Potential Supply of Natural Gas in the United States

Report of the Potential Gas Committee (December 31, 2022)

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AGA
American Gas Association

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API
American Petroleum Institute

Preface

The objective of the Potential Gas Committee is to provide assessments, based upon expert knowledge, of the potential supply of natural gas, which, together with an independent determination of proved reserves of natural gas, make possible a meaningful appraisal of the nation's long-range natural gas supply.

The Potential Gas Committee assesses the natural gas resource potential for each of 90 geologic provinces comprising six geographic areas of the Lower 48 States and Alaska, 56 of which are onshore and 34 offshore. For each onshore province, separate assessments are given for (1) resources postulated to occur at drilling depths of less than 15,000 ft, and (2) resources postulated to occur at drilling depths between 15,000 and 30,000 ft. Offshore provinces are separated into those that occur beneath water depths of less than 200 m (that is, the continental shelf) and those beneath water depths of 200 to 1,000 m (continental slope). Two additional provinces encompass U.S. territorial waters deeper than 1,000 m (outer continental slope)—one within the Gulf of Mexico and a second in the Bering Sea off southwestern Alaska.

Assessments of Traditional natural gas resources, defined as those within conventional, tight and shale reservoirs collectively, for each geologic province and area are given in terms of a distribution of values ("minimum," "most likely" and "maximum") for each of three categories of resource – Probable, Possible and Speculative. The Committee believes that reporting resources in this manner provides users with a proper understanding of the uncertainties inherent in the resource assessments for any particular province. Similar ranges of assessments for coalbed gas are given at the correlative province level, that is, by coal region or basin.

In addition to reporting assessments as the arithmetic sums of the "most likely" (modal) values at the province, area and national levels, the Committee also reports "mean" values, which are determined by a series of separate statistical aggregations of all province-level distributions of Traditional resource assessments to yield area totals (total onshore and total offshore, by resource category) and national subtotals and totals (Lower 48 States and Total United States, by resource category). Still another separate aggregation is performed for coalbed gas assessments. PGC believes that these computations together provide the most valid statistical basis for comparison of our results with assessments made from time to time by other organizations. The Committee cannot stress too often the importance of understanding the differences between the "most likely" and "mean" value datasets.

Dedication

By action of the Board of Directors, this Report is dedicated to Marshall C. Crouch, III.

Marshall was active in the PGC for several decades, serving on the Board of Directors, as Vice President of the Western Region and as the Alaska Province Chair. Marshall passed away on April 16, 2022, at the age of 78, while vacationing at his favorite place in Maui, Hawaii. Marshall had his wife, Jane, and several members of his family close by with him in his final hours. Fortunately, he spent the last few months of his life visiting all of his four sons and daughters-in-law and their 12 grandchildren scattered across the country, sharing quality time with his closest family members.

Born in 1944, Marshall was raised in Park Hill, attended Regis High School, and received a professional degree in Geology and Geological Engineering from the Colorado School of Mines in 1967.

During his career, Marshall was involved in the discovery of several natural gas fields in Colorado and Kansas and helped to develop oil and gas fields all over the Rockies. He often took his sons out to wellsites with him. Family trips across the country were opportunities to have a captivated or captured audience, depending on the age of the boys, for reading aloud the "Roadside Geology" of various states and stops at "Points of Geological Interest."

Marshall was a leader in natural gas research and exploration and a long-time member of the Potential Gas Committee.

Acknowledgments

We respectfully acknowledge the contributions of all past and present volunteers—800 and counting—through whose tireless efforts, we have achieved a most credible 58-year record of preparing informed and objective assessments of the potential natural gas resource base of the United States.

For their financial and technical support, the Potential Gas Committee and Potential Gas Agency gratefully acknowledge the companies and organizations whose names appear on page *ii*. Please take a moment to review those contributors.

Cover Image

View of the “Eternal Flame” at Chestnut Ridge Park, Orchard Park, New York. The flame, which occurs at the top of the Upper Devonian Hanover Shale is sourced by natural gas generated from the burial and thermal maturation of Upper Devonian organic-rich shale. The gas migrates upward through the sedimentary pile through a series of naturally occurring fracture sets and vents to the surface in a small, protected alcove within a waterfall formed by the overlying Dunkirk Shale. Photo courtesy of David R. Blood. Used with permission.

The Potential Gas Committee (PGC) originally was organized as the Future Gas Requirements and Supply Committee in the early 1960s. That committee published its first national resource assessment in 1964. Colorado School of Mines was selected in 1965 to sponsor the work of the committee, which was reorganized as the Potential Gas Committee in 1966 with the support of the American Gas Association, the Independent Natural Gas Association of America and the American Petroleum Institute. Since its founding and continuing to the present time, the sole purpose of the Potential Gas Committee has been to organize and train geological scientists, engineers and others for the timely and regular preparation and dissemination of assessments of the technically recoverable natural gas resource base of the United States. Except for 1974, the PGC has prepared and published these assessments on a biennial basis.

The Potential Gas Committee consists of knowledgeable and highly experienced volunteer members who work in the natural gas exploration, production, transportation and distribution industries and in the field and technical services and consulting sectors. The Committee also benefits from the input of respected technical advisors and various observers from federal and state government agencies, academia, and industry and research organizations. Although the PGC functions independently, the Potential Gas Agency (PGA) at the Colorado School of Mines provides the Committee with guidance, technical assistance, training and administrative support, and assists the Committee with new member recruitment and public outreach efforts. The Potential Gas Agency receives financial support from E&P and gas pipeline companies and distributors, as well as industry trade and research organizations and unaffiliated companies and individuals.

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Cautionary Note

Readers of this and previous Potential Gas Committee reports are cautioned that the assessments reported herein are of volumes of natural gas that the Potential Gas Committee deems to exist and considers technically recoverable. The conversion of these postulated resources into economically recoverable volumes of natural gas will necessarily be company-specific and will depend on many factors, including but not limited to company size, lease positions and stipulations, risk tolerance, operating expenses, required capital expenditures, wellhead commodity prices, pipeline access and regulatory constraints. The Potential Gas Committee and Potential Gas Agency, and their officers and members, cannot guarantee the validity or accuracy of these assessments. Nor can they be held responsible for any actions taken by companies and individuals who use these assessments and other information contained herein, or for their outcome.

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Report of the Potential Gas Committee

Executive Summary

Introduction

The assessments reported herein are of volumes of natural gas that the Potential Gas Committee (PGC) deems to exist and considers technically recoverable. These assessments represent the current status of a highly dynamic system in which, in simplest terms, potential resources pass into proved reserves and ultimately into production as a result of discovery and development of new pools and fields and field extensions, as illustrated in simple terms in Figure 1. (See full definitions of these terms in the chapter, Methodology of the Potential Gas Committee.) Concurrently, PGC members continually evaluate their assessments of remaining potential resources based on knowledge they have gained by examining the results of the latest exploration, drilling, well testing and other field developments. In practice, they then may reevaluate and reclassify any given category of potential resource (in whole or part) either within the same category (reallocation of volumes among the distribution of assessed values), to the category of next greater geological certainty (from Possible to Probable, for example), to proved reserves and/or production, or to some combination thereof.

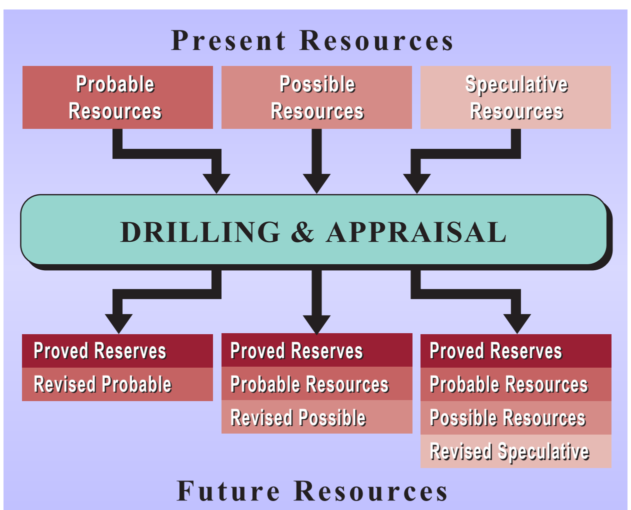


Figure 1. Effect of drilling and reappraisal on the progression of present potential natural gas resources into future resources and reserves.

The PGC's assessments are "baseline estimates" in that they attempt to provide a reasonable appraisal of volumes of natural gas that the PGC deems to exist and considers technically recoverable. As such, they assume neither a time schedule nor a specific market price for the discovery and production of future gas supply. Furthermore, the PGC's technically recoverable resources are separate from and do not include proved reserves, which are reported annually by the Energy Information Administration (EIA) of the United States (U.S.) Department of Energy. Finally, the PGC cautions readers that the conversion of postulated technically recoverable resources into economically recoverable volumes of natural gas is necessarily company-specific in nature and may depend on many, often complex and interrelated factors, such as company size, exploration strategy, lease positions and stipulations, wellhead commodity prices, pipeline access, operating expenses, required capital expenditures and risk tolerance.

National Resource Assessments, 2022

The PGC's assessments of the potential supply of natural gas in the United States, as of December 31, 2022, are summarized in Table 1. The national total of Traditional resources is 3,196,190 billion cubic feet (Bcf, mean value), a decrease of 15,400 Bcf (0.5 percent) from the year-end 2020 assessment. In addition to Traditional resources, the PGC has assessed recoverable coalbed gas resources of 156,730 Bcf (mean value), unchanged from 2020. These two values are arithmetically added to the Grand Total U.S. potential resource of 3,352,920 Bcf, a net decrease of 15,400 Bcf (0.5 percent) from year-end 2020.

This small decrease in total domestic resource is the result of minor decreases in the Atlantic, Pacific and Gulf Coast onshore resources, offset by upward revisions in the combined gas resource volumes of the Rocky Mountain Area.

The PGC reports aggregated mean values for its assessments at the national and area levels but not at the province, basin or play level. We believe that this approach imparts greater statistical validity to the results and allows for more direct comparison with resource assessments prepared from time to time by other organizations. The PGC's totals are derived by statistical aggregation of the distributions created by the "minimum," "most likely" and "maximum" values that are assessed for each of three resource categories (Probable, Possible, Speculative) for each of the PGC's 90 onshore and offshore geologic provinces. Note that the "most likely" values for any given province represent the best judgment of individual PGC members at the time of preparation and are considered the most credible estimates for purposes of analysis, planning and exploration. (The rationale for this approach is discussed in the chapter entitled Methodology of the Potential Gas Committee.)

Table 2 presents the historical tabulation of all the PGC's national-level aggregated mean values since it first began computing them. These include Probable, Possible and Speculative resources, separately aggregated (rather than arithmetically derived) total Traditional resources (except for 1988) and separately aggregated coalbed gas resources. The latter two quantities, however, do add arithmetically to yield the grand total of potential resources.

Using the values in Table 2, Figure 2 tracks total U.S. potential gas resource assessments as the arithmetic sum of Traditional resources (in all noncoal reservoirs) plus coalbed gas resources. The assessments for 2008 through 2022 illustrate dramatically the effects of the PGC's ongoing shale gas evaluations, which are included within Traditional resources.

Figure 3 compares, for the same time period, mean values for the entire U.S. and for the Lower 48 States, exclusive of coalbed gas. The relatively constant differential between these two data sets arises from the fact that biennial assessments for Alaska have changed little during this period but nevertheless remain a vital and substantial component of the nation's total gas resource potential.

Mean-value assessments of Probable, Possible and Speculative Traditional resources for the total U.S. and Lower 48 States are tracked and compared individually in Figure 4. The "Alaska effect" is apparent in these charts as well, but because the hydrocarbon potential of so many of Alaska's onshore and offshore basins has yet to be investigated by drilling, the greatest differences between the data sets are seen in the Speculative resources category.

Table 1. Potential Gas Committee's assessment of potential natural gas resources in the United States, December 31, 2022 (statistically aggregated mean values, billion cubic feet, rounded from computed values).

Resource Category/Depth	Probable Resource	Possible Resource	Speculative Resource	Total Potential Resource(1)
Traditional Resources				
Lower 48 States:				
Onshore (all drilling depths)	1,017,530	1,265,070	601,445	2,874,255
Offshore (all water depths)	16,830	52,060	59,230	128,120
Total Lower 48 States(2)	1,025,580	1,317,135	660,675	3,002,380
Alaska:				
Onshore (all drilling depths)	31,720	22,300	40,420	94,440
Offshore (all water depths)	5,130	19,480	74,760	99,370
Total Alaska(2)	36,850	41,780	115,180	193,810
Total U.S. Traditional Resources(3)	1,062,430	1,358,915	775,855	3,196,190
Total U.S. Coalbed Gas Resources	14,620	46,570	95,550	156,730
Grand Total United States(4)	1,077,050	1,405,485	871,405	3,352,920

1. All Total Potential Resource values, except Grand Total, are derived by separate statistical aggregation and not by arithmetic summation of Probable, Possible and Speculative values.
2. Probable, Possible and Speculative Resource values are derived by separate statistical aggregation and not by arithmetic summation of respective onshore and offshore totals.
3. Probable, Possible and Speculative Resource values are derived by separate statistical aggregation and not by arithmetic summation of respective Lower 48 States' and Alaska totals.
4. Grand Total Probable, Possible, Speculative and Total Potential Resource values are derived by arithmetic summation of respective Total US. Traditional Resource and Total Coalbed Gas Resource values.

Table 2. Potential Gas Committee's historical assessments of potential natural gas resources, 1988 through 2022, by resource category (mean values, billion cubic feet). Values are graphed in Figures 2, 3 and 4.

Year	Probable Resource	Possible Resource	Speculative Resource	Total Traditional Resources(1)	Coalbed Gas Resources	Grand Total Potential Resources(2)	Change in Traditional Resources Bcf	%	Change in Total Resources Bcf	%
Total United States										
1988	214,953	295,768	332,064	817,835	*	817,835	-	-	-	-
1990	206,840	304,417	344,034	855,329	147,302	1,002,631	37,494	4.6%	184,796	22.6%
1992	203,994	302,945	346,639	853,511	147,311	1,000,822	-1,818	-0.2%	-1,809	-0.2%
1994	197,946	301,028	382,315	881,310	146,652	1,027,962	27,799	3.3%	27,140	2.7%
1996	216,210	300,517	402,118	920,989	146,333	1,067,322	39,679	4.5%	39,360	3.8%
1998	216,032	292,957	385,700	896,121	141,422	1,037,543	-24,868	-2.7%	-29,779	-2.8%
2000	207,037	332,234	397,761	935,817	155,180	1,090,997	39,696	4.4%	53,454	5.2%
2002	210,494	324,997	421,965	958,260	168,860	1,127,120	22,443	2.4%	36,123	3.3%
2004	206,765	346,208	396,628	949,957	169,298	1,119,255	-8,303	-0.9%	-7,865	-0.7%
2006	270,100	426,408	460,740	1,154,809	166,141	1,320,950	204,852	21.6%	201,695	18.0%
2008	441,363	736,949	500,743	1,673,447	162,976	1,836,423	518,638	44.9%	515,473	39.0%
2010	536,575	687,675	518,300	1,739,175	158,600	1,897,775	65,728	3.9%	61,352	3.3%
2012	708,480	952,330	558,660	2,225,620	158,240	2,383,860	486,445	28.0%	486,085	25.6%
2014	848,410	930,080	586,120	2,356,800	158,090	2,514,890	131,180	5.9%	131,030	5.5%
2016	993,840	1,056,919	607,530	2,658,285	158,670	2,816,955	301,485	12.8%	302,065	12.0%
2018	1,120,230	1,375,690	721,620	3,217,540	156,730	3,374,270	559,255	21.0%	557,315	19.8%
2020	1,125,600	1,351,430	734,560	3,211,590	156,730	3,368,320	-5,950	-0.2%	-5,950	-0.2%
2022	1,062,430	1,358,915	775,855	3,196,190	156,730	3,352,920	-15,400	-0.5%	-15,400	-0.5%
Lower 48 States										
1988	177,771	253,983	216,897	648,301	*	-	-	-	-	-
1990	169,562	262,651	228,766	661,095	*	-	12,794	2.0%	-	-
1992	166,707	261,137	231,467	659,267	*	-	-1,828	-0.3%	-	-
1994	160,655	259,193	267,182	687,006	*	-	27,739	4.2%	-	-
1996	179,363	258,697	287,346	725,277	*	-	38,271	5.6%	-	-
1998	179,173	251,158	270,615	701,721	*	-	-23,556	-3.2%	-	-
2000	170,182	290,342	281,706	740,584	*	-	38,863	5.5%	-	-
2002	173,641	283,202	306,160	765,636	*	-	25,052	3.4%	-	-
2004	169,930	304,848	280,285	756,494	*	-	-9,142	-1.2%	-	-
2006	233,248	384,823	347,906	965,618	*	-	209,124	27.6%	-	-
2008	404,524	695,148	385,265	1,484,920	*	-	519,302	53.8%	-	-
2010	499,700	645,890	405,810	1,551,180	*	-	66,260	4.5%	-	-
2012	671,630	913,660	442,210	2,011,430	*	-	460,250	29.7%	-	-
2014	813,100	88,310	469,040	2,169,590	*	-	158,160	7.9%	-	-
2016	956,990	1,015,140	492,350	2,464,470	*	-	294,880	13.6%	-	-
2018	1,083,380	1,333,900	606,440	3,023,729	*	-	559,259	22.7%	-	-
2020	1,088,750	1,309,650	619,380	3,017,780	*	-	-5,949	-0.2%	-	-
2022	1,025,580	1,317,135	660,675	3,002,370	*	-	-15,410	-0.5%	-	-

1. Total Traditional Resource values are derived by separate statistical aggregation and not by arithmetic summation of Probable, Possible and Speculative Resource values.
2. Grand Total Potential Resource values are derived by arithmetic summation of Total Traditional Resource and Coalbed Gas Resource values.
* Statistically aggregated total was not determined.

Future Gas Supply and Ultimately Recoverable Resources

Lastly for the national review, we examine how the PGC's assessments factor into the determination of the country's Future Supply and Ultimately Recoverable Resources of natural gas. The "Total Traditional Resources" column in Table 2 becomes the second column in Table 3, which illustrates this progression. PGC's Traditional gas resources and coalbed gas resources (both converted to trillion cubic feet, Tcf) are added to the EIA's latest available published value of proved reserves (year-end 2021in this case[1, 2]) to yield Future Gas Supply—that is, the volume of natural gas known and postulated to exist within the ground (represented

1. Energy Information Administration, 2022, U.S. crude oil and natural gas proved reserves, year-end 2021: U.S. Dept. of Energy, Energy Information Administration, Independent Statistics and Analysis, Rept. DOE/EIA–0216(2019), and reports for preceding years.

2. At the time the PGC finalizes its resource assessments, early in the odd-numbered calendar year (2023 in this case) following the end of the even-numbered reporting period (2021–2022), the EIA has not yet released its year-end proved reserves figures for that even-numbered year (2022). Instead, reserves only for the preceding odd-numbered year (2021) are available. Consequently, the PGC must use the latter value in determining Future Gas Supply in the current version of Table 3.

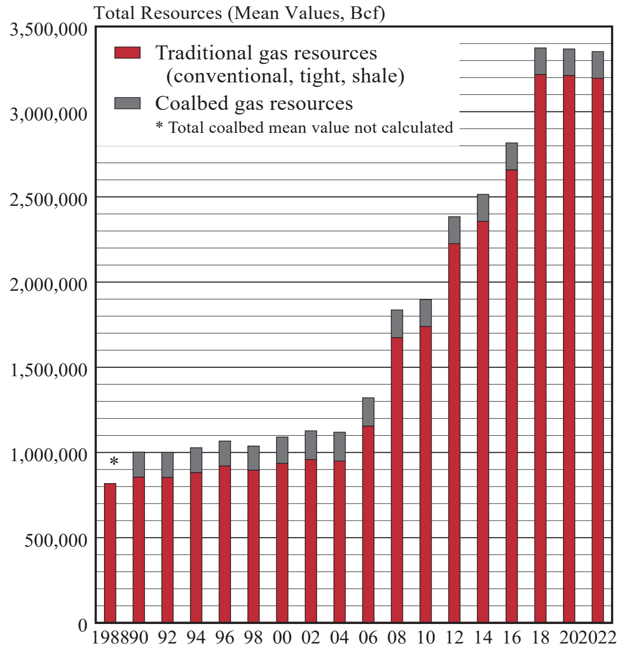


Figure 2. Potential Gas Committee's historical assessments of total recoverable natural gas resources for the United States, Traditional and coalbed gas, 1988 through 2022 (mean values, billion cubic feet, from Table 2).

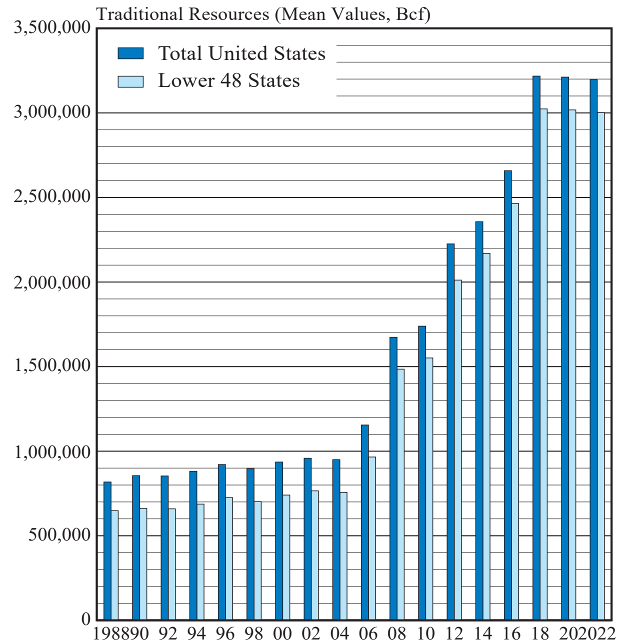


Figure 3. Potential Gas Committee's historical assessments of Traditional natural gas resources for the total United States and for the Lower 48 States, 1988 through 2022 (mean values, billion cubic feet, from Table 2).

by the four columns outlined in blue). Then, within the columns outlined in violet, the sum of Future Gas Supply and cumulative historical production (through 2022) yields the Ultimately Recoverable Resource (URR).

The PGC's current assessment of Traditional resources year-end 2020 to year-end 2022 reported a decrease of 15 Tcf (Table 2). During this same timeframe, the Future Gas Supply increased by 137 Tcf (Table 3). Adding the current Future Gas Supply (3,978 Tcf) to cumulative production (1,554 Tcf) changes the URR to 5,532Tcf, an increase of 213 Tcf (4.0 percent) from year-end 2020.

The historical changes in these quantities are portrayed graphically in Figure 5. Notice first the generally uniform increase in cumulative production – an indication of fairly constant annual production, which is different from annual consumer demand or consumption. What are not readily apparent at this scale are the recent increases in annual production well above average historical levels, primarily the result of accelerated development of Appalachian, Mid-Continent and Gulf Coast shale gas. Since 2009, annual marketed-gas production has reached levels not seen since the 1970s. Increases in production have been driven by a concomitant rise in consumption in the past decade due to the use of natural gas for various purposes, including power generation, transportation fuel, liquid natural gas (LNG) production, and as feedstock for petrochemical production. As the United States continues to navigate the energy transition over the next several decades, the use of natural gas to generate alternative fuels such as hydrogen is also anticipated to drive continued production. Drilling and exploration activities expected to accompany the energy transition, especially those related to the search for geologic carbon storage reservoirs, may also serve to facilitate discovery of domestic natural gas resources in new areas or assist in the refinement of our knowledge of existing gas reservoirs.

Potential resource assessments have shown considerably more variations in the past several biennial reporting cycles. This variability is a direct reflection of the highly dynamic spectrum of drilling and appraisal (Figure 1) through which PGC members reevaluate, reclassify and reallocate categories of potential resources. Such changes are particularly well exemplified by the "spikes" and "plateaus" seen in assessments since 2006 – attributable almost entirely to reevaluations of shale gas resources over time. The last notable "spike" in the nation's total natural gas resource volume was reported in 2018, when an upward revision, contributed mostly by shale gas resource assessments of the Atlantic Area, was reported at nearly 20 percent. Since then, modest decreases in the total gas resource volume have been reported at -0.2 percent (year-end 2020) and -0.5 percent (year-end 2022).

Based on the trends observed in our datasets, particularly over the past two decades, the PGC envisions a reliable,

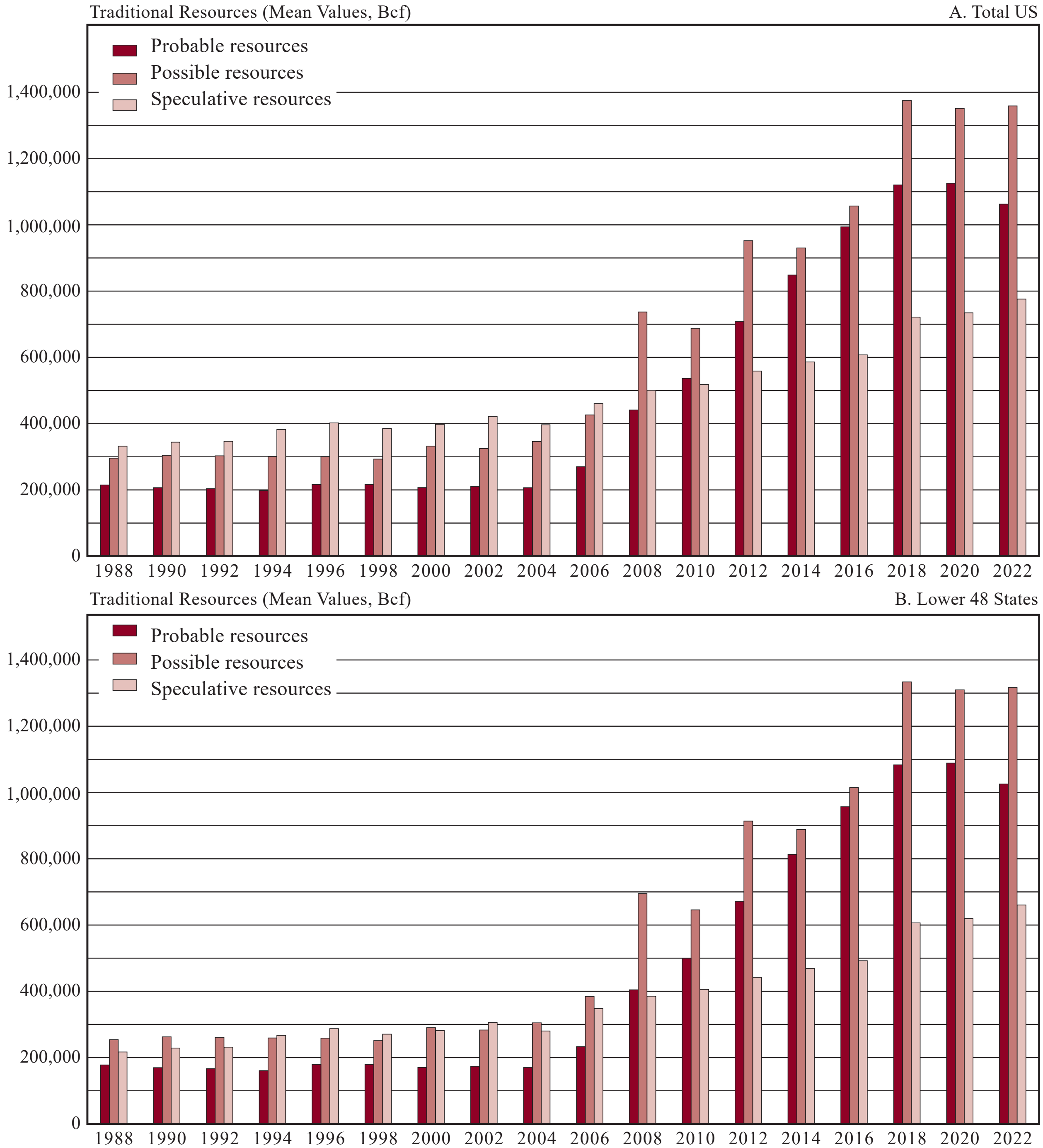


Figure 4. Potential Gas Committee's historical assessments of Traditional natural gas resources, 1988 through 2022 by category (mean values, billion cubic feet, from Table 2). A. Total United States. B. Lower 48 States.

robust national gas supply future, with:

- industry increasing domestic production, processing and storage levels to satisfy demand;
- producers offsetting production depletion by proving up higher volumes of reserves through new field discoveries, field extensions and new pool discoveries in known fields;
- industry aggressively pursuing new domestic markets and expanding existing markets, particularly natural gas for power generation, transportation fuel and petrochemical feedstock; and
- industry investing billions of dollars to construct gas liquefaction facilities to supply overseas markets with domestically produced natural gas exported as LNG.

Table 3. Potential Gas Committee's historical determinations of future supply and ultimately recoverable volumes of natural gas in the United States, 1988 through 2022 (trillion cubic feet), using mean values of Traditional and coalbed gas resources, and production and proved reserves values reported by EIA. Values are graphed in Figure 5.

Year	EIA Proved Reserves(1)	+	PGC Potential Resources: Traditional Gas Resources(2)	+	PGC Potential Resources: Coalbed Gas Resources(2)	=	**Future Gas Supply**(3)	+	Cumulative Production(4)	=	**Ultimately Recoverable Resource**
1988	168		818		(5)		986		741		1,727
1990	169		855		147		1,172		777		1,949
1992	165		854		147		1,166		815		1,981
1994	164		881		147		1,192		853		2,045
1996	166		921		146		1,234		893		2,127
1998	164		896		141		1,202		933		2,134
2000	177		936		155		1,268		973		2,241
2002	187		958		169		1,314		1,013		2,327
2004	193		950		169		1,312		1,053		2,364
2006	211		1,155		166		1,532		1,091		2,623
2008	245		1,673		163		2,081		1,132		3,213
2010	305		1,739		159		2,202		1,176		3,379
2012	308 (6)		2,226		158		2,692		1,226		3,918
2014	338 (6, 7)		2,357		158		2,853		1,278		4,131
2016	324 (7, 8)		2,658		159		3,141		1,343		4,484
2018	505 (7, 8)		3,218		157		3,879		1,405		5,284
2020	473 (7, 8)		3,212		157		3,841		1,478		5,319
2022	625 (7,8)		3,196		157		3,978		1,554		5,532

1. Proved dry-gas reserves values derived from U.S. Department of Energy, Energy Information Administration Report Series DOE/EIA-0216, U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves (Annual Reports and Advance Summaries).
2. Separately aggregated mean values, not the arithmetic sums of Probable, Possible and Speculative mean values.
3. Future Gas Supply is derived by arithmetic summation of Proved Reserves, Traditional Resources and Coalbed Gas Resources.
4. Cumulative marketed-gas production is derived from Energy Information Administration reports. Values for prior years may differ slightly from those shown in previous PGC reports as a result of subsequent revisions by EIA. Current biennium cumulative total includes estimated annual totals.
5. Statistically aggregated total was not determined.
6. Value is the dry-gas content of reported wet-gas reserves, as estimated by EIA.
7. Value is total gas as estimated by EIA. It is reported by EIA as wet gas, but is also contains dry gas. PGC decided to use wet gas values from 2016 onwards instead of dry gas values as wet gas from EIA is more similar to the total gas assessed by PGC.
8. Due to the timing of the release of EIA's annual estimates, the PGC must use for the current (even-numbered) year's value of Proved Reserves the EIA's reported value for the immediately preceding odd-numbered year. In the PGC's next report, this value will be revised to reflect the actual even-numbered year-end value, which EIA will have published in the interim. Accordingly, the previous biennium's reported values for Proved Reserves, Future Gas Supply and Ultimately Recoverable Resource, shown in the table above, differ from those published in the preceding PGC report because the latter two calculated values now incorporate the EIA's subsequently published value of Proved Reserves for that even-numbered year.

Regional Resource Assessments, 2022

Tabulations of Mean Values

Table 4 presents the breakdown of the year-end 2022 mean values of Traditional resources by category (Probable, Possible and Speculative) and drilling theater for each of PGC's seven assessment areas. (Refer to Figure 6 for a map of the areas and geologic provinces.) Area onshore totals represent the aggregations of "most likely" values for both drilling-depth intervals combined, measured in feet (ft) (0–15,000 ft, 15,000–30,000 ft). Similarly, each offshore total represents the aggregation of "most likely" assessments for all water-depth intervals combined, measured in meters (m) (0–200 m, 200–1,000 m, >1,000 m). All Area totals (Probable, Possible, Speculative and Total, onshore and offshore), as well as all Subtotal Lower 48 States onshore and offshore, Total Lower 48 States and Total U.S. Traditional resource values, are separately aggregated mean values and are not derived by addition of the respective category or onshore/offshore subtotals. Only the Total U.S. Traditional and separately aggregated Total U.S. Coalbed Gas values are arithmetically summed to derive Grand Total U.S. values.

As a result of the current assessment, the Atlantic Area continues to rank first as the country's richest resource area with 40.0 percent of total Traditional resources, followed by the Mid-Continent Area with 18.5 percent, Rocky Mountain Area with 17.0 percent, and the Gulf Coast (including the Gulf of Mexico) with 16.3 percent.

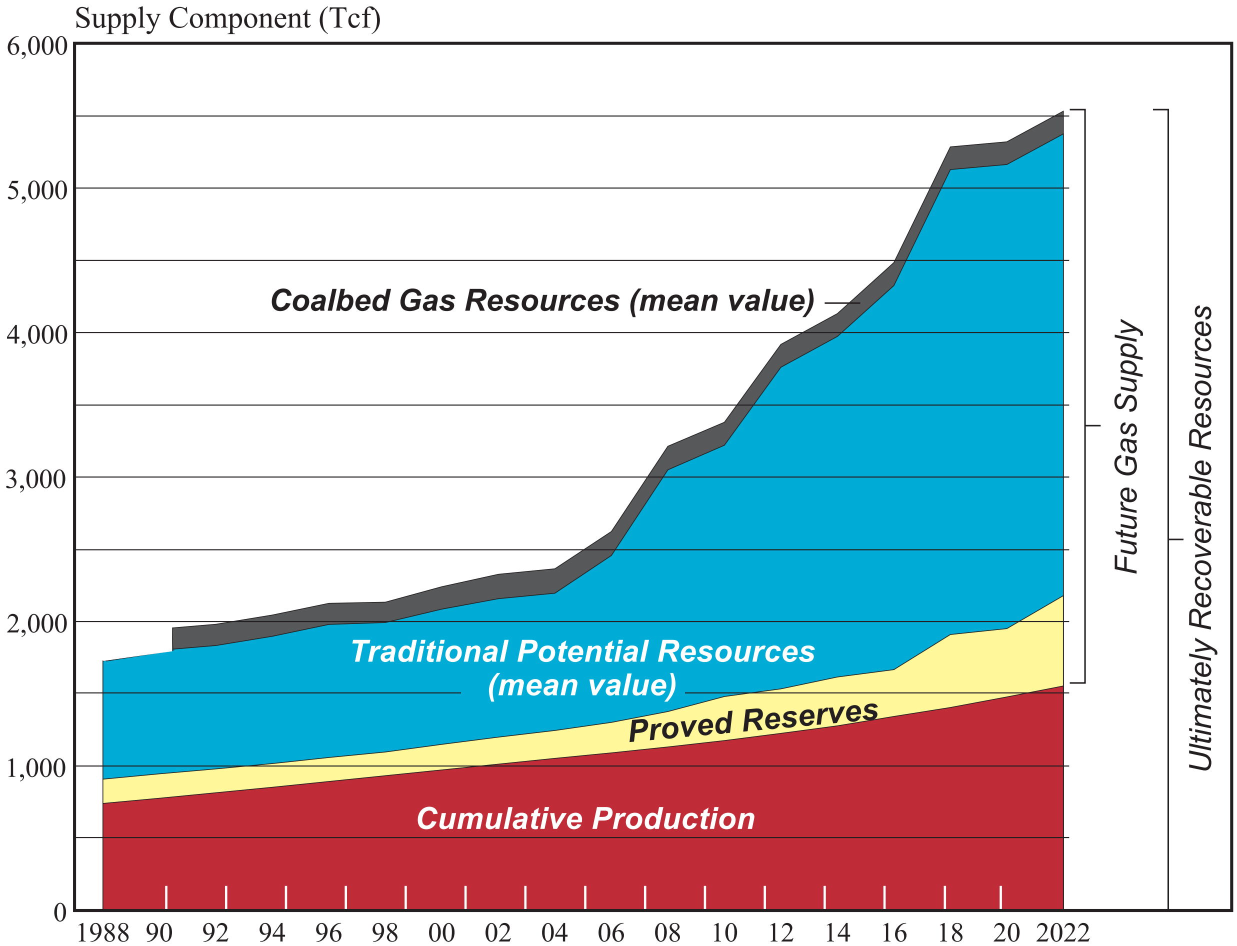


Figure 5. Potential Gas Committee's historical determinations of future supply and ultimately recoverable resources of natural gas in the United States, 1988 through 2022 (trillion cubic feet), using mean values of Traditional and coalbed gas resources from Table 3, and production and proved reserves values reported by EIA.

Table 5 compares the 2022 separately aggregated assessments from Table 4 with the corresponding values for year-end 2020. Changes from 2020 to 2022 arose from ongoing evaluations of geological, geophysical, drilling, well-test and production data from established plays and analysis of newly available data from plays just coming into development or production, particularly shale gas (or gas and liquids). In either case, any or all of the three resource categories may be revised upward or downward. Commonly, resources in one category may be reallocated to a category of higher certainty based on such factors as the onset or continuation of production and designation of proved reserves from discovered (Probable) resources; measurable success of well tests and applied drilling, completion and stimulation technologies; and expectations about reservoir extent and quality and recovery factors.

To help visualize better the biennial changes indicated in Table 5, refer to Figure 7A, which compares the values of total Traditional resources for 2020 and 2022 by area in descending order of total Traditional resources for 2022, with a separate comparison for total U.S. coalbed gas. This chart reveals that the ranking of areas as follows: Atlantic #1, Mid-Continent #2, Rocky Mountain #3, Gulf Coast #4, Alaska #5, Pacific #6, and North Central #7. The Rocky Mountain assessment increased from 500,330 in 2020 to 544,470 Bcf in 2022, but the assessments for the Atlantic, Gulf Coast and Pacific Areas all decreased. The Alaska, Mid-Continent, and North Central Areas remained unchanged from 2020, as did the total coalbed gas assessment. Figure 7B examines the ranking when considering the onshore and offshore Gulf Coast provinces separately. Since the year-end 2020 assessment, the ranking order has not changed; the Mid-Continent, Rocky Mountain and Gulf Coast Onshore Areas are ranked #2, #3 and #4, respectively.

Table 4. Potential Gas Committee's assessment of Traditional natural gas resources, by area, December 31, 2022 (mean values, billion cubic feet, rounded from computed values).

Area and Drilling Theater	Probable Resource	Possible Resource	Speculative Resource	Total Potential Resource
Atlantic				
Onshore (all drilling depths)	504,395	626,940	128,160	1,259,495
Offshore (all water depths)	0	0	19,400	19,400
Atlantic Area Total*	504,395	626,940	147,560	1,278,895
North Central				
Onshore (all drilling depths)	2,220	4,190	10,370	16,780
North Central Area Total	2,220	4,190	10,370	16,780
Gulf Coast				
Onshore (all drilling depths)	123,620	156,700	147,880	428,200
Offshore (all water depths)	16,700	41,530	33,530	91,760
Gulf Coast Area Total*	140,320	198,230	181,410	519,960
Mid-Continent				
Onshore (all drilling depths)	181,350	273,780	145,190	591,530
Mid-Continent Area Total	172,570	273,780	145,190	591,530
Rocky Mountain				
Onshore (all drilling depths)	202,405	192,270	150,795	544,470
Rocky Mountain Area Total	202,405	192,270	150,795	544,470
Pacific				
Onshore (all drilling depths)	3,540	11,190	19,050	33,780
Offshore (all water depths)	130	10,530	6,300	16,960
Pacific Area Total*	3,670	21,725	25,350	50,745
Subtotal Lower 48 States**				
Onshore (all drilling depths)	1,017,530	1,265,070	601,445	2,874,255
Offshore (all water depths)	16,830	52,060	59,230	128,120
Total Lower 48 States	1,025,580	1,317,135	660,675	3,002,380
Alaska				
Onshore (all drilling depths)	31,720	22,300	40,420	94,440
Offshore (all water depths)	5,130	19,480	74,760	99,370
Alaska Area Total*	36,850	41,780	115,180	193,810
Total U.S. Traditional Resources**	1,062,430	1,358,915	775,855	3,196,190
Total U.S. Coalbed Gas Resources	14,620	46,570	95,550	156,730
Grand Total United States‡	1,077,050	1,405,485	871,405	3,352,920

* Area Total is a separately aggregated value, not the arithmetically added sum of onshore and offshore values.
** All Subtotal Lower 48 States and Total U.S. Traditional Resource values are separately aggregated values, not the respective arithmetically added sums of Area totals.
† Production has not been established to date; resources have not been assessed.
‡ Aggregated Total Coalbed Gas Resource mean values are arithmetically added to Total U.S. Traditional Resource mean values to derive the Grand Total U.S. values.
Note: Totals are subject to rounding and slight differences due to statistical aggregation of distributions.

Table 5. Comparison of the Potential Gas Committee's assessments of Traditional natural gas resources for 2020 and 2022, by area (mean values, billion cubic feet).

	Probable Resource		Possible Resource		Speculative Resource		Total Resources		Biennial Change	
Area	2020	2022	2020	2022	2020	2022	2020	2022	Bcf	%
Atlantic										
Onshore	540,350	504,395	642,630	626,940	108,750	128,160	1,291,730	1,259,495	-32,235	-2.5%
Offshore	†	†	†	†	19,400	19,400	19,400	19,400	0	0%
Area Total*	540,350	504,395	642,630	626,940	128,150	147,560	1,311,130	1,278,895	-32,235	-2.5%
North Central	2,220	2,220	4,190	4,190	10,370	10,370	16,770	16,780	10	0.1%
Gulf Coast										
Onshore	160,690	123,620	154,960	156,700	130,670	147,880	446,320	428,200	-18,120	-4.1%
Offshore	16,700	16,700	41,530	41,530	33,530	33,530	91,750	91,760	10	0.0%
Area Total*	177,390	140,320	196,490	198,230	164,190	181,410	538,070	519,960	-18,110	-3.4%
Mid-Continent	172,570	172,570	273,780	273,780	145,190	145,190	591,530	591,530	0	0.0%
Rocky Mountain	192,290	202,405	170,480	192,270	137,570	150,795	500,330	544,470	44,140	8.8%
Pacific										
Onshore	3,820	3,540	11,560	11,190	21,220	19,050	36,590	33,780	-2,810	-7.7%
Offshore	130	130	10,530	10,530	6,300	6,300	16,960	16,960	0	0%
Area Total*	3,940	3,670	22,100	21,725	27,520	25,350	53,550	50,745	-2,805	-5.2%
Subtotal Lower 48**										
Onshore	1,071,930	1,017,530	1,257,590	1,265,070	560,150	601,445	2,889,670	2,874,255	-15,415	-0.5%
Offshore	16,820	16,830	52,060	52,060	59,230	59,230	128,110	128,120	10	0.0%
Total Lower 48 U.S.	1,088,750	1,025,580	1,309,650	1,317,135	619,380	660,675	3,017,780	3,002,380	-15,400	-0.5%
Alaska										
Onshore	31,720	31,720	22,300	22,300	40,420	40,420	94,440	94,440	0	0%
Offshore	5,130	5,130	19,480	19,480	74,760	74,760	99,370	99,370	0	0%
Area Total*	36,850	36,850	41,780	41,780	115,180	115,180	193,810	193,810	0	0%
Total U.S. Traditional**	1,125,600	1,062,430	1,351,430	1,358,915	734,560	775,855	3,211,590	3,196,190	-15,400	-0.5%
Total U.S. Coalbed Gas	14,620	14,620	46,570	46,570	95,550	95,550	156,730	156,730	0	0.0%
Grand Total U.S.‡	1,140,220	1,077,050	1,398,000	1,405,485	830,110	871,405	3,368,320	3,352,920	-15,400	-0.5%

* Area Total is a separately aggregated value, not the arithmetically added sum of onshore and offshore values.

** All Subtotal Lower 48 U.S. and Total U.S. Traditional values are separately aggregated values, not the respective arithmetically added sums of Area totals.

† Production has not been established; resources have not been assessed.

‡ Aggregated Total Coalbed Gas mean values are arithmetically added to Total U.S. Traditional mean values to derive the Grand Total U.S. mean values.

Note: Current-year totals are subject to rounding and slight differences due to statistical aggregation of distributions.

Highlights of Biennial Assessment Changes, 2020–2022

Below are synopses of the changes in PGC's regional assessments from 2020 to 2022. Please refer to the Area Assessments chapter for more detailed discussions.

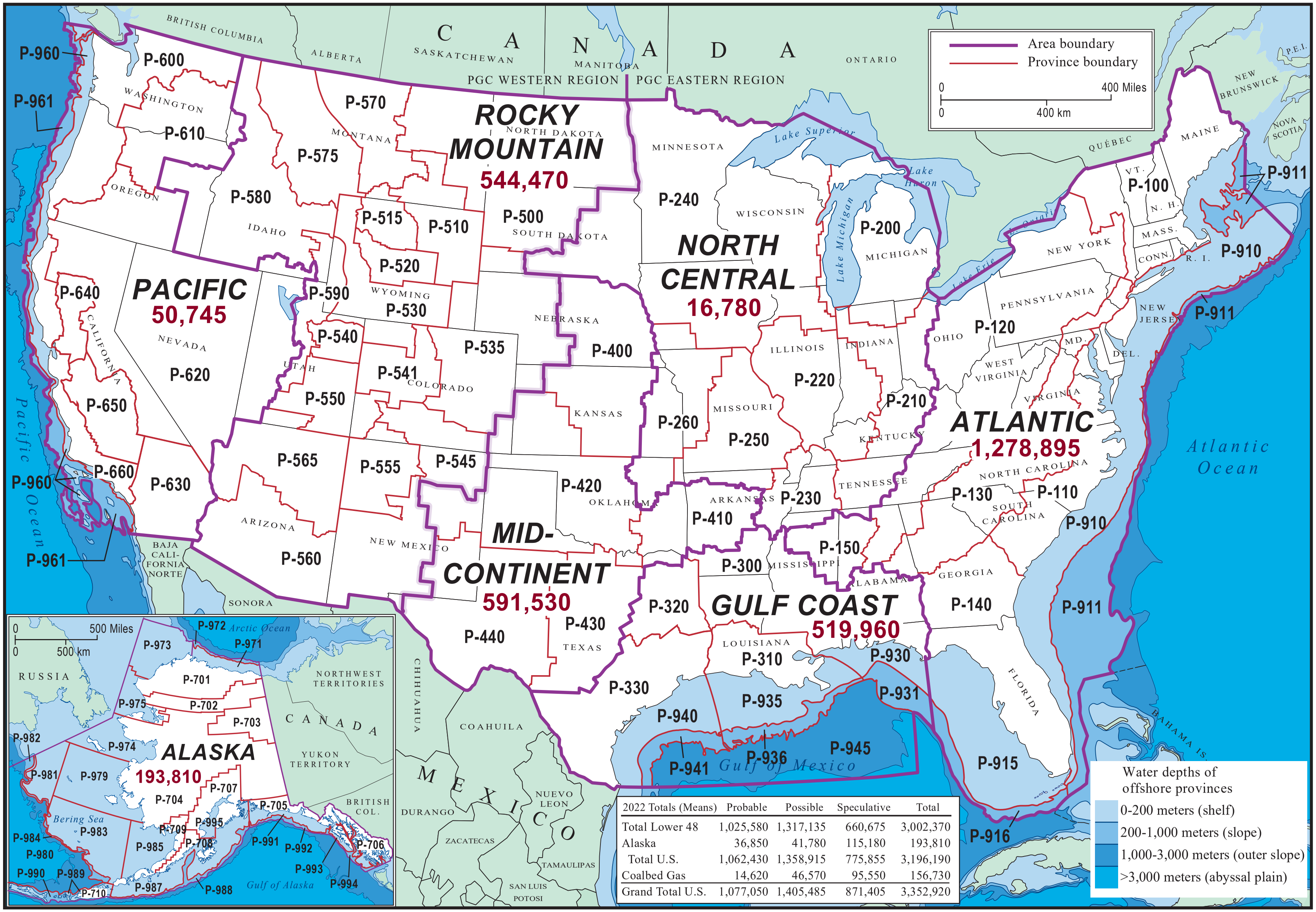
Atlantic Area – The year-end 2022 assessment for the Atlantic Area has decreased by approximately 3 percent since the last biennial reporting period. All of the increases in the Atlantic Area's assessment since 2016 arose from ongoing evaluation of Appalachian basin shales, predominantly the prolific Marcellus in Pennsylvania and West Virginia. The basin's shale gas assessment also includes contributions from the liquids-rich Utica Shale of eastern Ohio, the Geneseo-Burket shales of Pennsylvania and West Virginia, and other Devonian shales in the Appalachian basin.

North Central Area – The PGC's year-end 2022 assessment remains unchanged since the year-end 2020 assessment.

Gulf Coast Area – The PGC's year-end 2022 assessment for the Gulf Coast Area has decreased by 29,175 Bcf (6.3 percent) relative to 2020. The overall decrease in potential resources for the onshore area is attributed to downward revisions to the Louisiana-Mississippi-Alabama Salt basins (P-300) and Texas Gulf Coast basin (P-330), despite an upward revision for the East Texas basin (P-320).

Mid-Continent Area – The 2022 assessment for the Mid-Continent Area remains unchanged from 2020.

Rocky Mountain Area – This total assessment increased by 37,975 Bcf from the year-end 2020 assessment, due to a combination of upward revisions in the Wind River basin (P-520), Denver et al. (P-535), Uinta (P-540), Piceance,



2022 Totals (Means)	Probable	Possible	Speculative	Total
Total Lower 48	1,025,580	1,317,135	660,675	3,002,370
Alaska	36,850	41,780	115,180	193,810
Total U.S.	1,062,430	1,358,915	775,855	3,196,190
Coalbed Gas	14,620	46,570	95,550	156,730
Grand Total U.S.	1,077,050	1,405,485	871,405	3,352,920

Figure 6. Potential Gas Committee Work Areas and geologic provinces, showing PGC's year-end 2022 assessments of total Traditional gas resources by area (mean values, billion cubic feet) with a summary of national Probable, Possible and Speculative totals and grand totals.

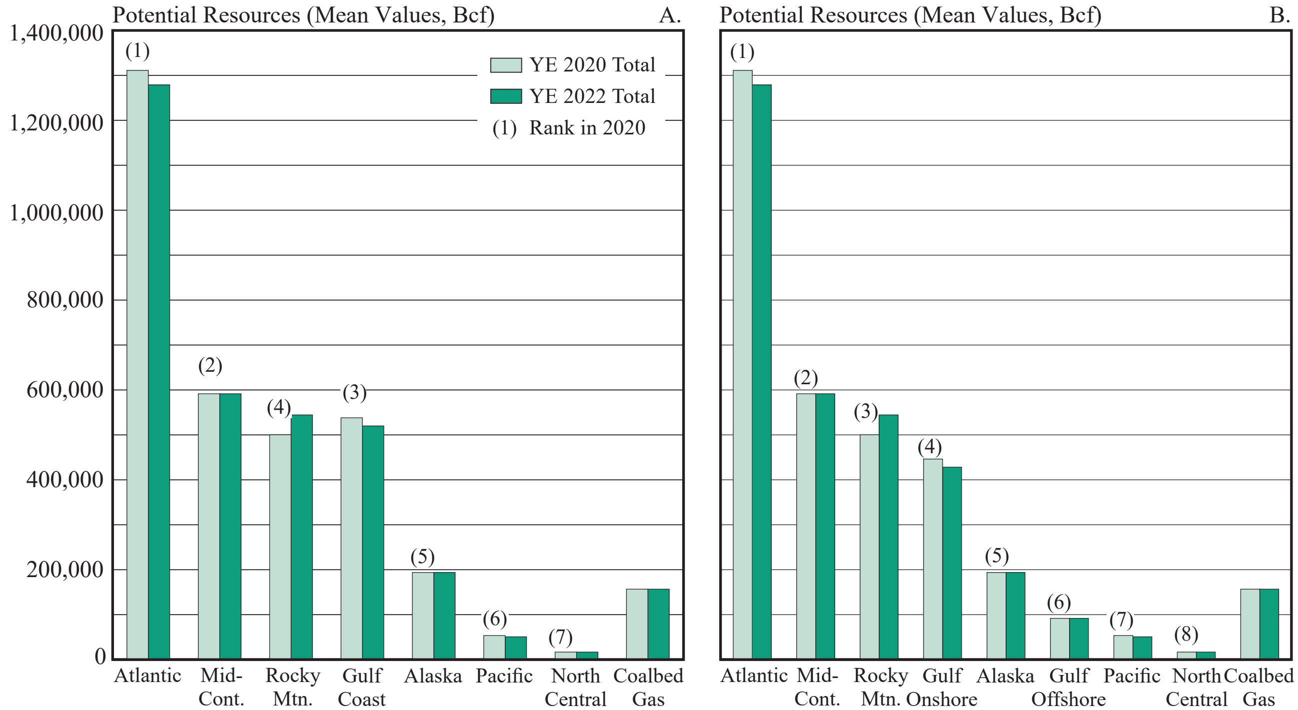


Figure 7. Comparison of the Potential Gas Committee's assessments of total Traditional and coalbed gas resources for year-end 2020 and year-end 2022 (mean values, billion cubic feet), by area in descending order, using values from Table 5. A. Gulf Coast Area onshore and offshore provinces combined. B. Gulf Coast Area onshore and offshore provinces separated.

Eagle, Lake and Park (P-541), and San Juan (P-555) basins. Resource assessments for other Rocky Mountain provinces remained unchanged.

Pacific Area – This current assessment reflects another minor downward revision in Traditional resources in the area's two principal onshore producing provinces, the Sacramento basin (P-640) and the San Joaquin basin (P-650), resulting in a decline of 495 Bcf (1.7 percent) in the Pacific Area's total Traditional resource volume.

Decennial Assessment Changes, 2012–2022

While the changes in area totals from one assessment cycle to the next are useful for short-term analysis (see Table 5 and Figure 7), it, too, can be informative to examine changes in assessments at the area level over a longer time interval, such as the preceding decade. Such analyses help to illustrate overall long-term impacts of newly developed plays, field extensions, new technologies and other key exploration and production trends, all part of the resource reevaluation dynamic alluded to previously. In Figure 8, we examine the percentage changes in mean values of Traditional resources for all areas and for total U.S. coalbed gas for the period 2012 – 2022.

The substanial change for the Atlantic Area over the decade relates directly to industry's aggressive development of and robust outlook for shale gas and liquids in the Appalachian basin since 2006. Although the Marcellus Shale still dominates, reevaluations of it, together with the Utica and the Geneseo-Burket shales, all contributed to significant increases within past reporting cycles.

Most of the growth in the Mid-Continent's resource base over the past decade is the result of substantial increases in shale gas assessments in the Arkoma basin (Fayetteville Shale of Arkansas), Fort Worth basin (Barnett Shale) and to a lesser extent the Anadarko basin (Woodford Shale). The other contributing factor was the substantial increase in the Permian basin assessment for 2018 resulting from new horizontal drilling in liquids-rich conventional and tight reservoirs under development via multiple-pay-zone and cross-formational completion strategies.

The increase for the Rocky Mountain Area relates in part to technological breakthroughs that have allowed greater access to the gas contained not only in Cretaceous tight sands, particularly in the Uinta, Piceance and Greater Green River basins, but also in fractured carbonates, principally in the Niobrara Formation of the Denver basin. Cretaceous shales, too, have contributed to higher assessments. While not yet developed into production to nearly the same degree as shales in other basins, their recognized gas and liquids potential is growing, as evidenced by higher assessments for the Piceance basin (Niobrara shale interval) from 2016 to 2018.

The key technological breakthroughs in horizontal drilling and stimulation that opened the prolific Barnett Shale play, in turn, provided an operational analog that, with fine-tuning, has facilitated exploitation of shale plays in Gulf Coast basins, beginning with the Haynesville in northern Louisiana and East Texas followed by the Eagle Ford play in the Texas Gulf Coast basin. The contribution of shale gas to the total resource decreased slightly in 2018 with the reassessment of the Tuscaloosa marine shale in the Louisiana Gulf Coast basin. The reassessment of the East Texas basin for the current reporting period added to the Area's resource, but those gains were offset by downward revision to Area shale gas resources due to production.

The decreases observed for the Pacific and North Central Areas over the past decade are likely due to a combination of factors. These are principally oil-producing areas with comparatively little associated and nonassociated conventional gas production or resources, and exploration for conventional gas in these areas beyond established fields has been limited. What's more, new shale gas or gas/liquids plays have been slow to materialize, compared to those in the Appalachians, Gulf Coast and Rockies.

Although the assessments for Alaska have not changed in recent reporting periods, the overall gas resource potential held within the diverse geological settings of this state cannot be overlooked. Exploring in Alaska presents unique and formidable challenges, which explains why so few development wells and even fewer exploration wells are drilled there each year.

Tabulations of "Most Likely" Values

Since 1964, the PGC has derived national gas resource totals by arithmetically summing the "most likely" values determined for all the provinces within each geographic assessment area. In 1990, the PGC also began computing and reporting aggregated mean values, which are statistically more valid for comparison with assessments made by other organizations. (Additional aggregations later were computed to derive the 1988 national mean totals shown in Table 2.) However, many readers still rely on the nonaggregated province-level assessment results (minimum, "most likely" and maximum values for each resource category, drilling-depth interval and water-depth interval). Indeed, the PGC deems these of greater value for purposes of analysis, planning and exploration. To examine these datasets, refer to the assessment tables in the following Area Assessments chapter and to the regional and national summary tables in the chapter, Methodology of the Potential Gas Committee.

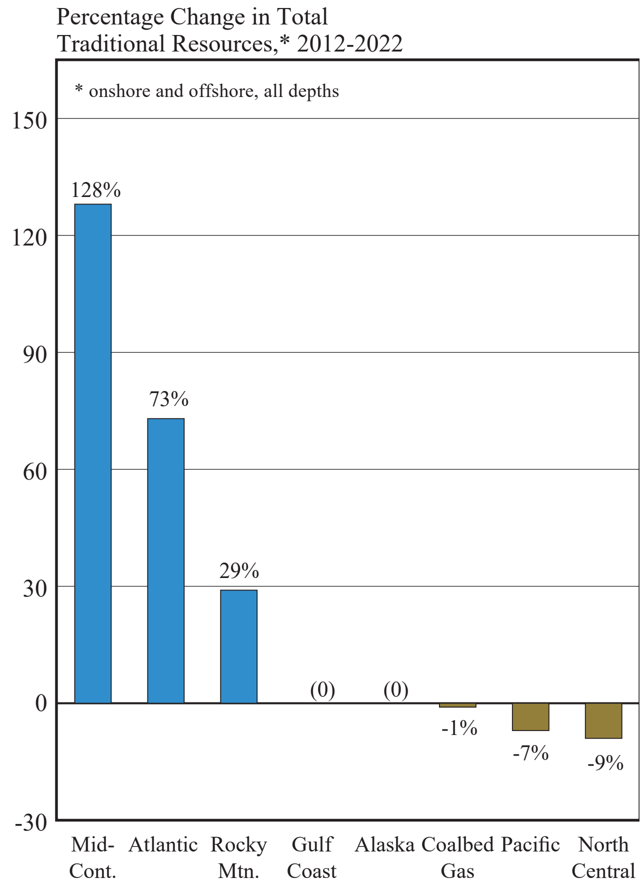


Figure 8. Decennial percentage changes in Traditional and coalbed gas resource assessments by the Potential Gas Committee, by area, 2012 through 2022 (based on aggregated mean values).

Coalbed Gas and Shale Gas Resource Assessments

Coalbed Gas

PGC's total coalbed gas assessment for year-end 2022 remains unchanged from that reported for 2020 (156,730 Bcf; Table 5).

The province-level and non-aggregated area-level coalbed gas resource data that appear in each area assessment table, found in the Area Assessments chapter, are summarized in a cumulative table in the concluding section of that chapter. That tabulation shows Area and Lower 48 States' subtotals, national totals and national aggregated means.

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Shale Gas

Given the continued pace of field development and the outlook for shale gas plays across the Lower 48 United States, the PGC continues to publish separately the results of its ongoing shale gas resource assessments. In as much as the PGC historically has treated gas resources in shale reservoirs as a component of "Traditional" resources, which also includes "conventional" and other "tight" (low-permeability) reservoirs, shale gas resources are now shown as separate entries in the area assessment tables even though they are considered a subset of Traditional resources. A separate tabulation of all producing, developing and emerging shale gas plays that the PGC has assessed for year-end 2022 appears in the Area Assessments chapter. This table reports the minimum, "most likely" and maximum volumes in each resource category for each assessed province. We also report aggregated mean values for shale gas.

The year-end 2022 total shale gas assessment of 1,791,310 Bcf ("most likely" value), represents a 36,474-Bcf (2.0 percent) decrease over that for year-end 2020. The year-end 2022 total shale gas mean value is 2,092,335 Bcf (Table 19). The net decrease impacted mostly by revised assessments of shales in the Appalachian basin of the Atlantic Area and the Louisiana-Mississippi-Alabama Salt basins and Texas Gulf basin of the Gulf Coast Area. Details of the changes are provided in the area summaries of the next chapter.

Comparing just the 2022 "most likely" values, shale gas accounts for 68.8 percent (1,793,920 Bcf) of the Lower 48 States' Traditional resources (2,604,170 Bcf; Table 22), increased from 65.8 percent in 2020, and 65.3 percent of the Total U.S. Traditional resources (2,747,220 Bcf; Table 22), increased from 62.4 percent in 2020. Based on the year-end 2022 mean values, total shale gas resources (2,092,335 Bcf) account for 65.4 percent of Traditional resources (3,196,190 Bcf; Table 5) and 62.4 percent of Grand Total mean U.S. potential gas resources (3,352,920 Bcf; Table 5).