

Contribution of Mid-Continent Area to the U.S. Gas Resources: Results from PGC Assessment of the Future Gas Supply*

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Abstract

The latest biennial assessment of the U.S. natural gas resources by the Potential Gas Committee (PGC) indicates that the country possesses a total technically recoverable resource base of 2,817 trillion cubic feet (Tcf) as of year-end 2016. This is the highest resource evaluation in the PGC's 52-year history, exceeding the previous high assessment (from 2014) by 302 Tcf (increase of 12%). When the PGC's assessments of technically recoverable resources are combined with EIA's latest determination of proved reserves (324 Tcf of natural gas as of year-end 2015), the U.S. future supply of natural gas stands at a record 3,141 Tcf, an increase of 288 Tcf (10%) over the previous evaluation. The increase resulted mainly from reassessments of shale gas resources in the Atlantic, Gulf Coast, Mid-Continent and Rocky Mountain areas. The Atlantic area ranks as the country's richest resource area with 39% of total U.S. traditional resources, followed by the Gulf Coast (including the Gulf of Mexico) with 20%, Rocky Mountains with 17%, and the Mid-Continent with 14%.

Mid-Continent assessments rose by 73 Tcf (25%) from 2014 to 2016, reflecting intensive developments of the Woodford Shale in the Anadarko Basin, the Barnett Shale in the Fort Worth Basin, as well as expansion of the Woodford and Mississippian shale development in the Permian Basin. The mean grand total of gas resources in conventional, tight and shale reservoirs stands at 369.6 Tcf as of year-end 2016. In addition, PGC estimated that there is 7.8 Tcf of gas resources in coal bed methane reservoirs (most likely value).

Contribution of Mid-Continent Area to the U.S. Gas Resources

Results From PGC Assessment of the Future Gas Supply

Alexei V. Milkov



SWS AAPG Annual Convention, El Paso, April 10, 2018

Presenter's notes: Hello. My name is Alexei Milkov. I am a Professor at Colorado School of Mines. I am also the Director of Potential Gas Agency. Today I will present to you the key results from the latest Report of the Potential Gas Committee on the Potential Supply of Natural Gas in the U.S.

Executive Summary

- Potential Gas Committee (PGC):
 - ▣ Non-profit group of ~80 volunteer geoscientists and engineers.
 - ▣ Biennial assessments of technically recoverable U.S. natural gas endowment since 1964.
- Assessment as of year-end 2016 (mean values):
 - ▣ 2,817 Tcf of total U.S. technically recoverable gas resources:
 - 302 Tcf or 12% increase over the previous year-end 2014 assessment.
 - Shale gas resources (1,797 Tcf) account for 64% of total gas resources.
 - ▣ With ~370 Tcf, Mid-Continent Area contributes about 14% of gas resources.
 - ▣ Total U.S. future gas supply (reserves+resources) stands at record 3,141 Tcf.



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Presenter's notes: Here are our key messages. I would like you to know that Potential Gas Committee is a non-profit organization of about 80 volunteer geoscientists and engineers. The Committee produces assessments of technically recoverable natural gases in the U.S. The first such report was published in 1964. We publish a new report every 2 years.

Last year we produced a new Report with assessments as of year-end 2016. Here are our main results. The total U.S. technically recoverable gas resources now stand at 2,817 Tcf. This is the mean value. This is 302 Tcf or 12% more than in the previous assessment done 2 years ago. We assess different types of reservoirs. Among them, shale reservoirs are very important as gas resources in these reservoirs account for 64% of total gas resources. When we combine resources assessed by the PGC with the reserves assessed by Energy Information Agency (EIA), we get the total future supply of natural gas in the U.S., which now stands at 3,141 Tcf.

Mid-Continent Area contributes about 14% of gas resources.

Let's now discuss PGC and the assessment in more details.

Organization

Potential Gas Committee (PGC)

~80 volunteers

Ronald J. Kelley
President/General Chairman

Natalie H. Reagan
Chairman of the Board

- Recruits personnel and supervises work
- Develops assessment policy and procedures
- Directs and manages studies of gas resources
- Prepares reports on natural gas resources

Contact Dr. Milkov if you want to join PGC!

Potential Gas Agency (PGA) Colorado School of Mines

Supported by industry

Dr. Alexei V. Milkov
Director

- Approves criteria and methods
- Ensures maintenance of standards and objectivity
- Reviews and evaluates reports
- Publishes final assessments of gas resources



Potential Gas Committee

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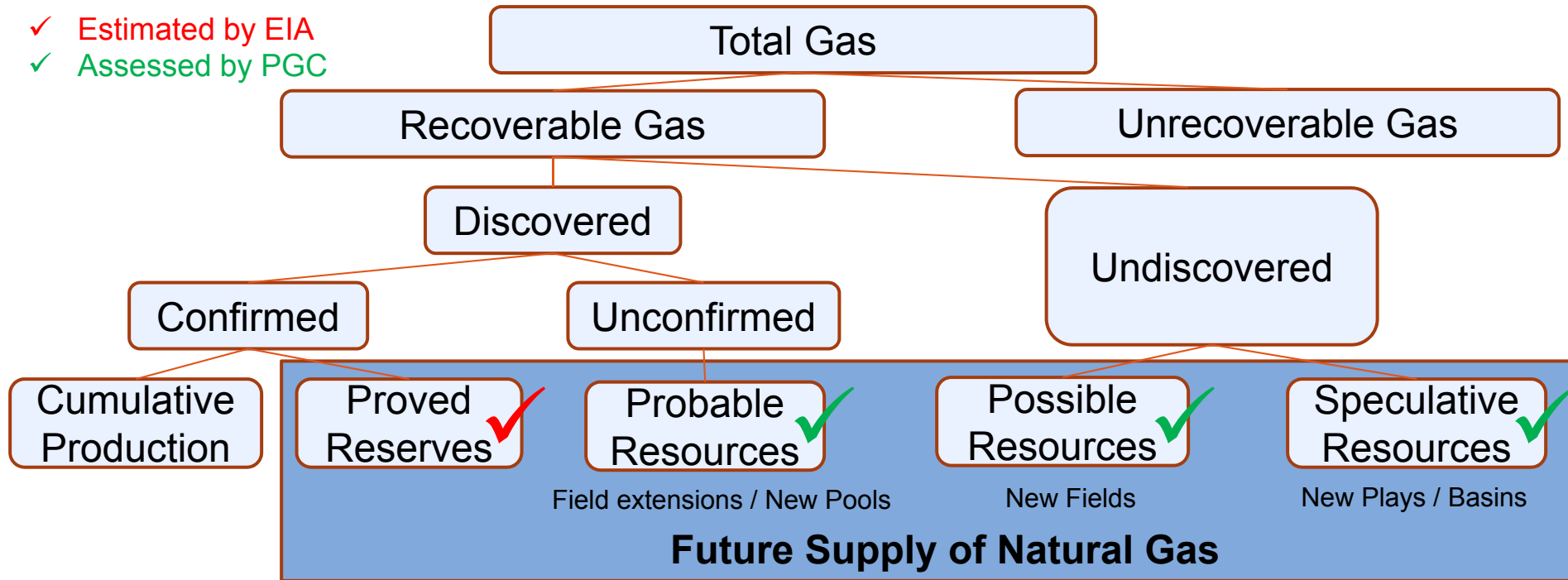


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Presenter's notes: Here is how we are organized to produce the assessment. The Potential Gas Committee or PGC is a non-profit organization of about 80 volunteers. These people are engineers and geoscientists who are very experienced in resource assessments and we are very grateful for the time and expertise that they provide. The Committee is led by Ronald Kelley, who is our President and General Chairman and the Board is chaired by Natalie Reagan. Both of them are present today and will be happy to answer your questions later. The role of PGC is to recruit volunteers, develop assessment procedures, do the assessments and prepare the report. Now, the Potential Gas Agency or PGA at Colorado School of Mines was created in 1965 to help PGC with the assessments. I am the fourth Director of the Agency and I started in this role last year. The main goal of the Agency is to provide technical guidance and assurance to the Committee, and review and publish the report.

PGC assesses future supply of natural gas

- ✓ Estimated by EIA
- ✓ Assessed by PGC



Presenter's notes: We assess the future supply of natural gas. Let's clarify some terms that you will see today. There is total gas, but only a portion of it is technically recoverable. Some of that technically recoverable gas is discovered, but some of it is not. Some gas accumulations are discovered and confirmed by appraisal. Some of the confirmed gas is already produced, so it goes into this bucket of cumulative production. Some of the confirmed gas is not produced yet, but it is economically recoverable and it is just waiting to be produced. This gas sits in the bucket of Proved Reserves. If the gas is not fully appraised, for example if it is located in field extensions or in the new pools of the discovered field, then this is probable resource. Among undiscovered gas, we have possible resources, which we think may exist in the new fields in the proven basins and plays. And we have Speculative resources, which we think may exist in the new plays and new basins. As we move from left side of this diagram to the right side, we have decreasing certainty and availability of geological and engineering data. At PGC we assess the Probable, Possible and Speculative resources. Then we use EIA estimate of Proved Reserves to calculate the total Future Supply of Natural Gas.

7 PGC work areas and 90 geologic provinces



- Settings:
 - ▣ Onshore
 - ▣ Offshore
- Depth intervals:
 - ▣ Shallow (0-15,000 ft.)
 - ▣ Deep (15,000-30,000 ft.)
- Reservoir types:
 - ▣ Traditional:
 - Conventional and tight
 - Shale gas
 - ▣ Coalbed gas (CBM)

Presenter's notes: For our assessment, we split the U.S. into 7 work areas and 90 geological provinces. On this map you can see these provinces outlined with the thin red boundaries and labeled with P and numbers, for example P-120 for the Appalachian basin. The provinces are grouped into 7 areas, specifically Atlantic, North Central, Gulf Coast, Mid-Continent, Rocky Mountain, Pacific and Alaska. We make the assessments for both onshore and offshore, for shallow and deep reservoirs. We assess Traditional reservoirs, including conventional, tight and shale reservoirs and also coalbed gas or CBM.

PGC resource assessment methodology

- Province-level assessments:
 - ▣ Publically-available data.
 - ▣ Individual expert judgement by practicing geoscientists and engineers.
 - ▣ Group discussions and peer-reviews.
 - ▣ Minimum – Most Likely – Maximum resource values for each province.
- Area-level assessments:
 - ▣ Statistical aggregation of province-level assessments to calculate Mean resources values.
- National-level assessment:
 - ▣ Statistical aggregation of area-level assessments to calculate mean Grand Total resources for the U.S.
 - ▣ Mean values for different types of reservoirs and different resource categories.
 - ▣ Addition of EIA's latest published proved reserves (year-end 2015) to calculate future gas supply.

Presenter's notes: Let's talk about our methodology. We start at the level of the geological provinces. As you remember from the previous slide there are 90 of them. We rely on publically-available data. Initial assessment is produced by our volunteer geoscientists and engineers. Then we have peer-reviews and group discussions to QC and assure the numbers. As a result, we get Minimum, Most Likely and Maximum resource values for each province. Then we aggregate these province-level values to the level of Area. We use statistical approach, run Monte-Carlo simulation and calculate the full probabilistic distribution of the values, including, most importantly, the Mean values, which we use for reporting. Then we do the next level of statistical aggregation and calculate resources at the national level. We calculate the mean Grand Total value. We also calculate mean values for different types of reservoirs and for different resource categories. We then add the most recent EIA published proved reserves to calculate the future gas supply.

Year-end 2016 assessment results

	Mean Technically Recoverable Volumes (trillion cubic feet or Tcf)
Traditional gas resources (conventional, tight and shale reservoirs)	2,658.3
Coalbed gas resources	158.7
Total gas resources	2,817.0
Proved gas reserves (EIA, year-end 2015)	324.3
Future gas supply in the U.S.	3,141.3



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Presenter's notes: And here are the results. We assessed traditional gas resources at about 2,658 tcf of mean technically recoverable resources. In addition, there is about 159 tcf of coalbed gas resources. The sum of these two values is the total gas resources. We then add proved gas reserves estimated by EIA and get future gas supply of about 3,141 tcf.

EIA as of Dec 31, 2015:

https://www.eia.gov/dnav/ng/ng_enr_wals_a_EPG0_R21_Bcf_a.htm

Natural Gas Proved Reserves, Wet After Lease Separation 324,303 bcf

Estimated Dry Natural Gas contained in Total Natural Gas Proved Reserves 307,730 bcf

Nonassociated Natural Gas Proved Reserves, Wet After Lease Separation 258,807 bcf

Associated-Dissolved Natural Gas Proved Reserves, Wet After Lease Separation 65,496 bcf

Shale Gas 175,601 bcf

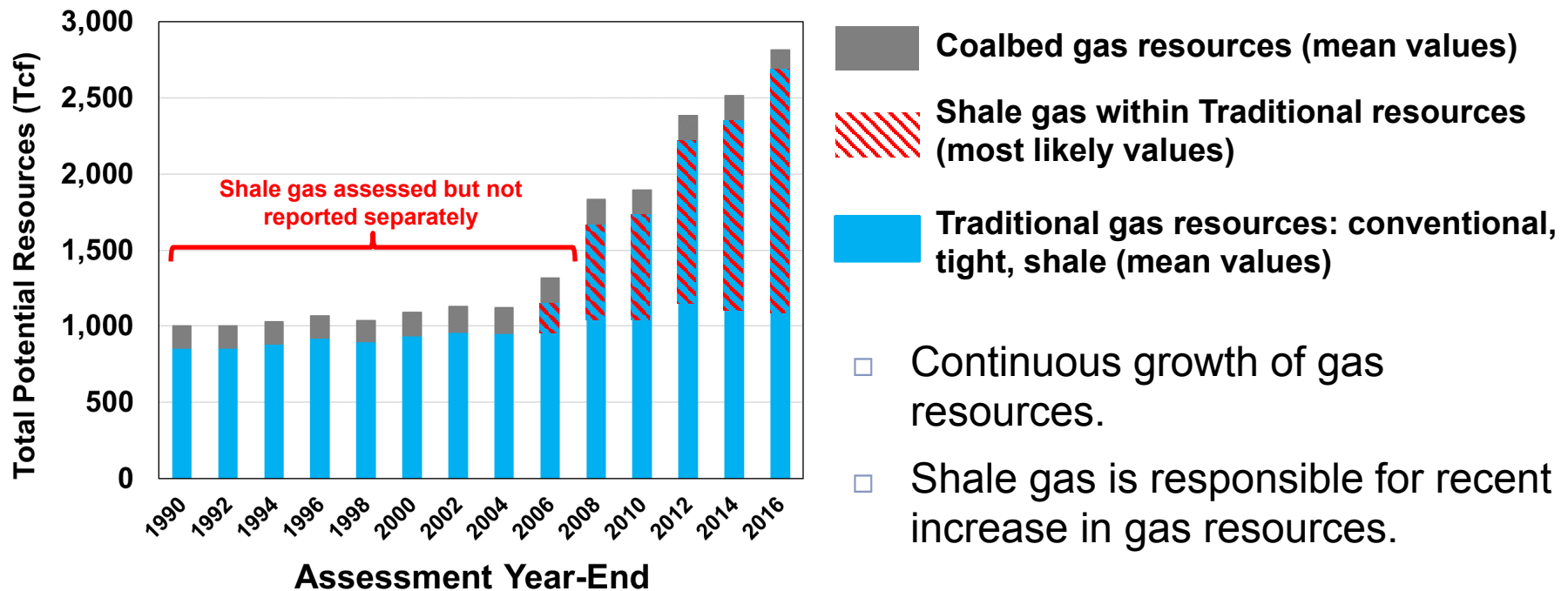
Coalbed Methane 12,517 bcf

Natural Gas Reserves Summary as of Dec. 31 – 324,303 bcf

https://www.eia.gov/dnav/ng/ng_enr_sum_a_EPG0_r21_BCF_a.htm

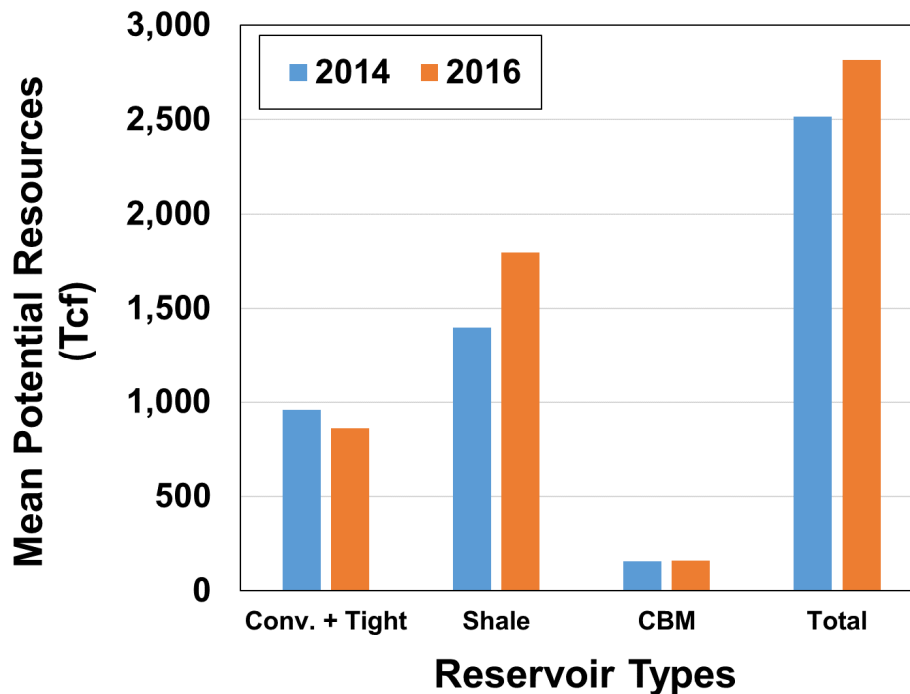
In the 2014 report PGC used dry gas only for EIA reserves at value 338.3 tcf. However, why only dry gas? Should be all gas. All gas in end-2013 was 354 tcf.

PGC gas resource assessments, 1990-2016



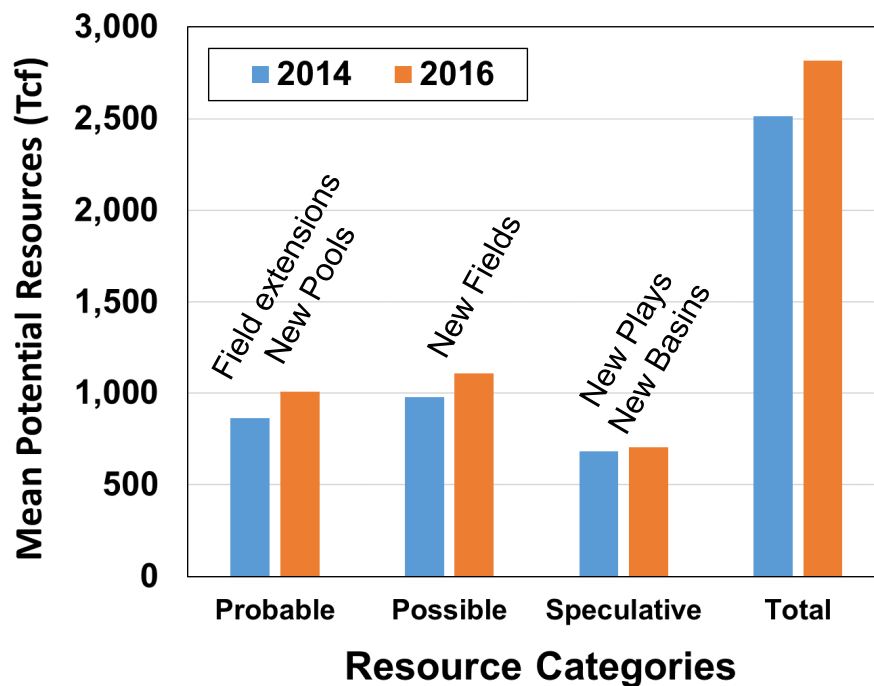
- Continuous growth of gas resources.
- Shale gas is responsible for recent increase in gas resources.

Change in gas resources relative to 2014: Reservoir types



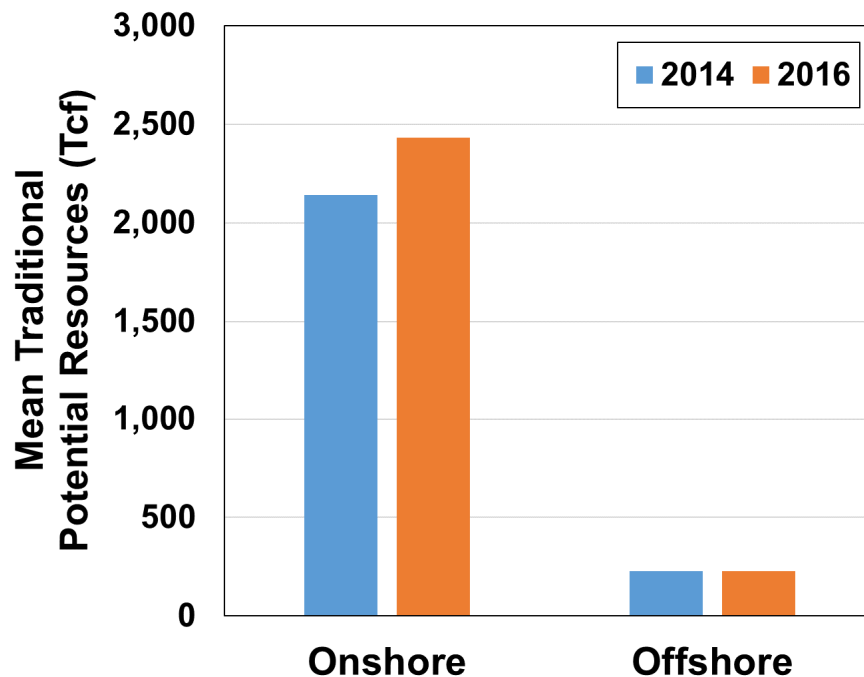
- Reduction of gas resources in conventional and tight sand/carbonate reservoirs (97 Tcf or 10%).
- Significant increase in shale gas resources (399 Tcf or 29%).
- Coalbed (CBM) resources are flat.
- Total mean potential gas resources increase of 302 Tcf or 12%.

Change in gas resources relative to 2014: Resource categories



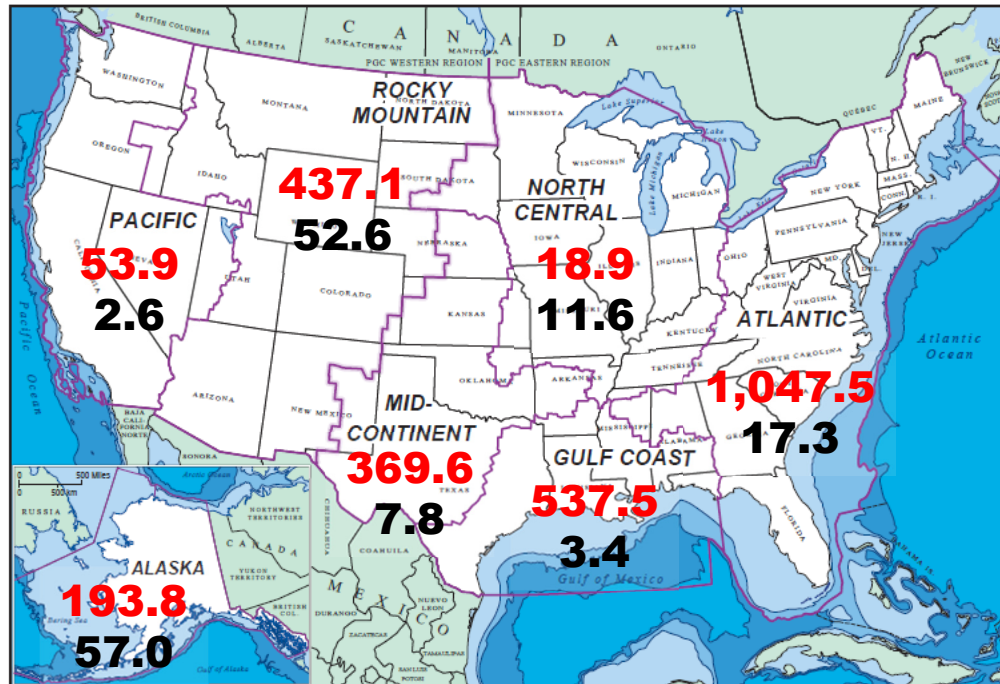
- Resources increased in all categories.
- Probable and Possible resources increased significantly, reflecting continuous development of established plays.
- Little growth of Speculative resources due to limited frontier exploration.

Change in Traditional gas resources from 2014: Onshore vs Offshore



- Traditional resources:
 - ▣ Conventional and tight reservoirs
 - ▣ Shale reservoirs
- Significant increase in Onshore gas resources (290 Tcf or 14%).
- No change in Offshore gas resources.

2016 gas resource assessment for Areas

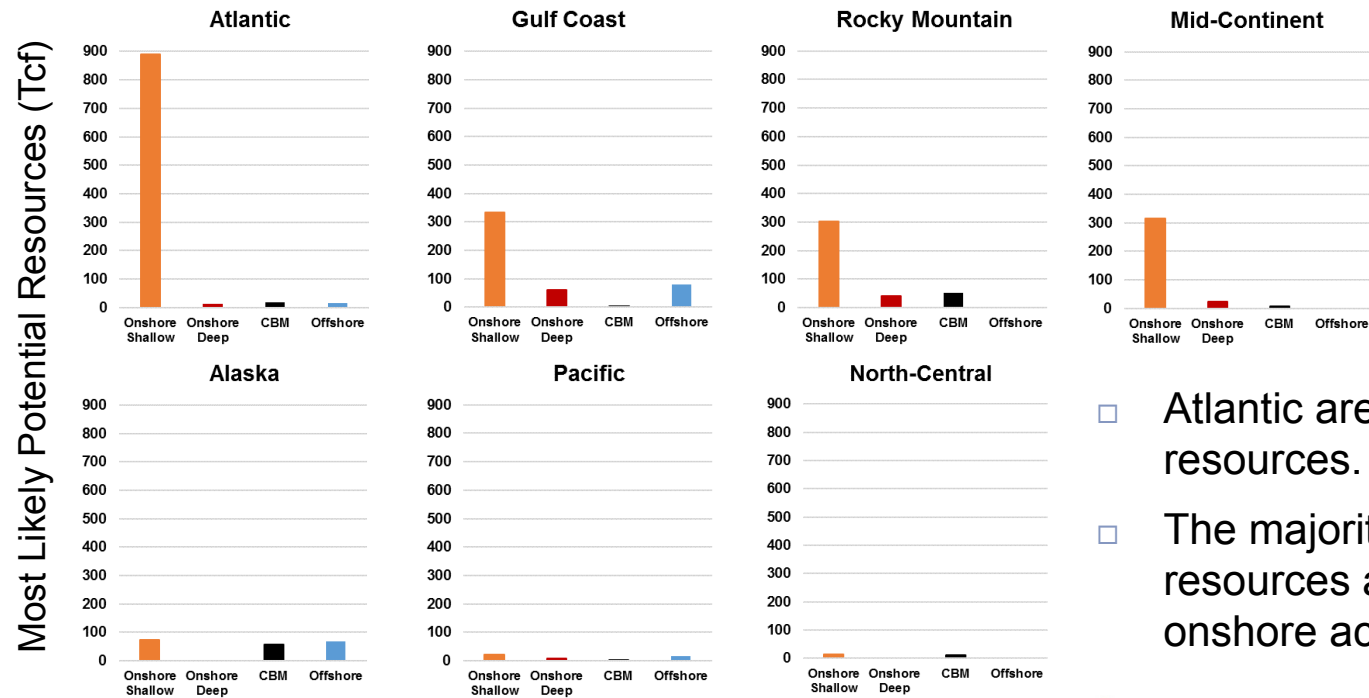


Red values – Total Traditional resources (conventional, tight, shale reservoirs) (mean values, Tcf)

Black values – Coalbed gas resources (most likely values, Tcf)

Presenter's notes: Now let's talk about our assessment areas. This map shows the areas – Atlantic, Gulf Coast, North Central, Mid-Continent, Rocky Mountain, Pacific and Alaska. Red values show the mean values for traditional resources and black values show most likely values for coalbed gas resources. You see that the Atlantic area has the largest amount of traditional resources, followed by the Gulf Coast and Rocky Mountain areas.

Comparison of gas resources in Areas



- Atlantic area has most gas resources.
- The majority of gas resources are in shallow onshore accumulations.

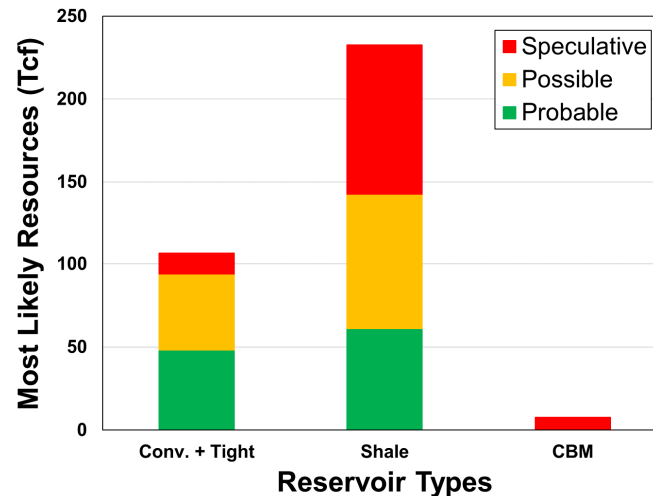
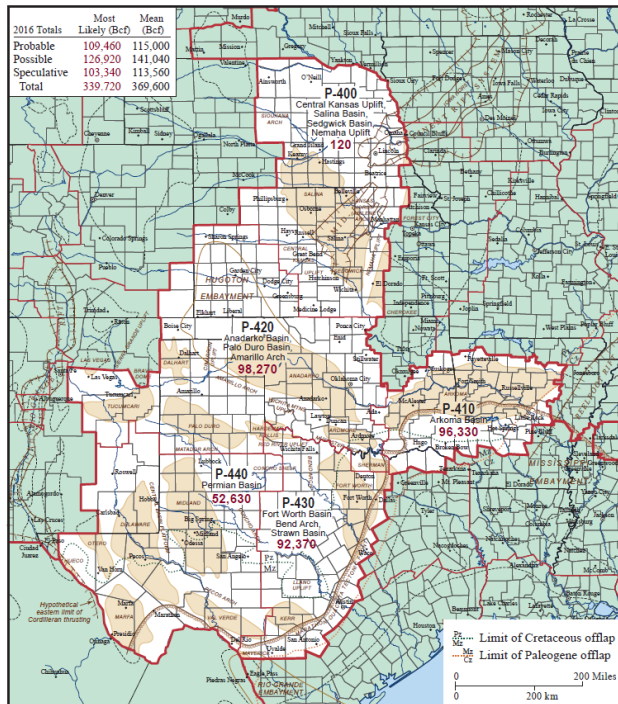
Presenter's notes: This slide compares the most likely values for 7 areas. The scale is the same for all Areas. Again, you see the dominance of the Atlantic area. These areas of Gulf Coast, Rocky Mountain and Mid-Continent have similar gas resources, while Alaska, Pacific and North Central areas have relatively small gas resources. You also can see that onshore shallow gas resources are very important in most areas, these are mostly shale gas plays.

Areas ranked based on total gas resources (excluding coalbed gas)

PGC Assessment Area	Mean Technically Recoverable Volumes (trillion cubic feet or Tcf)	Proportion
Atlantic	1,047.5	39.4%
Gulf Coast	537.5	20.2%
Rocky Mountain	437.1	16.5%
Mid-Continent	369.6	13.9%
Alaska	193.8	7.3%
Pacific	53.9	2.0%
North Central	18.9	0.7%
Total U.S.	2,658.3	

Presenter's notes: This slide compares the most likely values for 7 areas. The scale is the same for all Areas. Again, you see the dominance of the Atlantic area. These areas of Gulf Coast, Rocky Mountain and Mid-Continent have similar gas resources, while Alaska, Pacific and North Central areas have relatively small gas resources. You also can see that onshore shallow gas resources are very important in most areas, these are mostly shale gas plays.

Mid-Continent Area 2016 assessment

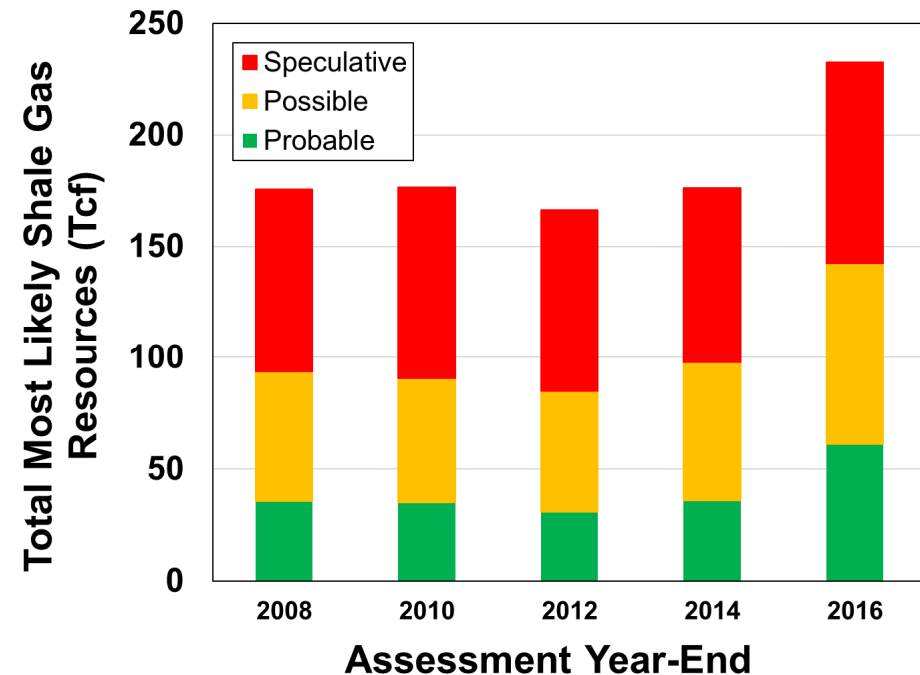


- Total Most Likely ~348 Tcf.
- Similar amount of gas (~90-100 tcf) in three basins:
 - Anadarko (P-420),
 - Arkoma (P-410),
 - Fort Worth (P-430).
- Shale gas dominates.

Presenter's notes: Now let's take a closer look at the Mid-Continent area. This map shows the provinces that we assess in the area. For example, province P-440 is for Permian basin. The brown number next to it indicates that we assess about 53 Tcf of traditional gas in that province. The total most likely gas resources in the area are about 350 Tcf. Three provinces have about the same gas resources around 90-100 tcf each – Anadarko, Arkoma and Fort Worth basins. You can see from this graph that shale gas reservoirs dominate the resource base, although conventional and tight reservoirs are still important.

CBM is in P-430 (Southwestern Coal Region) and in P-410 (Arkoma)

Mid-Continent Area shale gas resources



- PGC started to separately report shale gas resources in 2006.
- First report of shale gas for Mid-Continent Area in 2008.
- Total Most Likely ~233 Tcf at year-end 2016.
- 67% of all gas resources in the Area.
- Dominated by Arkoma (Fayetteville, Woodford) and Fort Worth (Barnett) basins.



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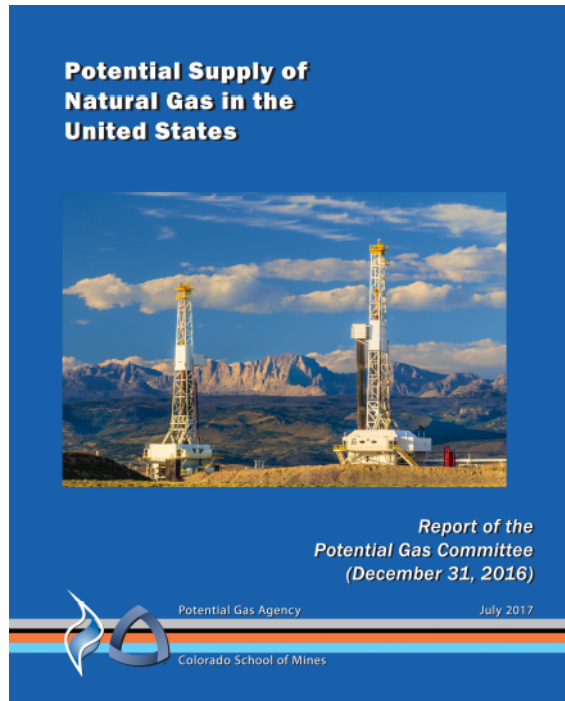
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Presenter's notes: This slide focuses on the shale gas resources in the Mid-Continent area. We at PGC started to report shale gas separately in 2006, when we separately assessed the New Albany shale in the Illinois basin. Our first report for the Mid-Continent area was in 2008 at about 180 Tcf. In this plot you see how shale gas resources increased since that time. We currently estimate that there is about 230 tcf of shale gas in the area. This amount is about 67% of all gas resources. Most assessed shale gas is located within Fayetteville and Woodford shales in the Arkoma basin and within Barnett shale in the Fort Worth basin.

Summary of year-end 2016 assessment

- 2,817 Tcf of total U.S. gas resources (mean value).
- 302 Tcf or 12% increase over the previous year-end 2014 assessment.
- Atlantic area has 39% of traditional U.S. gas resources. Mid-Continent has 14% (~370 tcf).
- Shale gas accounts for 64% of total U.S. gas resources. Shale gas also dominates resources in the Mid-Continent area (67%).
- Total U.S. future gas supply (reserves+resources) stands at record 3,141 Tcf. This is an increase of 288 Tcf or 10% over the previous year-end 2014 assessment.

Additional information



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Presenter's notes: In summary, we assess that there are 2,817 Tcf of total gas resources in the U.S. This is about 300 Tcf or 12% more than in the previous assessment. Atlantic area has the lion share of gas resources, about 39% of U.S. total traditional resources. Shale plays contribute very large resources, about 64% of total. When we add reserves and resources together, we have future gas supply, which now stands at record 3,141 Tcf. This is about 10% more than in the previous assessment.