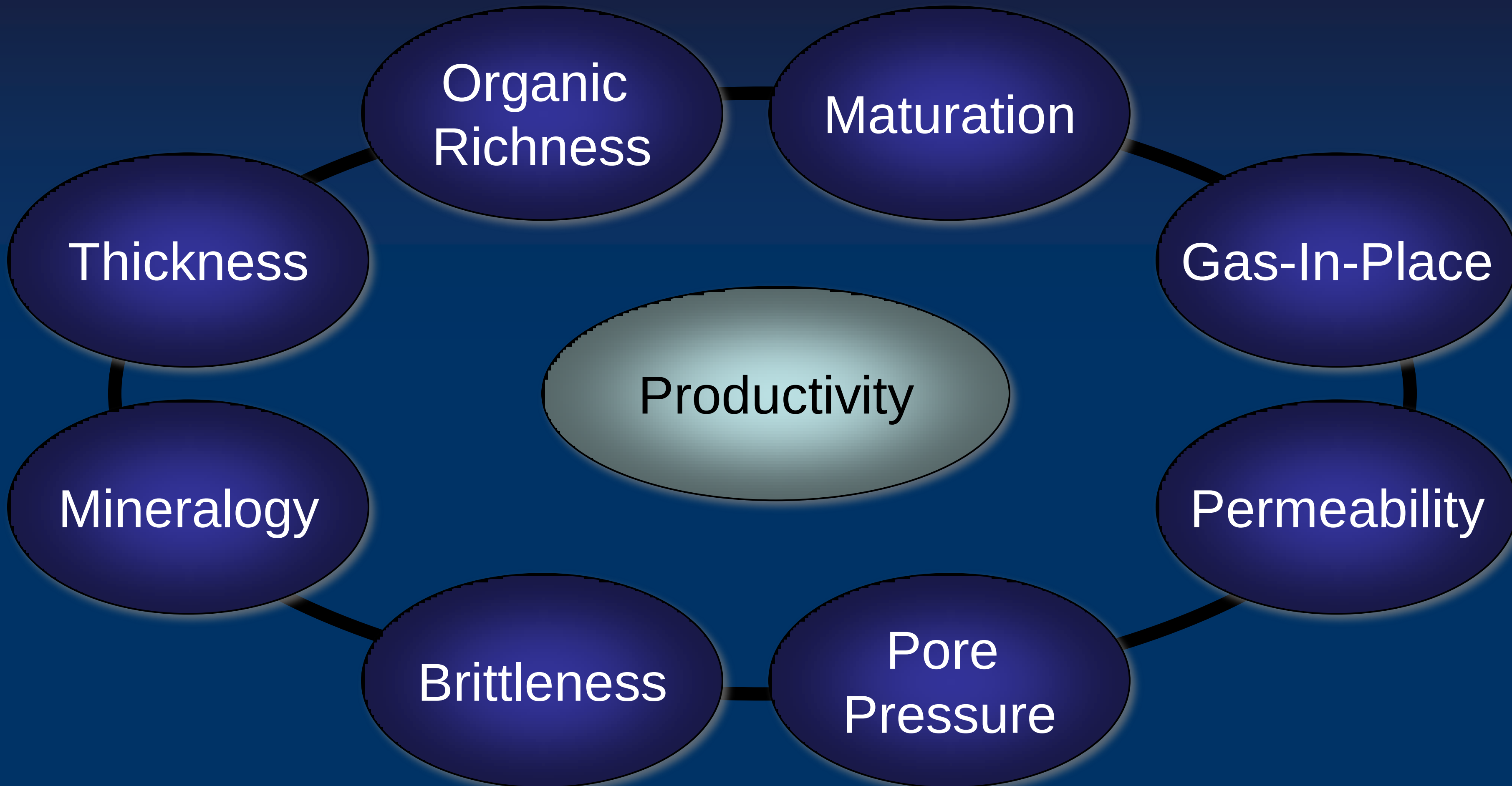
PGC Resource Assessments, 1990-2012

Total Potential Gas Resources (Mean Values)

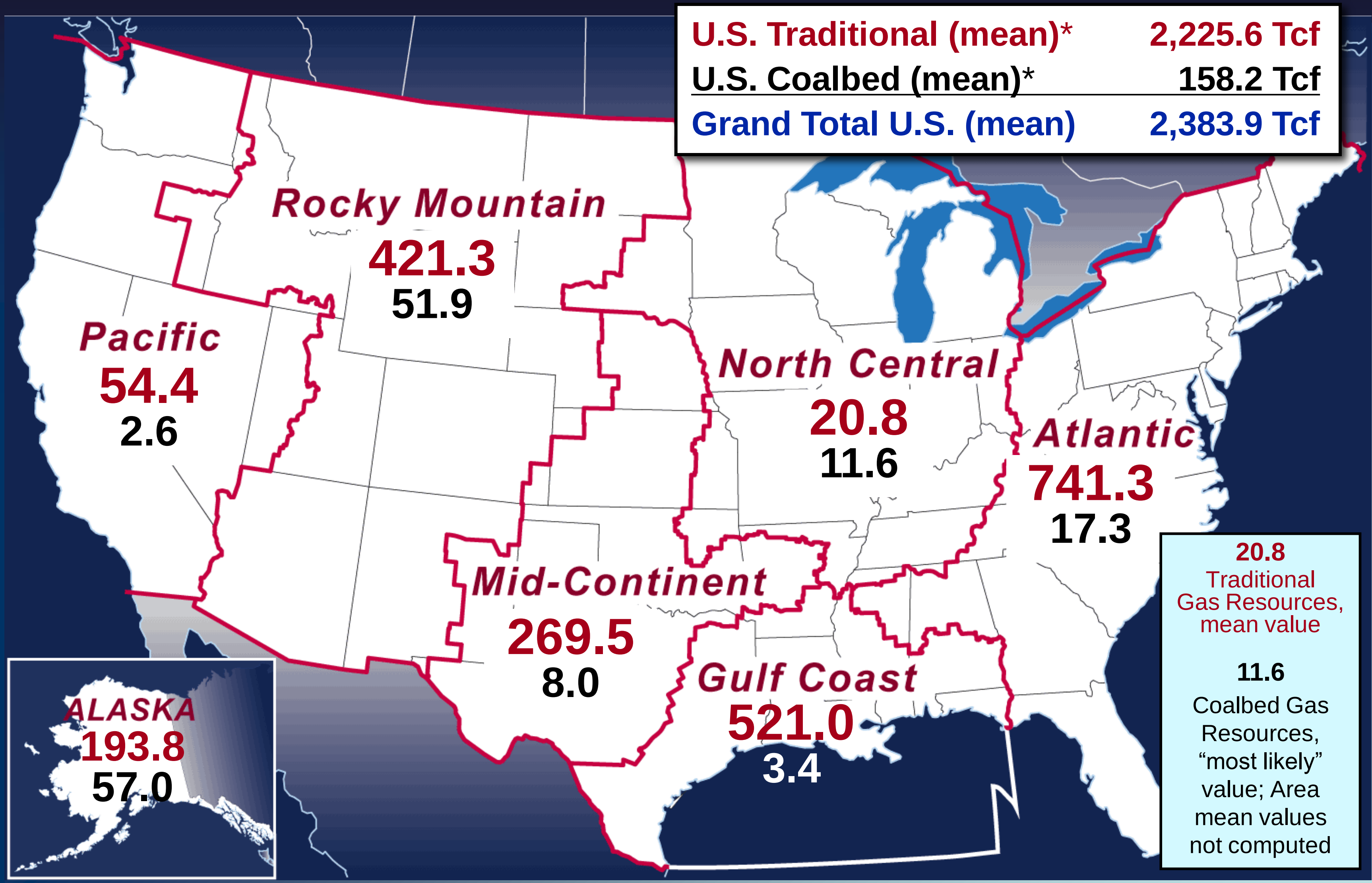


Data source: Potential Gas Committee (2013)

Some Elements of a Successful Shale Gas Play



Regional Resource Assessment

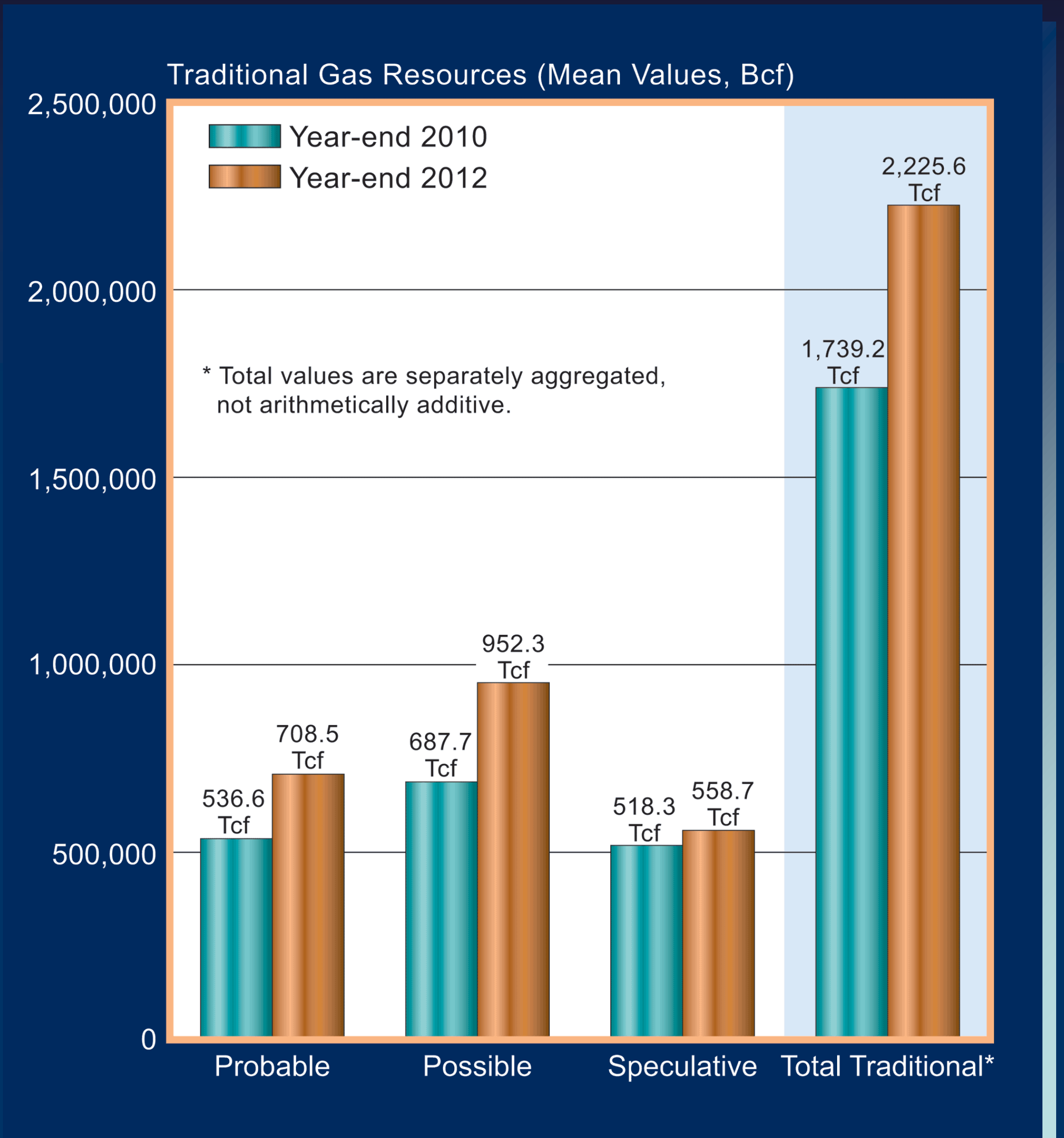


Data source: Potential Gas Committee (2013)

* Separately aggregated from all province data.

PGC Resource Assessment 2012

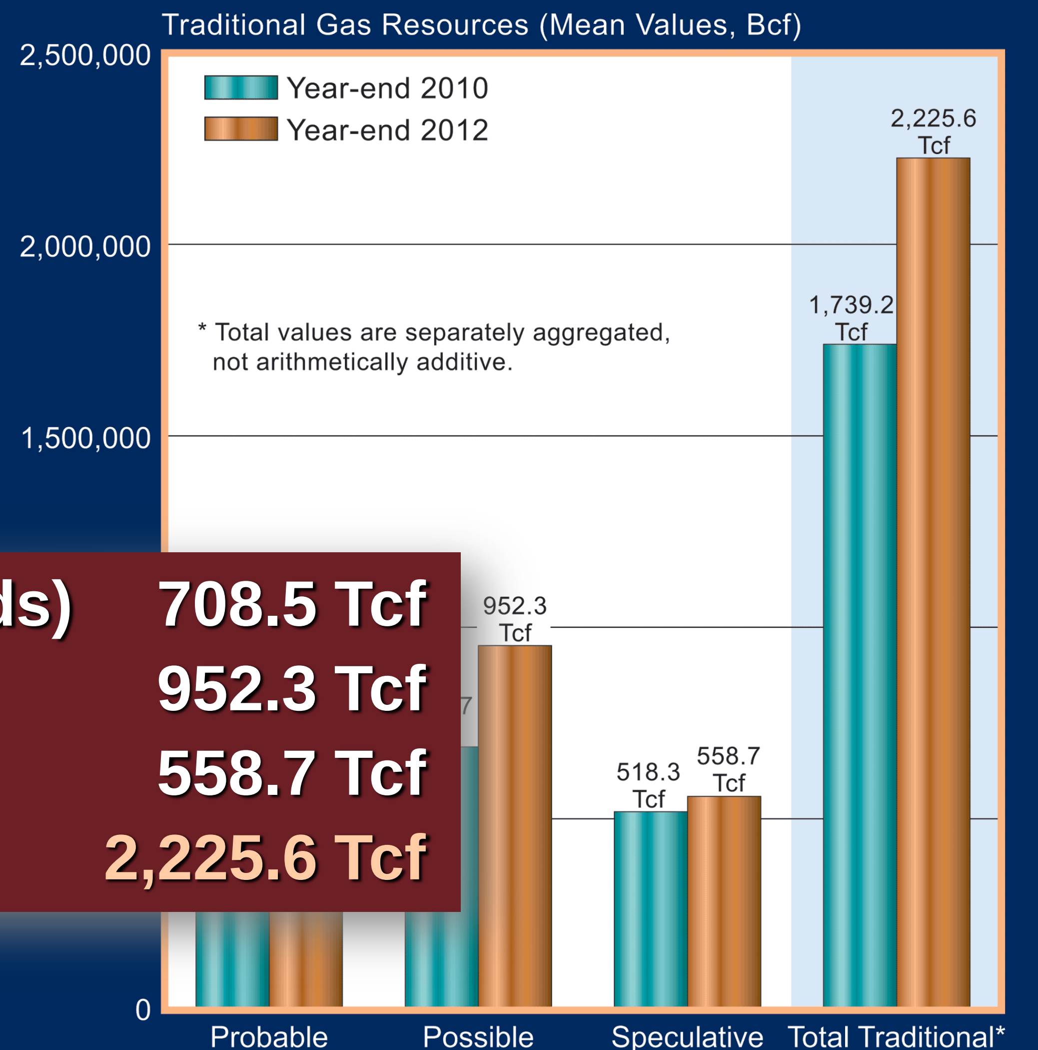
Total Traditional Resources (mean values) by category



Data source: Potential Gas Committee (2013)

PGC Resource Assessment 2012

Total Traditional Resources (mean values) by category



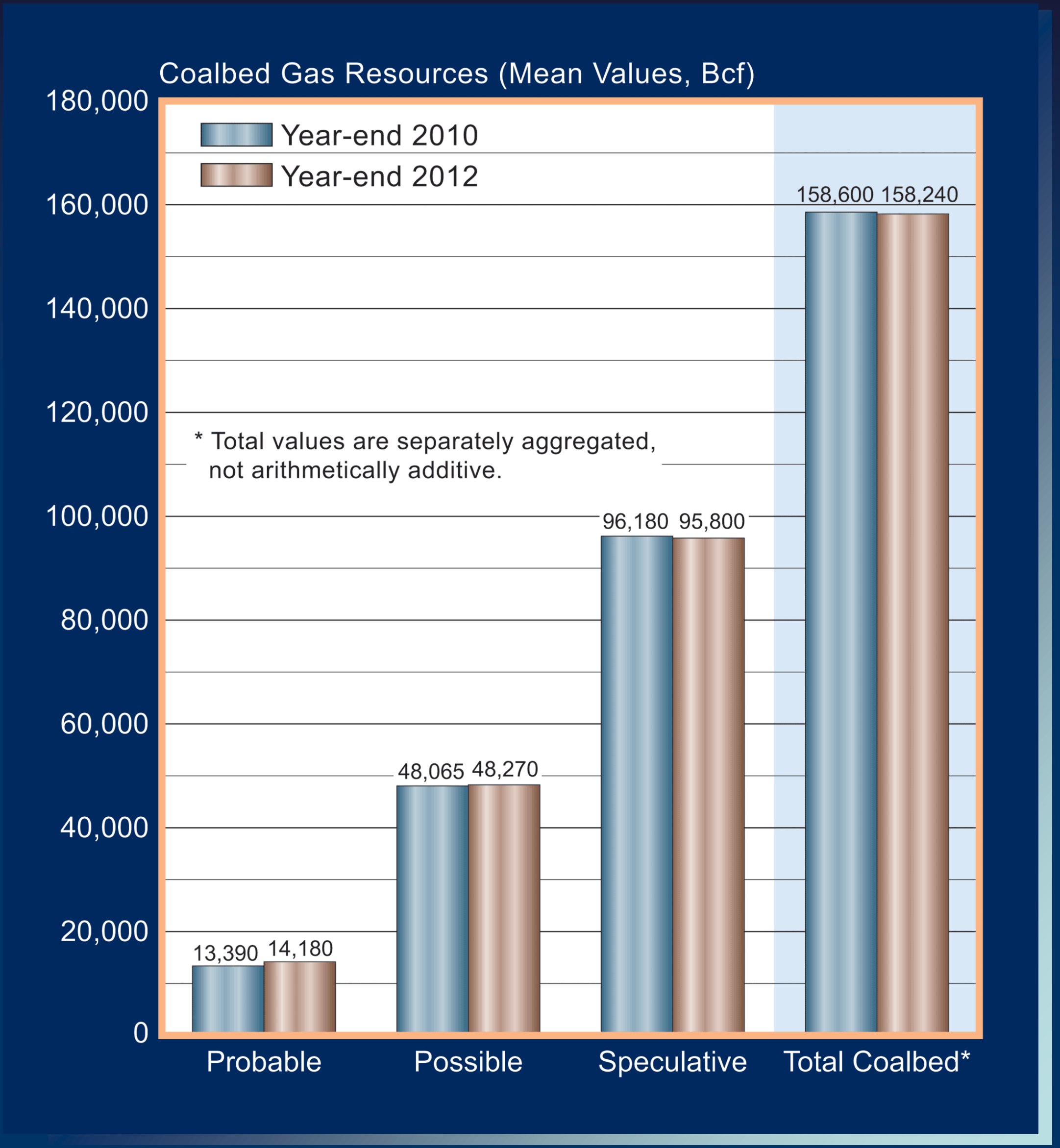
Probable (existing fields)	**708.5 Tcf**
Possible (new fields)	**952.3 Tcf**
Speculative (frontier)	**558.7 Tcf**
Total*	**2,225.6 Tcf**

* Separately aggregated value.

Data source: Potential Gas Committee (2013)

PGC Resource Assessment 2012

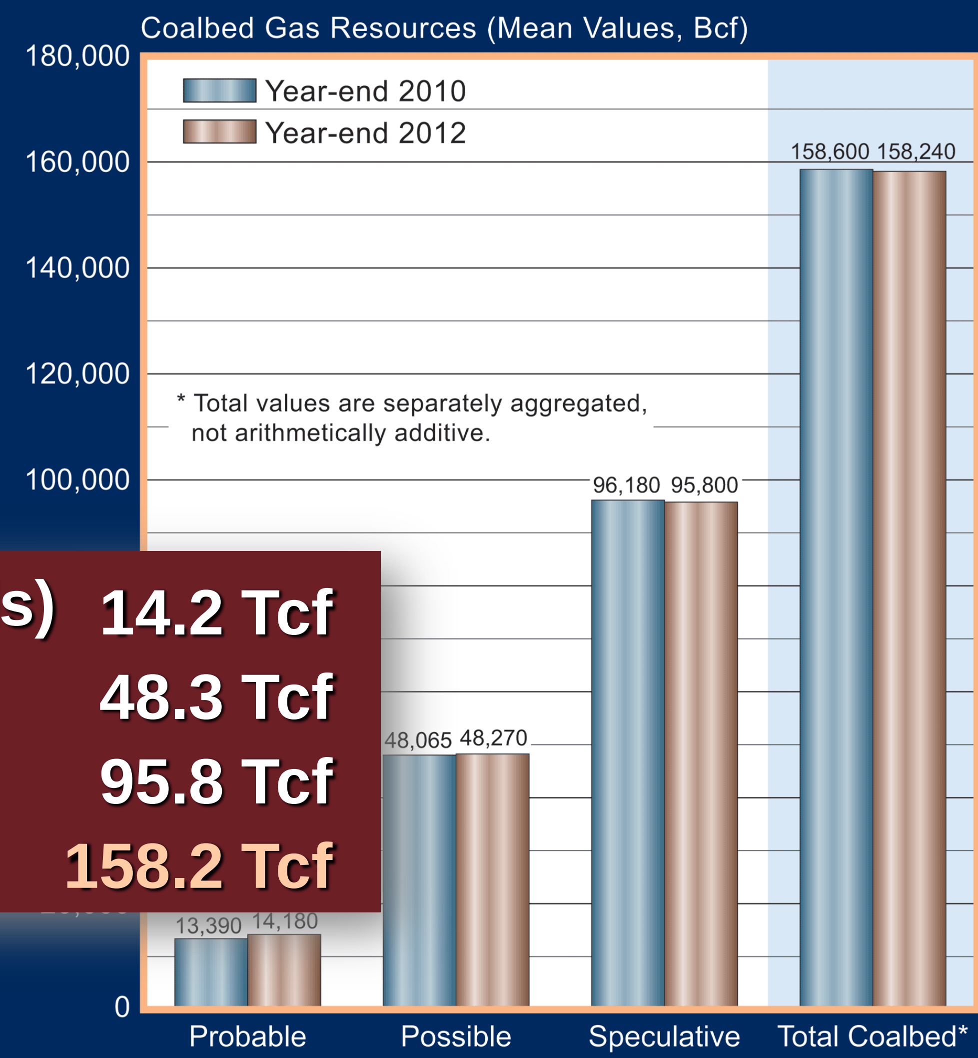
Total Coalbed Gas Resources (mean values) by category



Data source: Potential Gas Committee (2013)

PGC Resource Assessment 2012

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

Potential Gas Agency

Richard Nehring

Nehring Associates

american geosciences institute

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THE MYTH OF 100 YEARS OF GAS SUPPLY

AGI Forum, Fort Worth, TX

November 19, 2014

Richard Nehring

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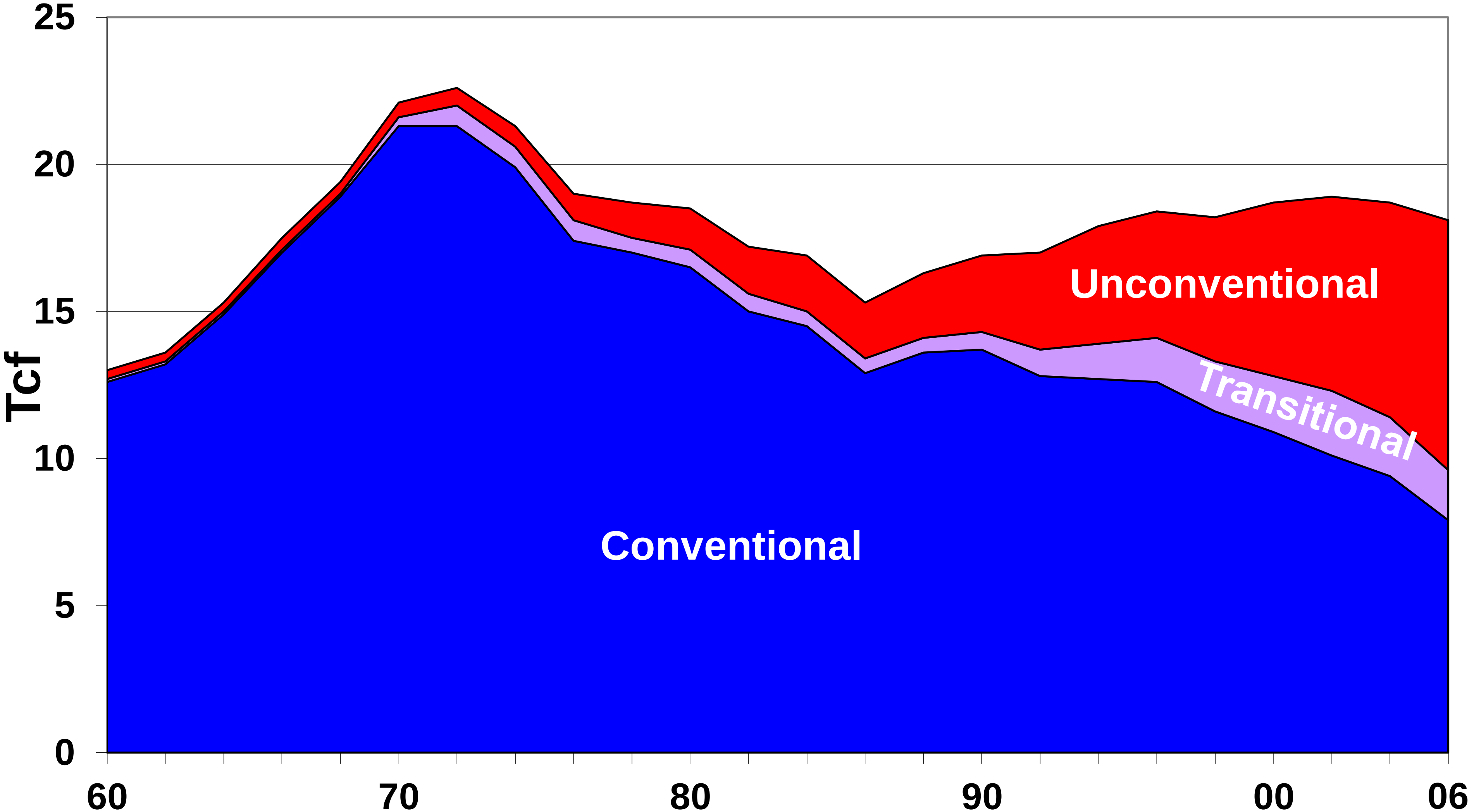
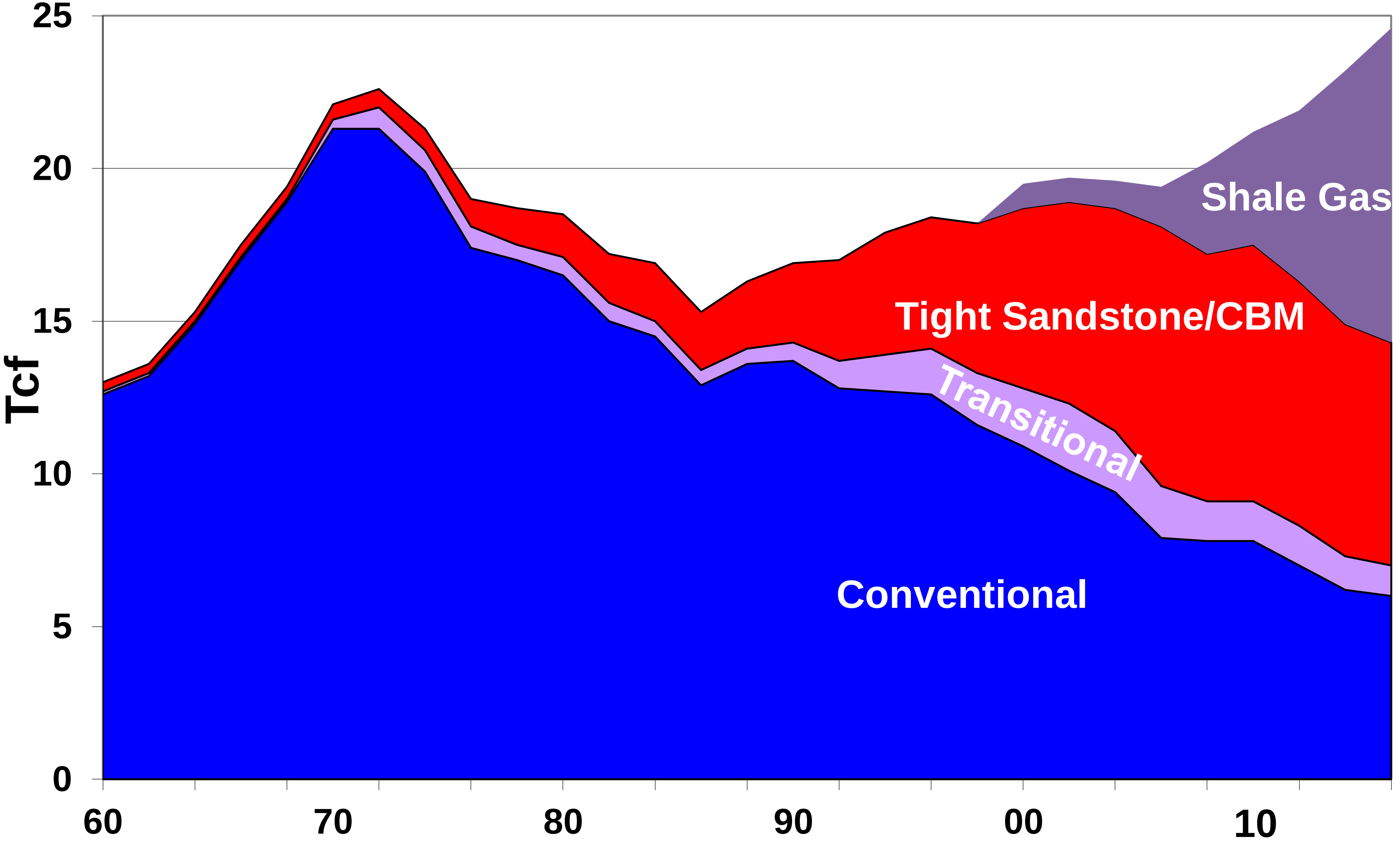
Fig. 1. Natural Gas Production by Type in the Contiguous U.S., 1960-2006



Sources: Nehring Associates, EIA

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

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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)

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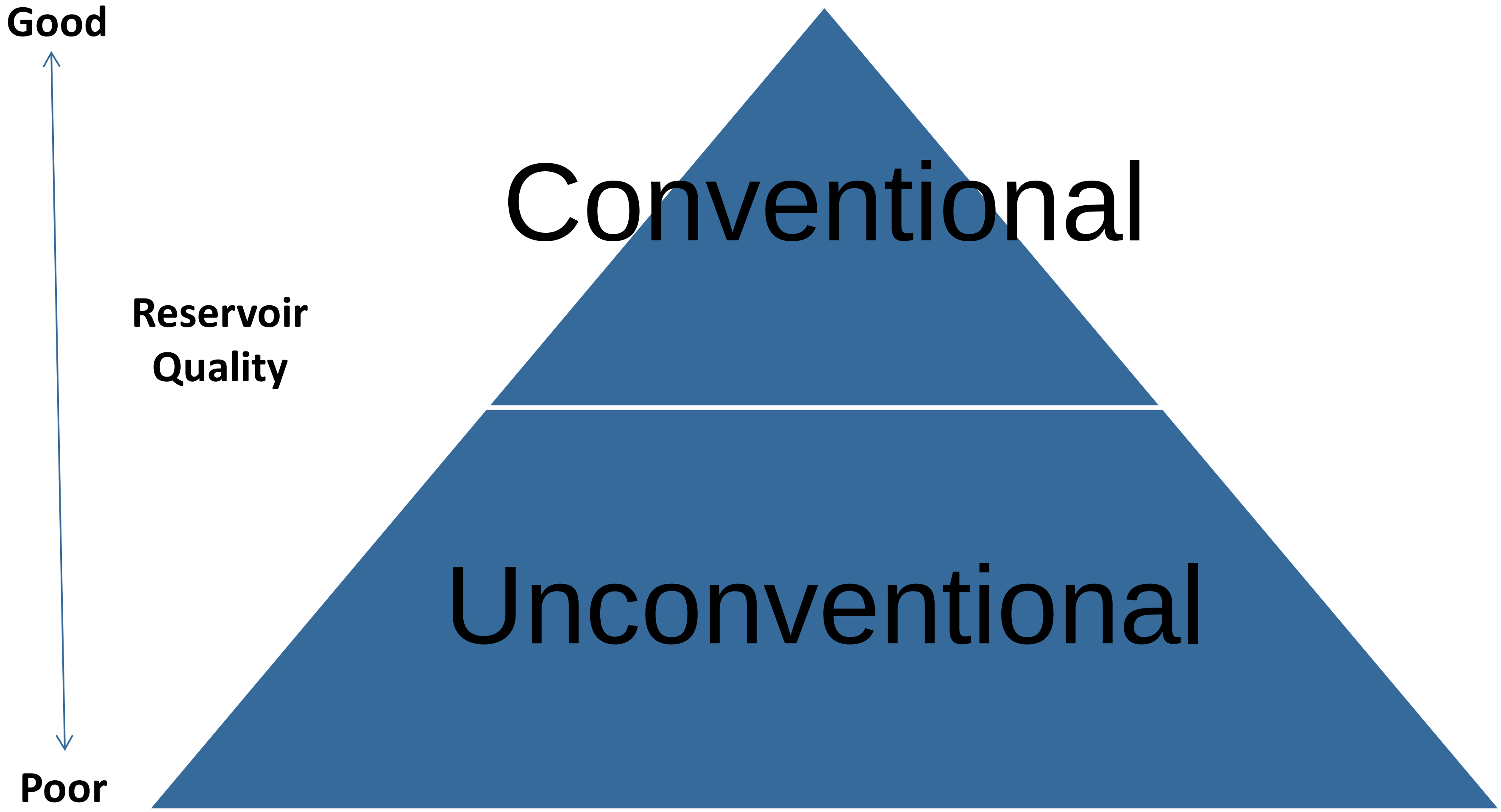
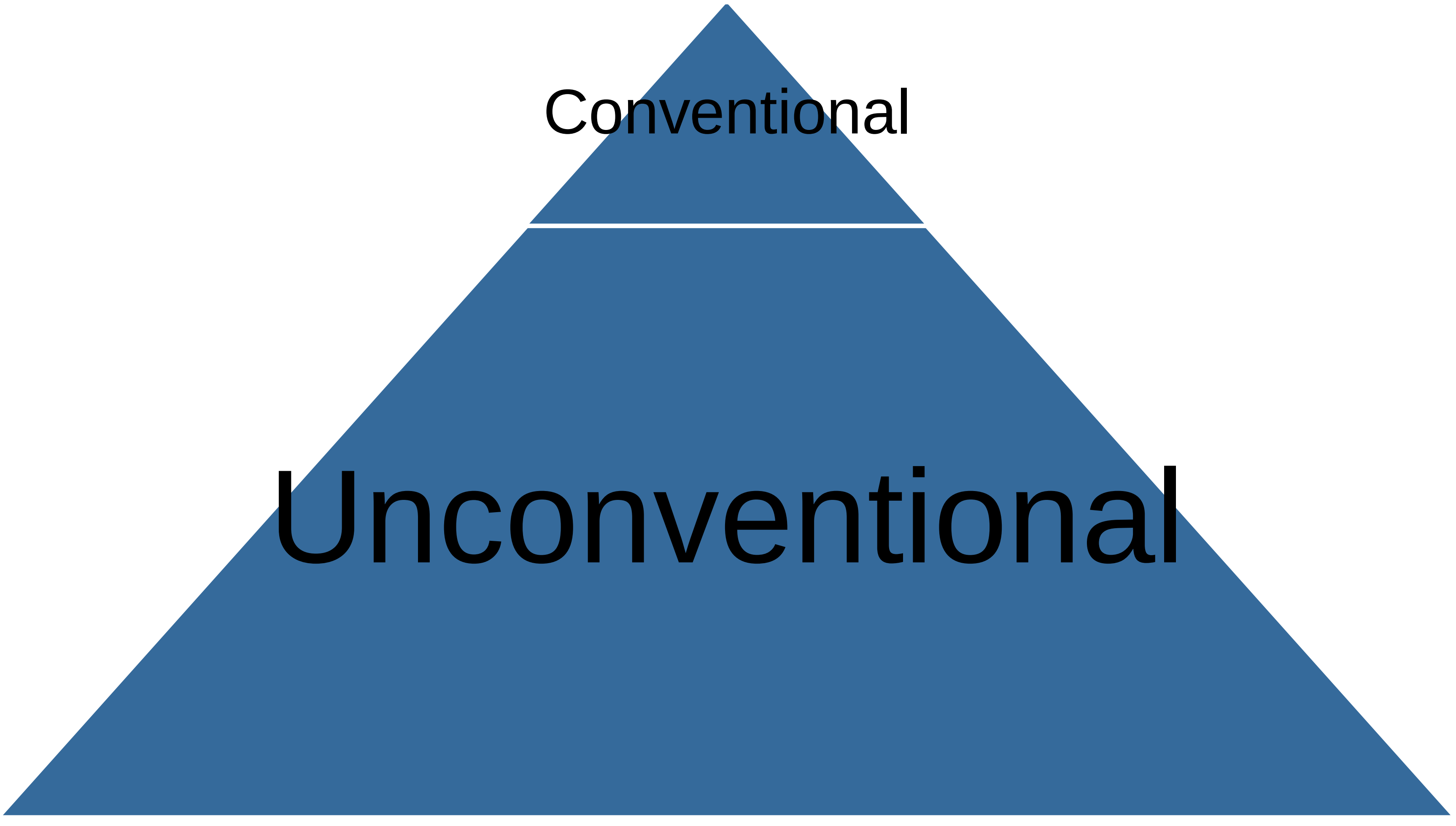
Intellectual Foundations: The Resource Pyramid

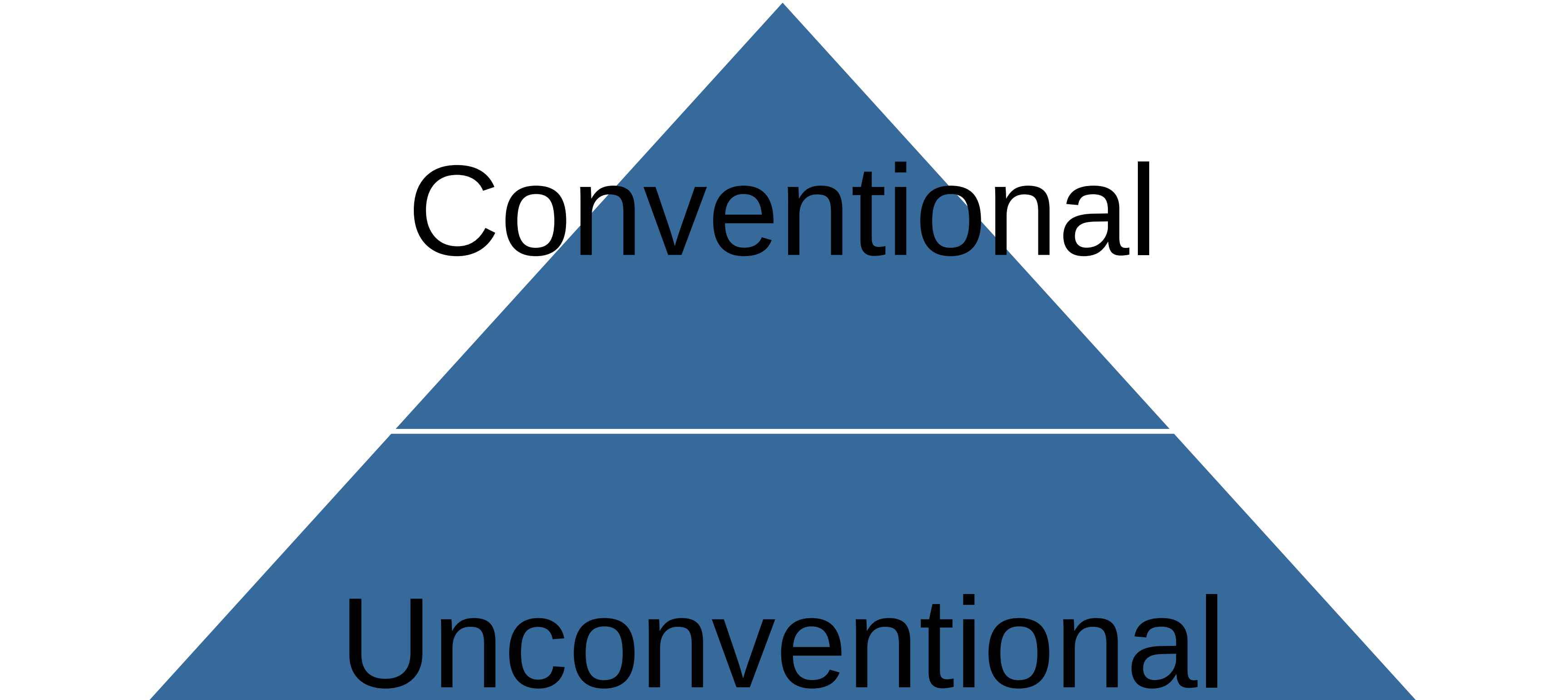


Source: Steve Holditch, SPE

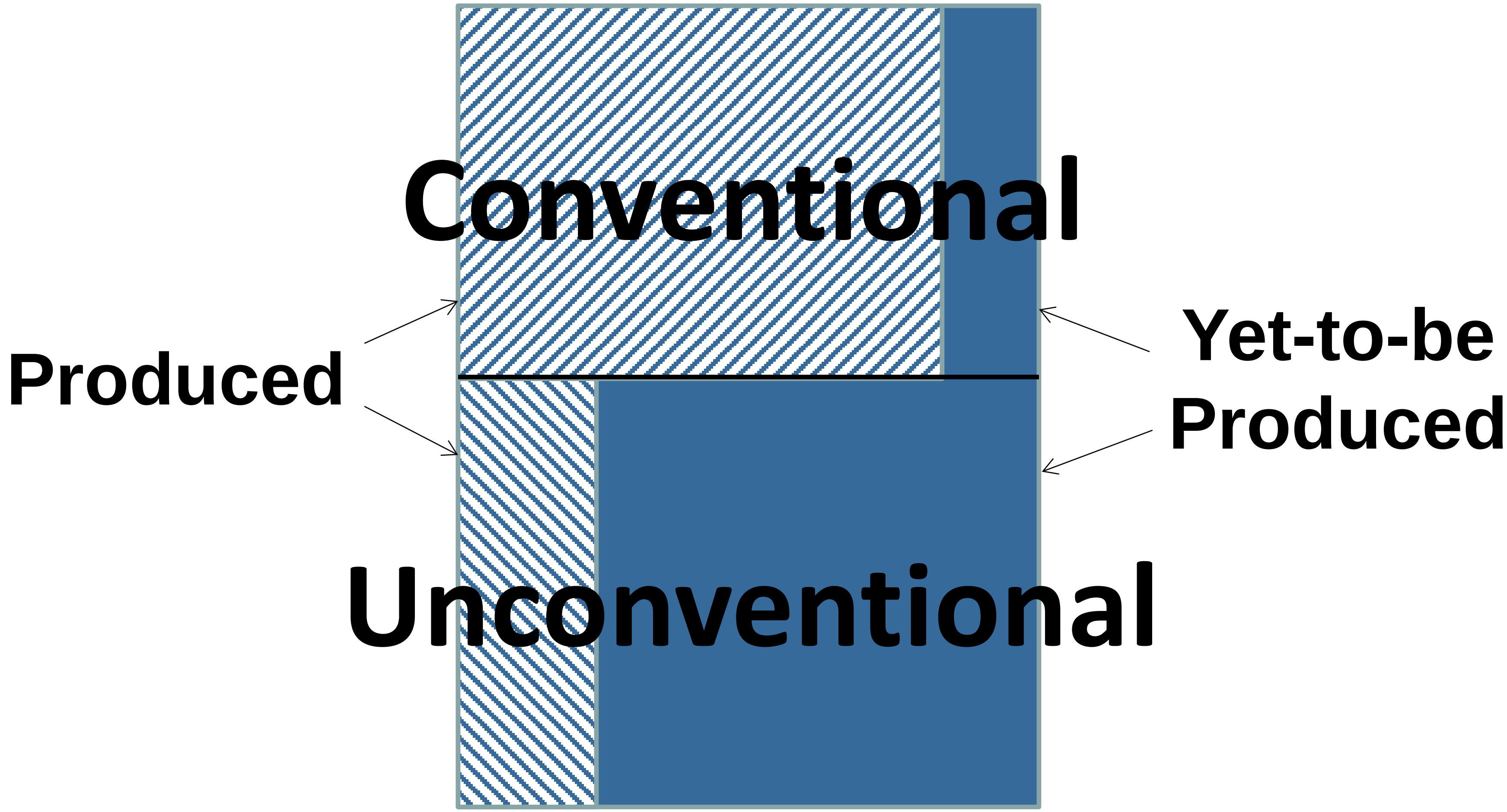
The U.S. Gas Resource Pyramid
View 1) Reservoir Rock Volume (12:1 Ratio)



The U.S. Gas Resource Pyramid
View 2) Porous Reservoir Rock Volume (3:1 Ratio)



The U.S. Gas Resource ~~Pyramid~~ Rectangle 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)

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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)

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U.S. MASSIVE GAS PLAY POTENTIAL

- Monster Mega (400+ TCF) 0 0 TCF
- Super Mega (100-400 TCF) 1 250
- Large Mega (60-100 TCF) 0 0
- Small Mega (30-60 TCF) 4 180

- Large Major (15-30 TCF) 6 120
- Small Major (3-15 TCF) 15-20 150-200
- Total: 700-750 TCF (26-31 plays)

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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)

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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

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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) posible 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

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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

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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

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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

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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)

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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

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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

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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

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L. Renee Orr

Bureau of Ocean Energy Management

BOEM
Bureau of Ocean Energy Management

U.S. Department of the Interior

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

National Policy

"(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]

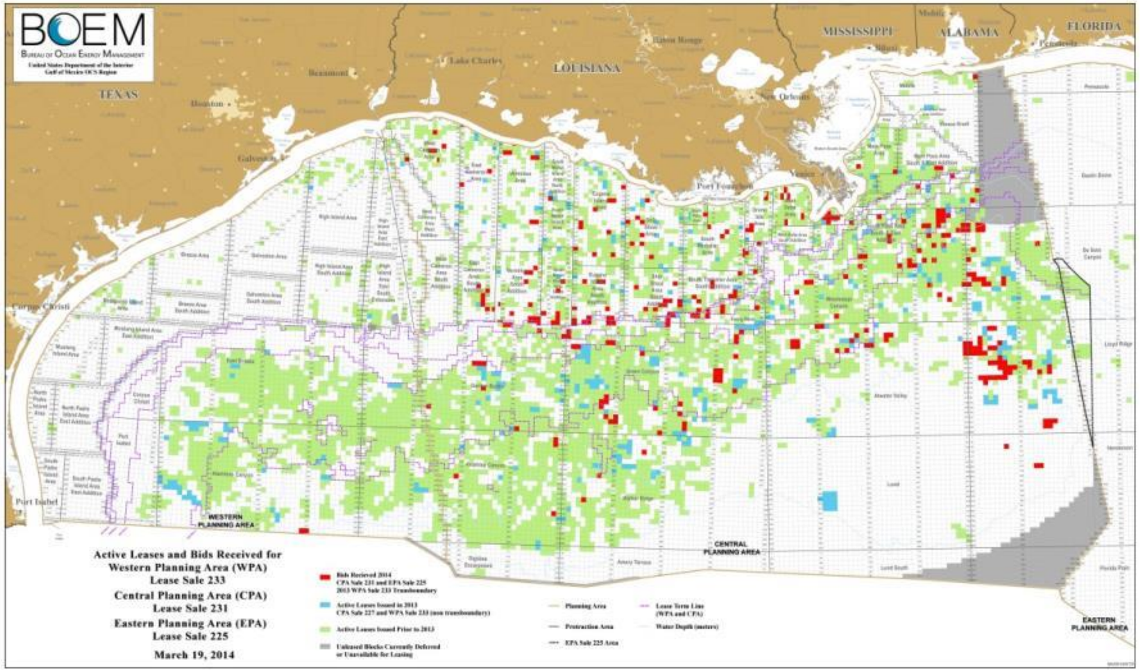
Outer Continental Shelf Lands Act
Sec. 3.(3)

BOEM’s Mission

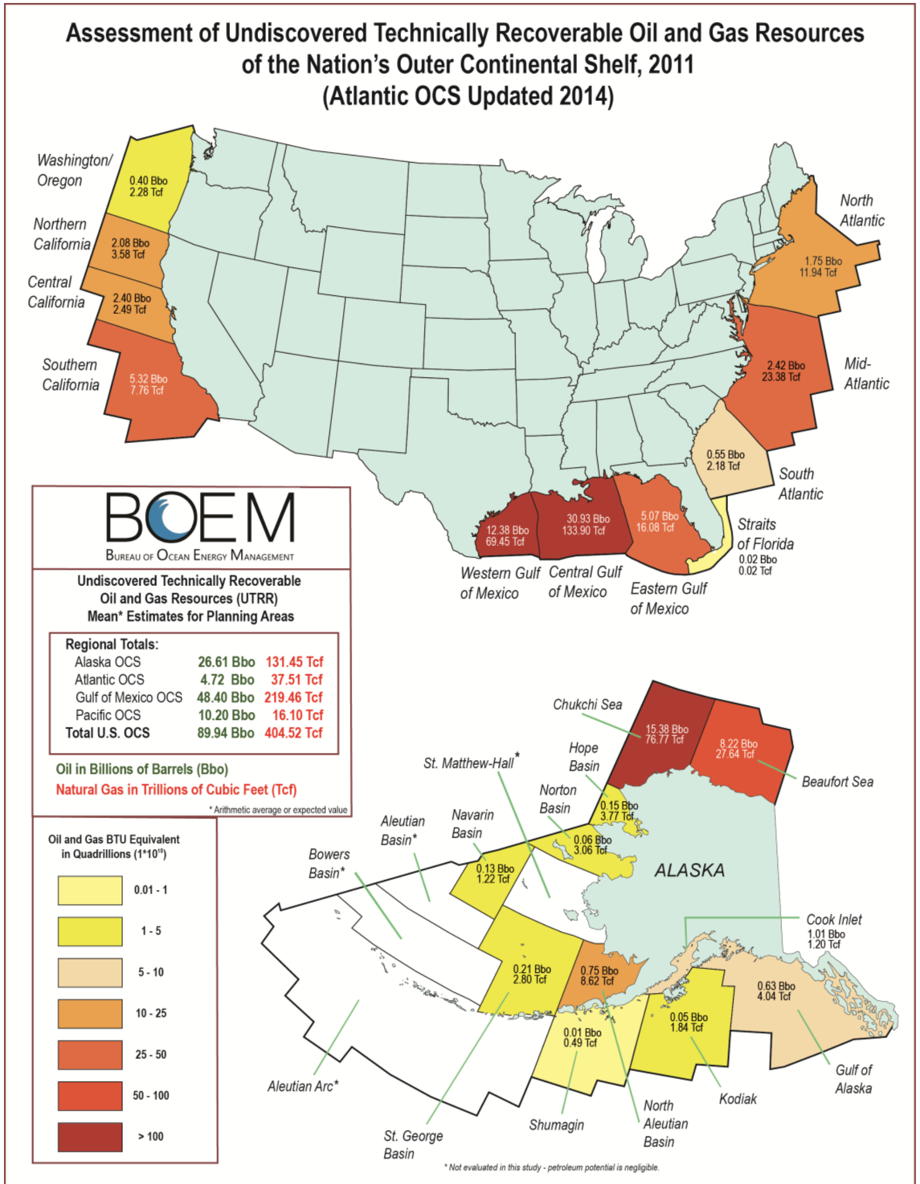
The Bureau of Ocean Energy Management (BOEM) promotes energy independence, environmental protection, and economic development through responsible, science-based management of offshore conventional and renewable energy resources.

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

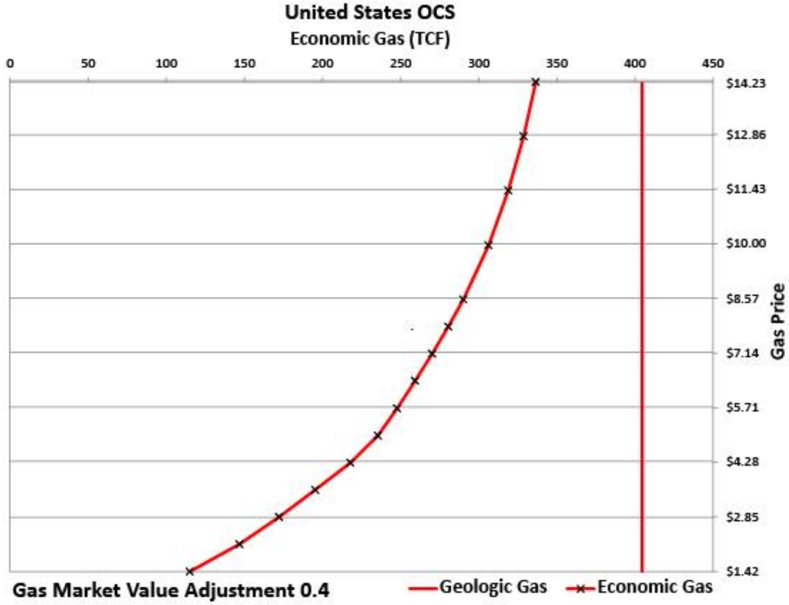


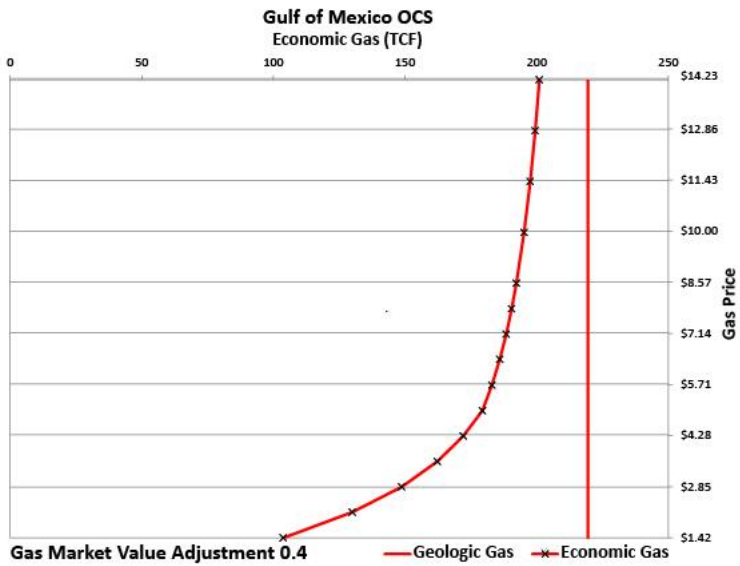
Use of Resource Estimates

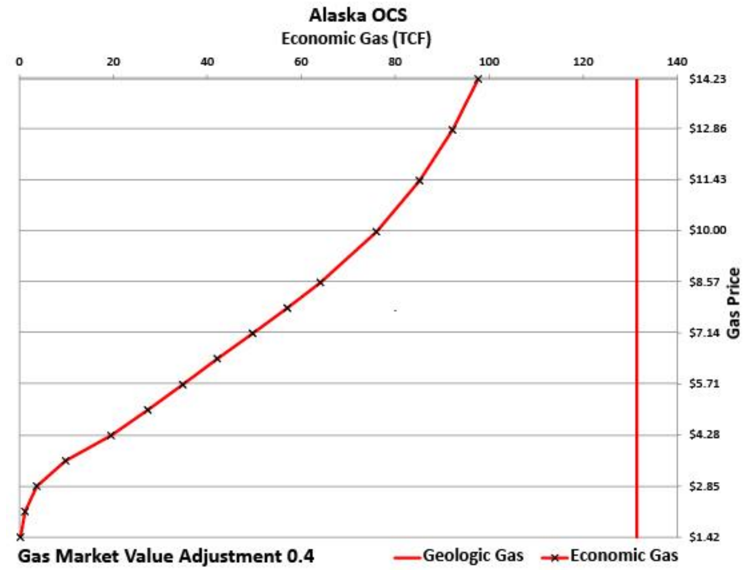


- Pre-lease
  - Identification of favorable areas
  - Forecasting OCS activity levels
  - Estimation of revenue
  - Environmental analysis
  - Energy policy planning
- Post-lease
  - Assure fair value in public/private transactions
  - Estimation of revenue
  - Estimation of reserves

Undiscovered Technically and Economically Recoverable Gas on the OCS







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Natural Gas Production: Federal Offshore and Total U.S.

Year	Federal OCS (Tcf)	Total U.S. (Tcf)	Federal OCS as Percentage of Total U.S.
2000	5.0	20.3	24.9%
2001	5.2	20.7	25.0%
2002	4.7	20.0	23.3%
2003	4.6	20.1	22.8%
2004	4.2	19.8	21.1%
2005	3.2	19.2	16.8%
2006	3.1	19.4	16.0%
2007	3.0	20.0	15.1%
2008	2.6	21.3	12.0%
2009	2.7	21.9	12.2%
2010	2.3	22.6	10.2%
2011	1.9	24.2	7.7%
2012	1.6	25.5	6.2%
2013	1.4	25.6	5.3%

Natural Gas Production: Federal Offshore and Total U.S.

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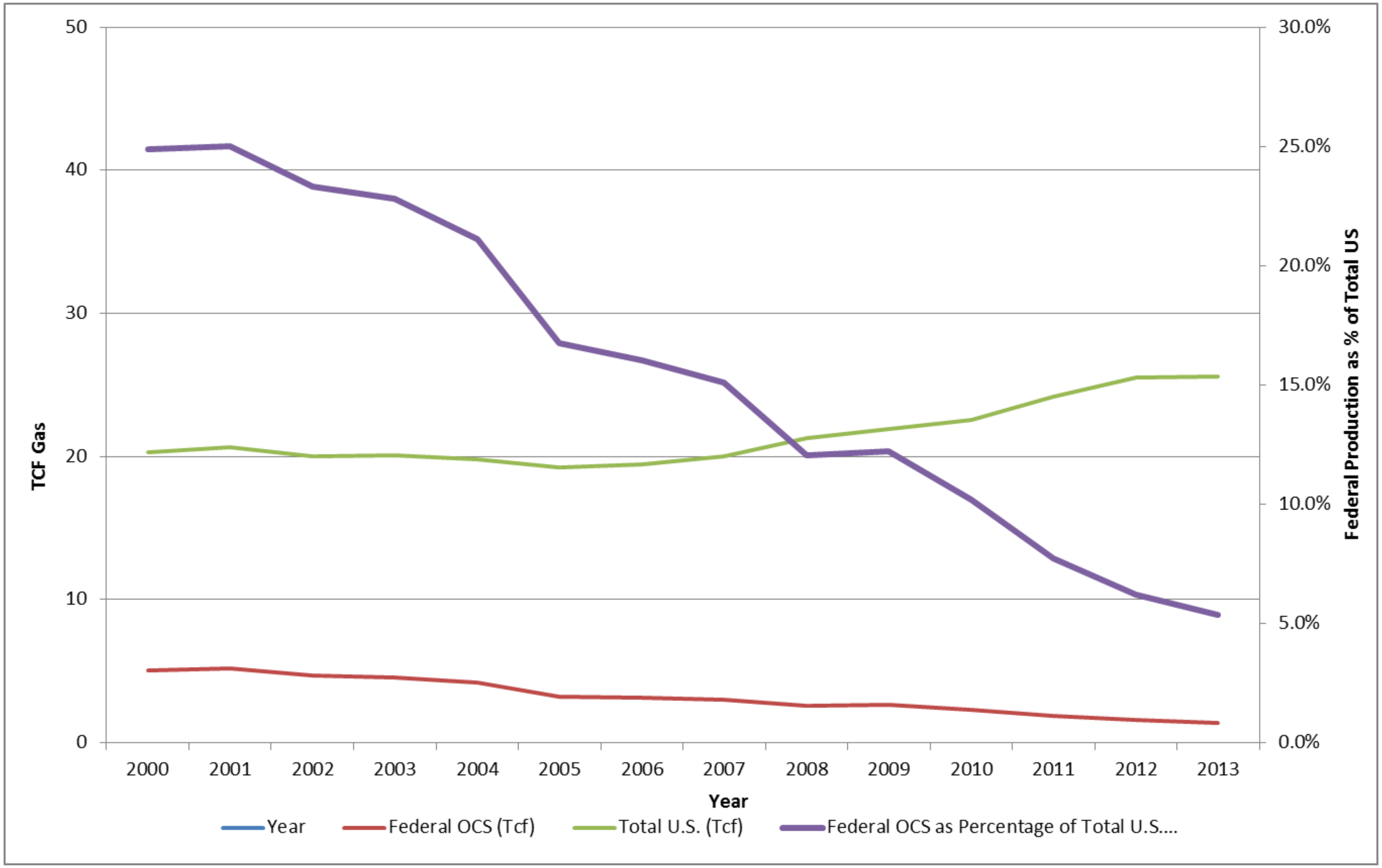
Bureau of Ocean Energy Management



Key Drivers and Outlook for OCS Natural Gas

- 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

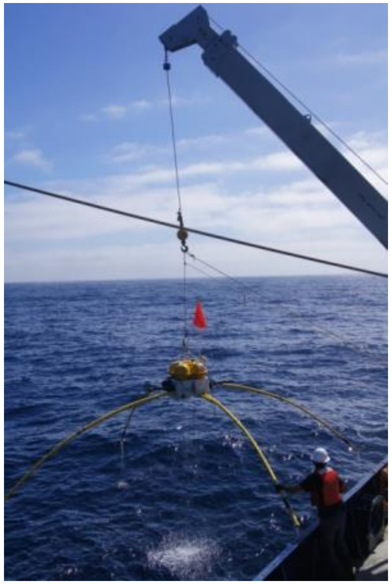
- Beginning in 2020 and up to 2050, natural gas production on the OCS has the potential to increase significantly as future deep water Gulf of Mexico Lower Tertiary discoveries are developed and access to OCS areas currently unavailable are considered for leasing.

- 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

Gas Hydrate – BOEM Outreach

<u>Other</u>

- 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



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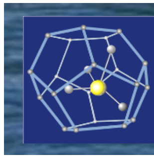
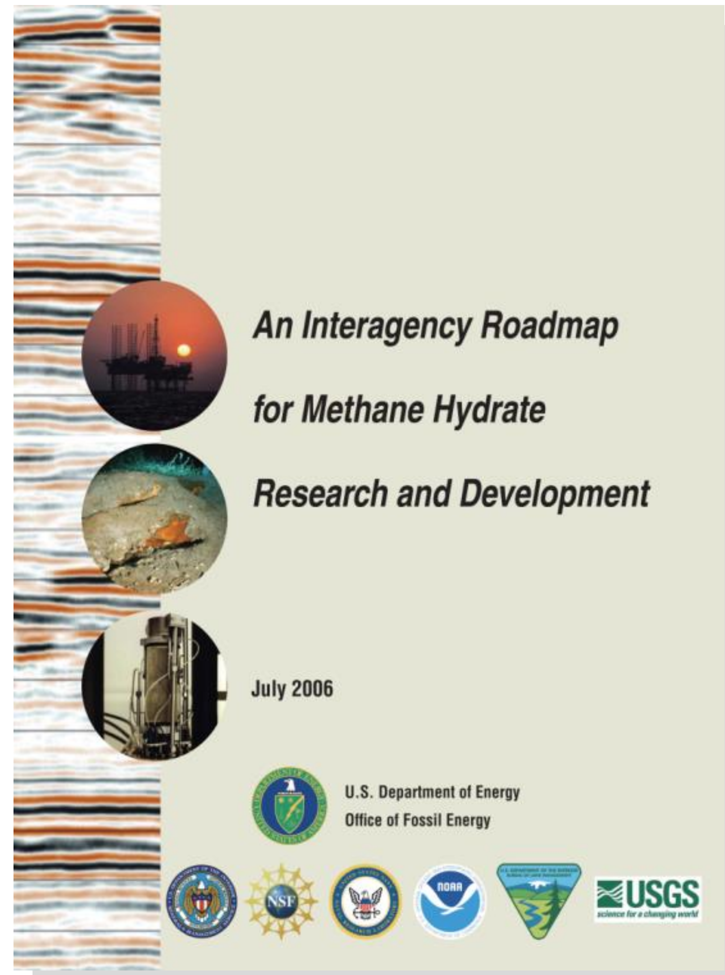


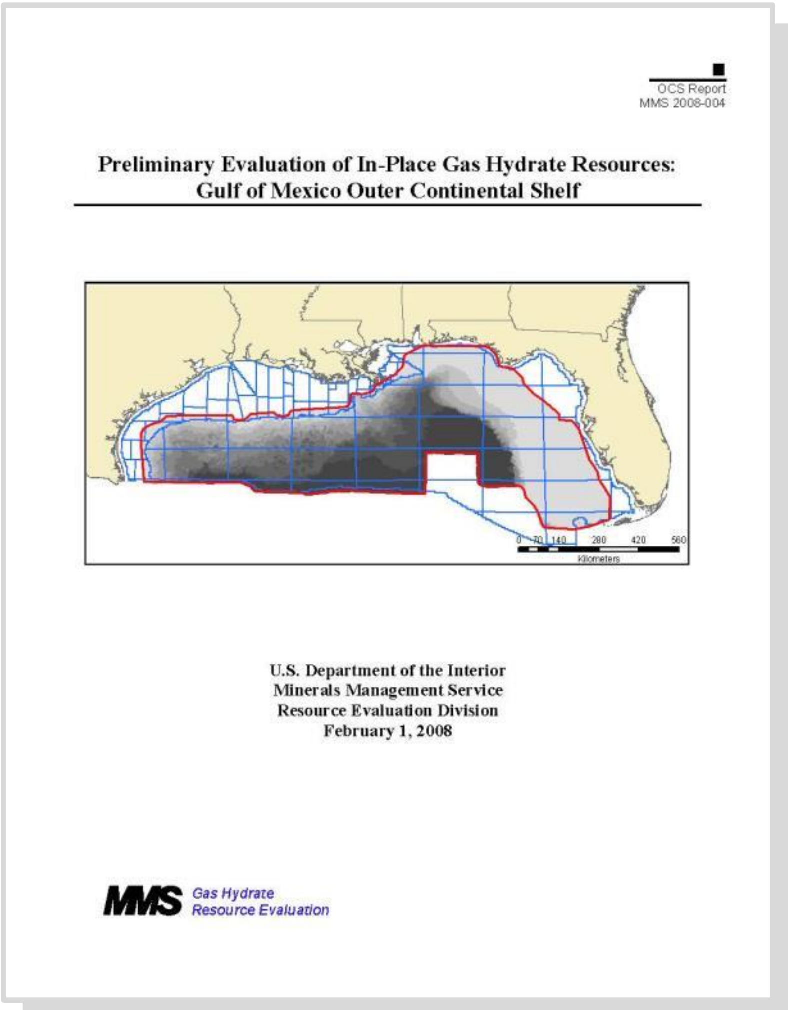
Gas Hydrate – Overview

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



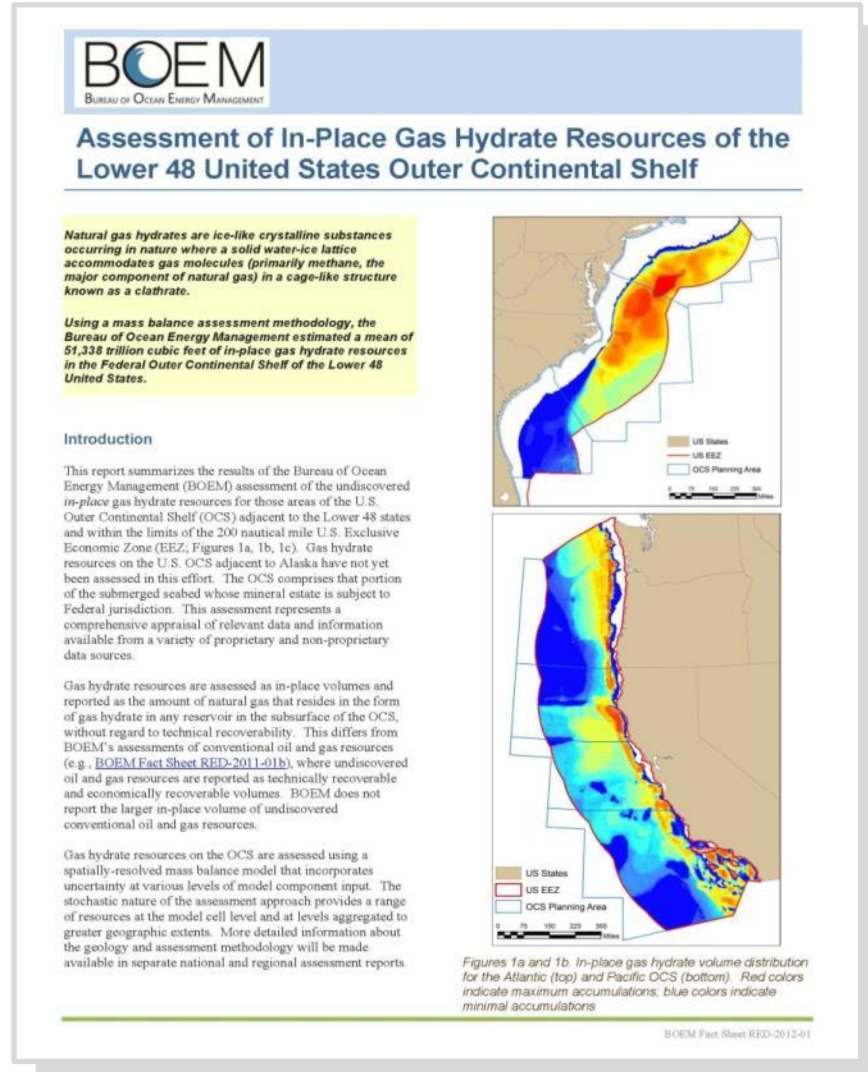
Gas Hydrate – BOEM OCS Assessment


OCS Report
MMS 2008-004

Preliminary Evaluation of In-Place Gas Hydrate Resources: Gulf of Mexico Outer Continental Shelf

U.S. Department of the Interior
Minerals Management Service
Resource Evaluation Division
February 1, 2008

MMS Gas Hydrate Resource Evaluation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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-ice 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 51,338 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 submerged seabed whose mineral estate 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 as 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 RED-2011-01b), 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 extents. More detailed information about the geology 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

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Tudor, Pickering, Holt & Co.

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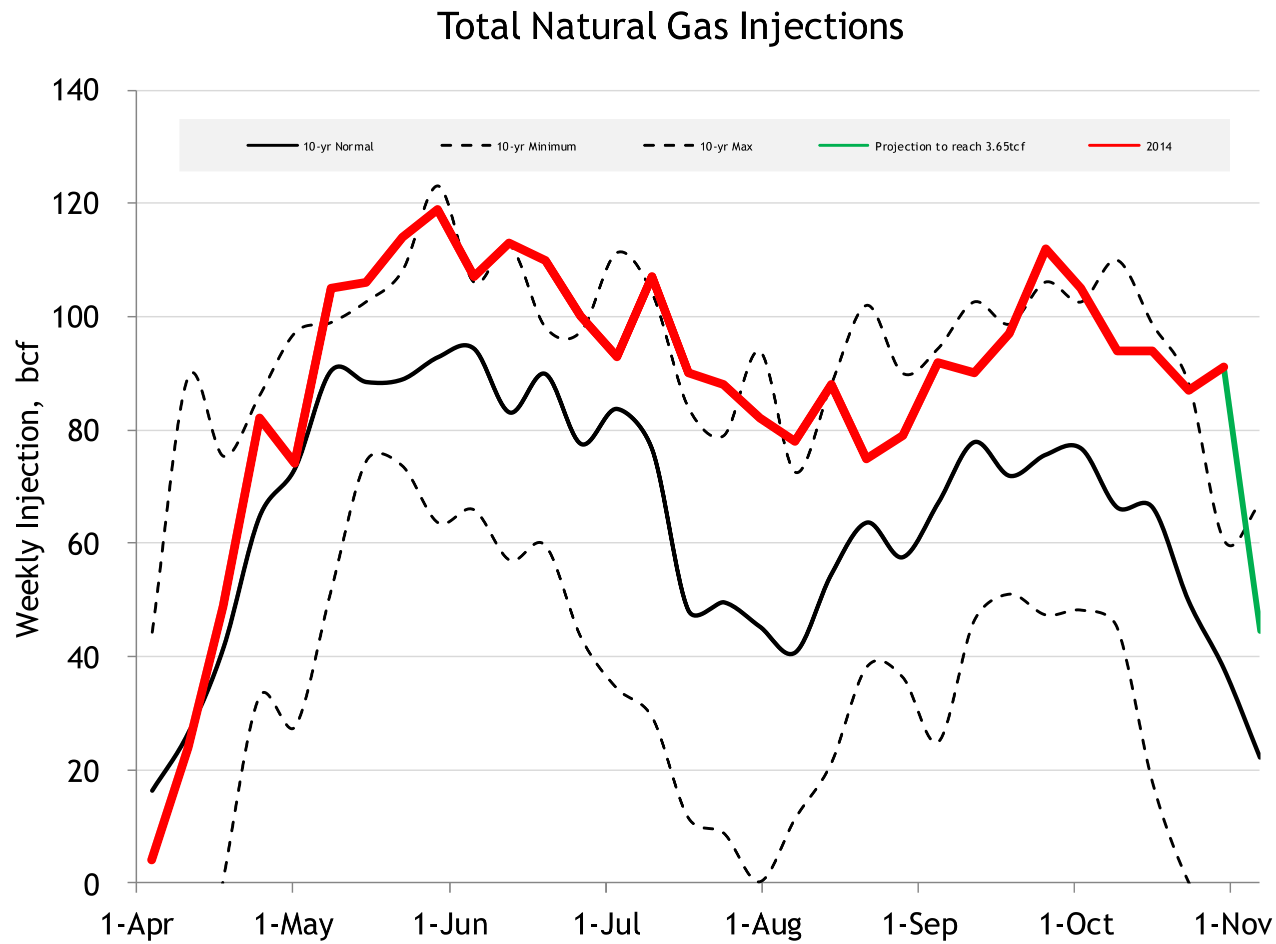
Natural Gas Thoughts

November 19, 2014

*Disclosures begin on page 8

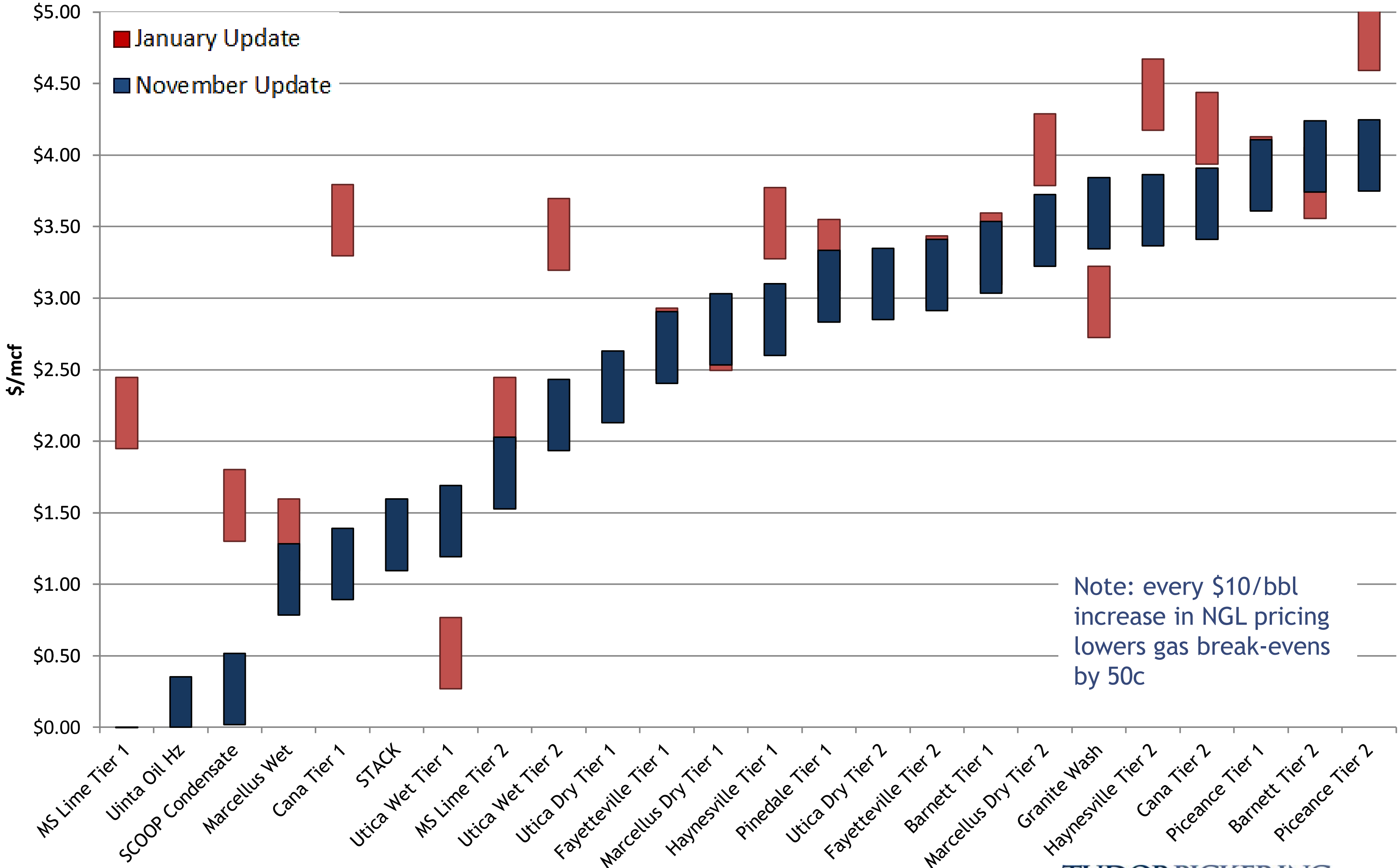
2014 Injections +3.5bcfd vs Norms

- 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



Source: **EIA, TPH Research**

Drop to Long-term $4.00 Price on Improving Well Economics



Source: TPH Research

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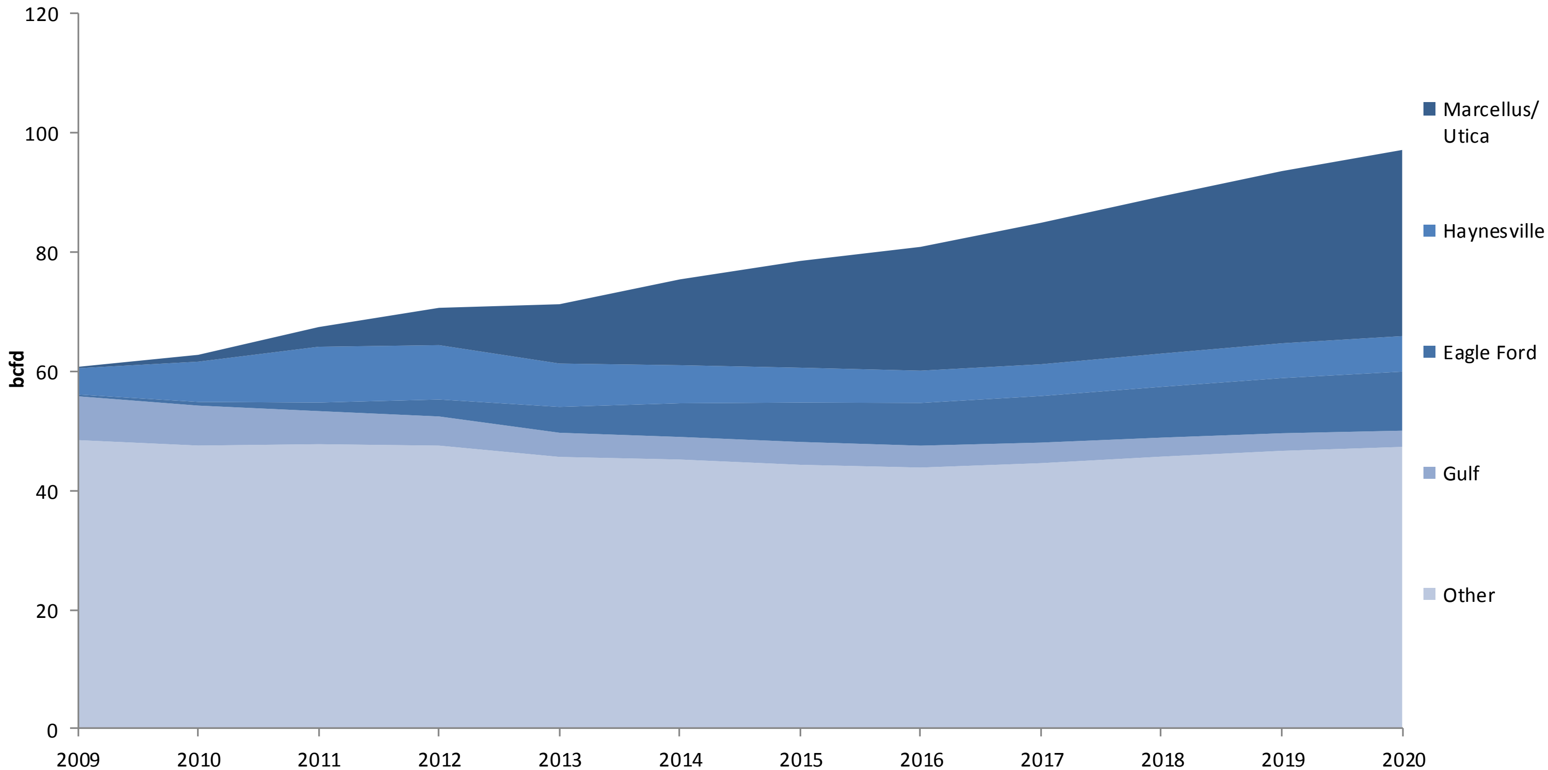
TPH Gas Production Forecast – Grouped



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2020 vs 2014
Marcellus/Utica	0	1	3	6	10	14	18	21	24	26	29	31	17
Eagle Ford	0	1	1	3	4	6	7	7	8	9	9	10	4
Haynesville	4	7	9	9	7	6	6	5	5	6	6	6	(0)
Gulf	7	7	6	5	4	4	4	4	3	3	3	3	(1)
Other	48	48	48	48	46	45	44	44	45	46	47	47	2
Total	61	63	67	71	71	75	79	81	85	89	94	97	22

Source: **EIA, TPH Research**

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TPH Gas Production Forecast – Grouped

Gas Production (Bcfd)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Marcellus/Utica	0.2	1.1	3.3	6.3	10.0	14.4	17.9	20.8	23.7	26.4	28.9	31.3
Eagle Ford	0.3	0.6	1.4	2.8	4.3	5.7	6.6	7.2	7.8	8.5	9.3	9.9
Haynesville	4.4	6.8	9.4	9.1	7.3	6.4	5.9	5.4	5.3	5.6	5.9	6.0
Gulf	7.4	6.7	5.6	4.9	4.1	3.8	3.8	3.7	3.5	3.2	3.0	2.7
Other	48.5	47.6	47.8	47.5	45.6	45.2	44.3	43.9	44.6	45.7	46.7	47.3
Total	61	63	67	71	71	75	79	81	85	89	94	97

Y/Y Change (Bcfd)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Marcellus/Utica		0.9	2.2	3.0	3.7	4.4	3.5	2.9	3.0	2.6	2.5	2.4
Eagle Ford		0.3	0.8	1.4	1.5	1.3	1.0	0.6	0.6	0.7	0.7	0.7
Haynesville		2.3	2.6	(0.2)	(1.8)	(0.9)	(0.5)	(0.4)	(0.1)	0.2	0.3	0.1
Gulf		(0.6)	(1.2)	(0.7)	(0.8)	(0.3)	0.0	(0.2)	(0.2)	(0.3)	(0.2)	(0.2)
Other		(0.9)	0.2	(0.2)	(1.9)	(0.4)	(0.9)	(0.5)	0.7	1.1	1.0	0.7
Total		2.0	4.7	3.2	0.6	4.2	3.1	2.4	4.0	4.4	4.2	3.6

Gas Price	**3.95**	**4.47**	**4.13**	**2.71**	**3.64**	**4.38**	**3.35**	**3.40**	**3.50**	**3.65**	**4.00**	**4.00**

Source: **EIA, TPH Research**

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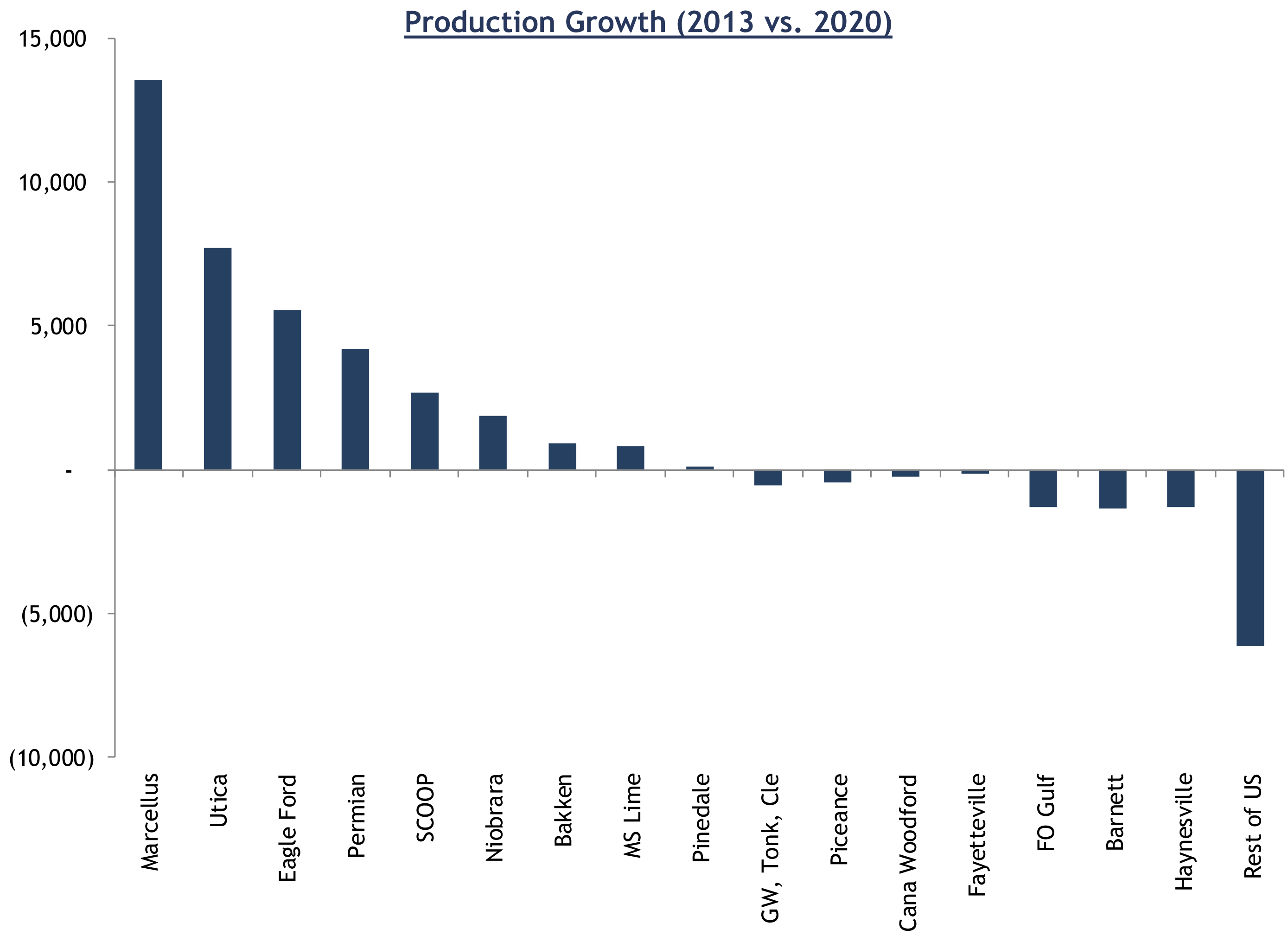
TPH Gas Production Forecast



Source: **EIA, TPH Research**

TPH Gas Production Forecast

Production Growth (2013 vs. 2020)

Gas (mmcf/d)	Actuals					Forecast							2020 vs.
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2013
Marcellus	226	1,146	3,292	6,208	9,536	12,793	14,799	16,443	18,313	19,961	21,595	23,129	13,593
Utica	0	2	9	56	421	1,613	3,121	4,337	5,432	6,418	7,306	8,124	7,703
Eagle Ford	297	609	1,433	2,845	4,339	5,653	6,612	7,168	7,814	8,523	9,254	9,905	5,566
Permian	4,444	4,283	4,282	4,635	5,136	5,592	6,144	6,667	7,281	7,924	8,613	9,351	4,215
SCOOP	43	72	94	128	260	423	648	1,193	1,888	2,438	2,812	2,961	2,701
Niobrara	547	575	635	699	862	1,163	1,395	1,622	1,897	2,169	2,437	2,720	1,858
Bakken	273	348	493	804	1,024	1,387	1,577	1,670	1,731	1,767	1,894	1,939	915
MS Lime	602	547	590	773	893	997	1,076	1,122	1,244	1,415	1,574	1,714	821
Pinedale	3,223	3,055	3,002	2,921	2,852	2,865	2,823	2,760	2,795	2,870	2,914	2,951	99
GW, Tonk, Cle	1,972	2,011	2,308	2,439	2,375	2,321	2,148	1,976	1,920	1,887	1,856	1,823	(552)
Piceance	2,749	2,521	2,569	2,497	2,249	2,078	1,942	1,805	1,780	1,805	1,803	1,797	(452)
Cana Woodford	825	839	883	955	1,081	1,088	933	876	838	824	822	815	(267)
Fayetteville	1,646	2,347	2,787	2,983	2,965	2,873	2,598	2,328	2,353	2,572	2,743	2,836	(130)
FO Gulf	7,357	6,710	5,553	4,896	4,058	3,793	3,835	3,674	3,452	3,193	2,953	2,732	(1,327)
Barnett	5,212	5,354	5,703	5,829	5,553	5,044	4,631	4,360	4,261	4,240	4,205	4,175	(1,378)
Haynesville	4,421	6,767	9,370	9,125	7,281	6,391	5,854	5,423	5,339	5,587	5,850	5,964	(1,317)
All Other US States	26,930	25,600	24,438	22,879	20,393	19,373	18,404	17,484	16,610	15,780	14,991	14,241	(6,152)
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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