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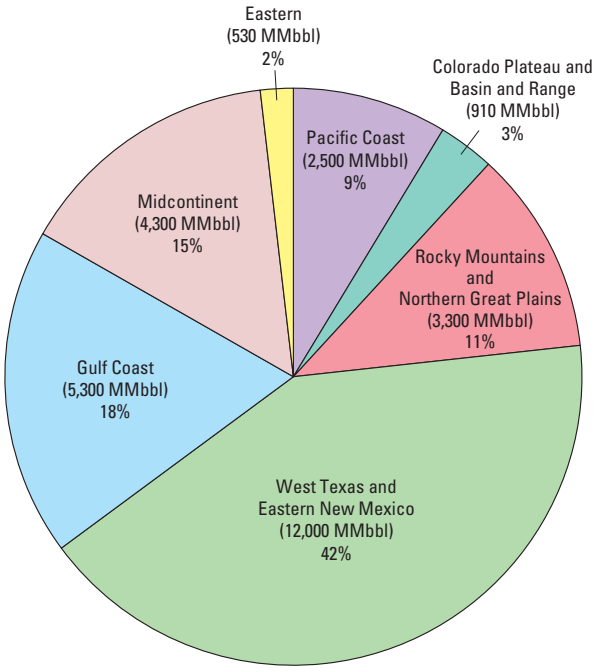
Energy Resources Program

National Assessment of Carbon Dioxide Enhanced Oil Recovery and Associated Carbon Dioxide Retention Resources—Summary

In 2020, the U.S. Geological Survey (USGS) completed a probabilistic assessment of the volume of technically recoverable oil resources that might be produced by using current carbon dioxide enhanced oil recovery (CO_2-EOR) technologies in amenable conventional oil reservoirs underlying the onshore and State waters areas of the conterminous United States. The assessment also includes estimates of the mass of CO_2 that could be stored (retained) in the assessed oil reservoirs following the application of the CO_2-EOR process. The USGS assessment team evaluated more than 3,500 oil reservoirs that were miscible to injected CO_2. The assessed reservoirs are in 185 previously defined USGS plays in 33 petroleum provinces of 7 national regions. The team estimated that the total technically recoverable oil resulting from the application of the CO_2-EOR process ranges from approximately 25,000 million barrels (MMbbl) at the P_5 percentile to as much as 32,000 MMbbl at the P_{95} percentile, with a mean of 29,000 MMbbl. The associated CO_2 retention ranges from approximately 7,400 million metric tons (Mt) at the P_5 percentile to as much as 9,500 Mt at the P_{95} percentile, with a mean of 8,400 Mt. The results are summarized in this fact sheet (figs. 1*A*, *B*, 2*A*, *B*; tables 1, 2) and are provided in more detail in the companion data release and circular (Warwick and others, 2022a, b).

The West Texas and Eastern New Mexico region (primarily its Permian Basin) and the Gulf Coast region together contain 60 percent of the mean assessed CO_2-EOR oil potential and 61 percent of the mean assessed CO_2 retention (figs. 1*A*, *B*, 2*A*, *B*). Other regions with significant resource potential include the Midcontinent region and the Rocky Mountains and Northern Great Plains region.

A. **Oil that could be produced with CO_2-EOR**



B. **CO_2 that could be retained with CO_2-EOR**

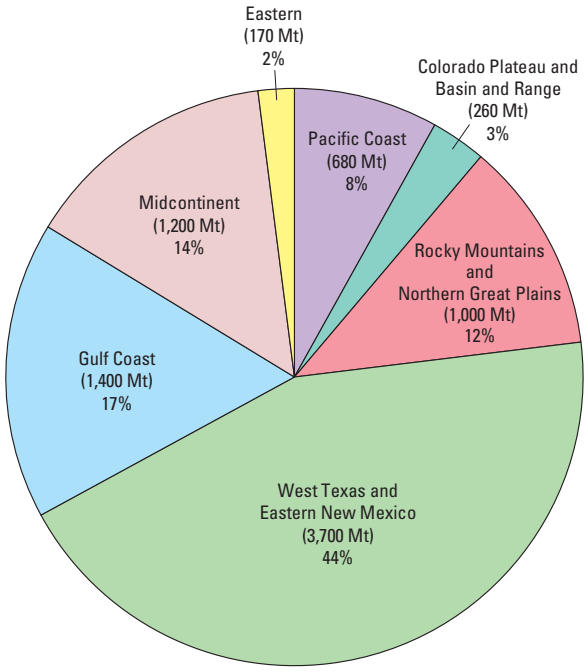


Figure 1. Pie charts showing regional mean estimates by the U.S. Geological Survey in 2020 of (*A*) technically recoverable volumes of oil that could be produced with the application of the carbon dioxide enhanced oil recovery (CO_2-EOR) process and (*B*) masses of subsurface carbon dioxide (CO_2) that could be stored (retained) with the application of the CO_2-EOR process in existing miscible oil reservoirs underlying onshore and State waters areas of the conterminous United States. A mean total of 29,000 million barrels (MMbbl) of oil was estimated to be producible from reservoirs amenable to the CO_2-EOR process. A mean total of 8,400 million metric tons (Mt) was estimated for subsurface CO_2 retention associated with the application of the CO_2-EOR process. Resources in Alaska, Hawaii, and federally owned offshore areas were not assessed. Mean values sum to totals but are reported to only two significant figures. Regional outlines are shown in figure 2.

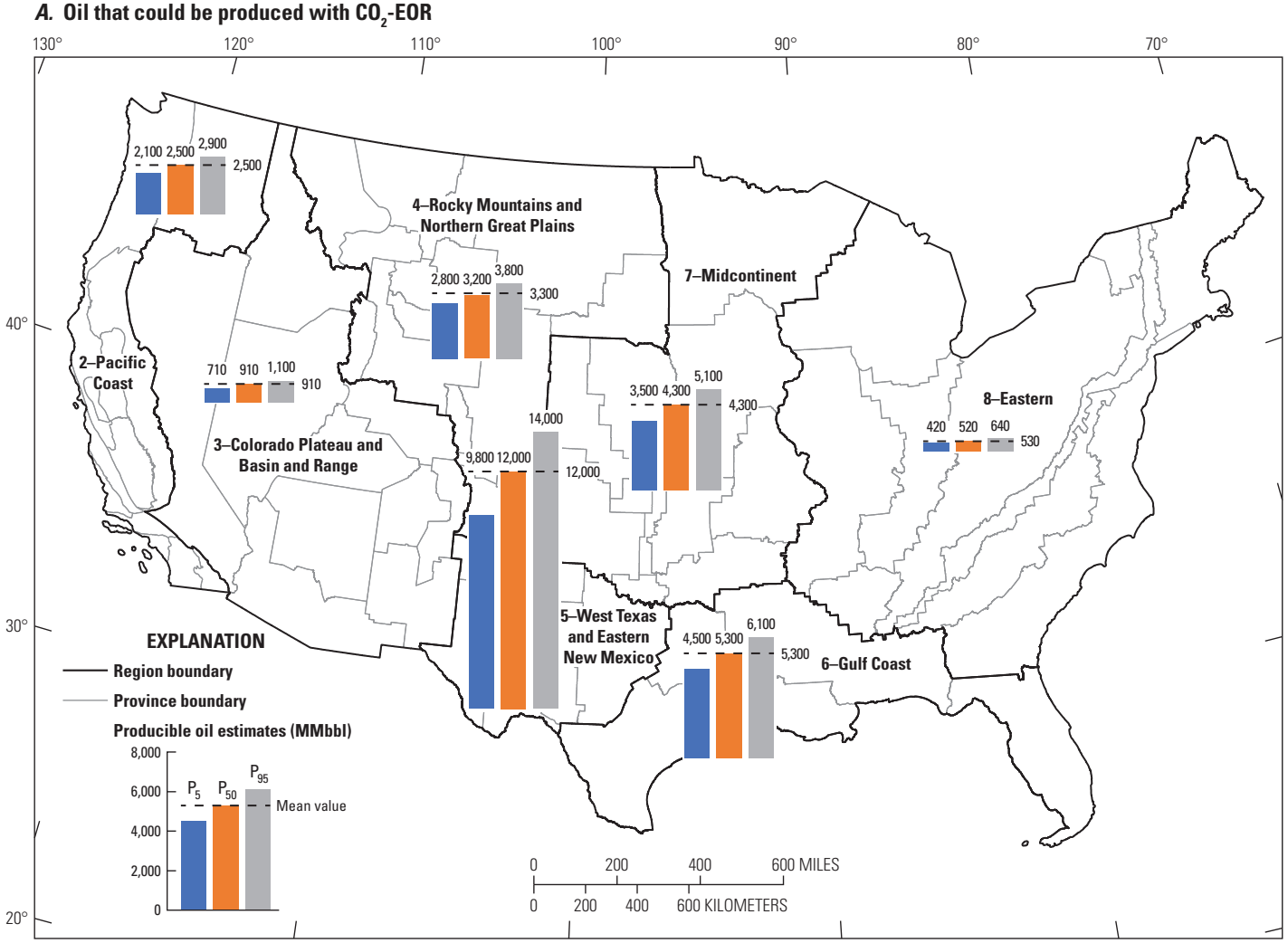


Figure 2. Maps of the conterminous United States and bar graphs showing regional estimates by the U.S. Geological Survey in 2020 of (*A*) technically recoverable volumes of oil, in millions of petroleum barrels (MMbbl), that could be produced with the application of the carbon dioxide enhanced oil recovery (CO_2-EOR) process and (*B*) masses of associated subsurface carbon dioxide (CO_2), in millions of metric tons (Mt), that could be stored (retained) with the application of the CO_2-EOR process in existing miscible oil reservoirs underlying onshore and State waters areas of the conterminous United States. The bar graphs show mean estimates and the P_5, P_{50}, and P_{95} probability percentiles, which represent the 5-, 50-, and 95-percent probabilities, respectively, that the true resource is less than or equal to the value shown. Regional results are also illustrated by pie charts in figure 1 and are listed in table 2. Values are reported to only two significant figures. Resources in Alaska (Region 1), Hawaii, and federally owned offshore areas were not assessed. Petroleum region and province boundaries are from the U.S. Geological Survey's 1995 National Oil and Gas Assessment (NOGA) (Beeman and others, 1996).

The Energy Independence and Security Act of 2007 (U.S. Congress, 2007) authorized the USGS to conduct a national assessment of geologic storage resources for CO_2 and requested the USGS to estimate the "potential volumes of oil and gas recoverable by injection and sequestration of industrial carbon dioxide in potential sequestration formations" (42 U.S.C. 17271(b)(4)). To accomplish this assessment, the USGS developed a national database that contained geologic and engineering parameters necessary for screening oil reservoirs for the application of CO_2-EOR methods (Carolus and others, 2017) and published a probabilistic methodology that could be used to assess qualifying oil reservoirs for their technically recoverable hydrocarbon potential and estimate the CO_2 remaining in the reservoir after the completion of the CO_2-EOR process (Warwick and others, 2019).

The use of CO_2-EOR techniques in identified hydrocarbon reservoirs can increase the national recoverable hydrocarbon resource volumes. Because some of the injected CO_2 is retained in the reservoir, use of anthropogenic CO_2 in the EOR process could potentially help reduce the amount of CO_2 released to the atmosphere that might contribute to global warming as a greenhouse gas. The International Energy Agency (2015) estimated that oil produced by using anthropogenic CO_2 in the CO_2-EOR process averages about 63 percent less carbon emitted than oil produced through traditional oil production methods.

The objective of this fact sheet is to summarize the results of a USGS assessment of (1) the volumes of oil that could be technically recoverable by applying the CO_2-EOR process to suitable oil reservoirs and (2) the mass of CO_2 that could be stored (retained) in petroleum reservoirs within the conterminous United States and State waters areas as a result of the application of the CO_2-EOR process (Warwick and others 2022a, b). The methodology used for the assessment (Warwick and others, 2019) follows the current practice in industry to maximize oil production rather than CO_2 retention because, in the general absence of regulations or economic incentives, industry practice is to minimize CO_2 retention in the subsurface (Jahangiri and Zhang, 2010). The assessment results are estimates of the technically recoverable oil resource that is available with the application of the CO_2-EOR process. The estimates do not include economic, logistical, legal, environmental, or political constraints, such as the availability of pipelines for CO_2 supply, surface ownership or use, or tax incentives for recovering the resource.

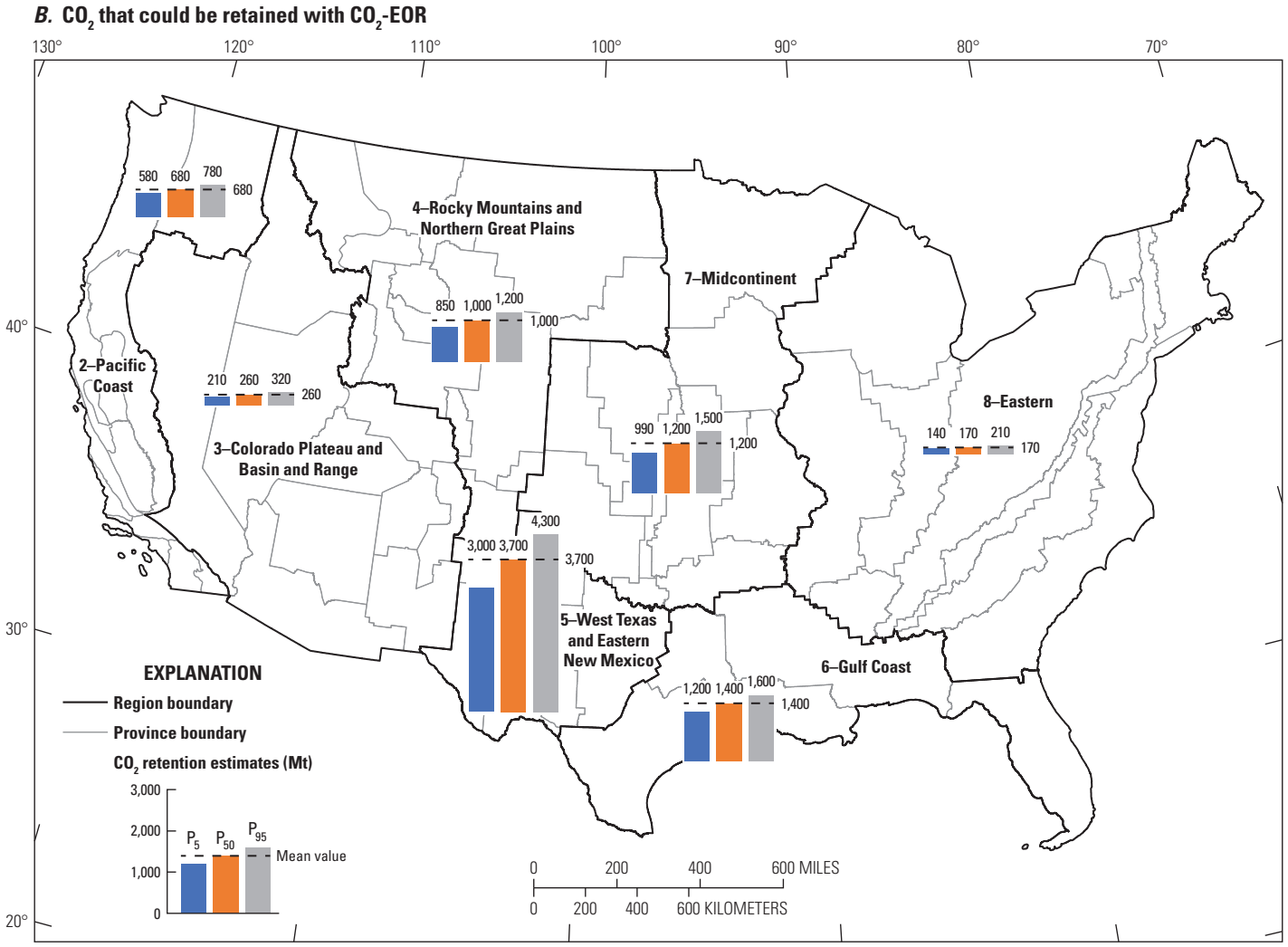


Figure 2. Continued

Table 1. Total estimated volume of oil that could be produced with carbon dioxide enhanced oil recovery (CO_2-EOR) and total mass of associated carbon dioxide (CO_2) that could be stored (retained) in existing reservoirs underlying onshore and State waters areas of the conterminous United States.

[Estimates of volumes of oil that could be produced with CO_2-EOR are in millions of petroleum barrels (MMbbl), and estimates of the mass of associated CO_2 that could be stored (retained) are in millions of metric tons (Mt). P_5, P_{50}, and P_{95} are probability percentiles and represent the 5-, 50-, and 95-percent probabilities, respectively, that the true resource is less than or equal to the value shown. The terminology used in this fact sheet differs from that used by the petroleum industry and follows standard statistical practice (for example, Everitt and Skrondal, 2010), where percentiles, or fractiles, represent the value of a variable below which a certain proportion of observations falls. The percentiles were calculated by using the aggregation method described in U.S. Geological Survey Geologic Carbon Dioxide Storage Resources Assessment Team (2013) and in Blondes and others (2013). Percentile values do not sum to totals because the aggregation procedure used partial dependencies between assessment units. Values are reported to only two significant figures]

Resource type	P_5	P_{50}	P_{95}	Mean
Oil produced during CO_2-EOR (MMbbl)	25,000	29,000	32,000	29,000
CO_2 retention (Mt)	7,400	8,400	9,500	8,400

Table 2. Estimated volume of oil that could be produced with carbon dioxide enhanced oil recovery (CO_2-EOR) and estimated mass of associated carbon dioxide (CO_2) that could be stored (retained) in existing reservoirs underlying onshore and State waters areas of the conterminous United States, aggregated by region and province.

[Estimates of volumes of oil that could be produced with CO_2-EOR are in millions of petroleum barrels (MMbbl), and estimates of the mass of associated CO_2 that could be stored (retained) are in millions of metric tons (Mt). P_5, P_{50}, and P_{95} are probability percentiles and represent the 5-, 50-, and 95-percent probabilities, respectively, that the true resource is less than or equal to the value shown; for more information on the percentiles, see table 1. The P_{50} (median) values may be less than mean values because most output distributions are right skewed. Values are reported to only two significant figures, and mean entries may not sum to totals because of rounding. A four-digit code identifies the USGS-specific province. Resources in Alaska (Region 1), Hawaii, and federally owned offshore areas were not assessed]

Province number	Province name	Oil produced with CO_2-EOR (MMbbl)				CO_2 retention with CO_2-EOR (Mt)			
		P_5	P_{50}	P_{95}	Mean	P_5	P_{50}	P_{95}	Mean
				Region 2–Pacific Coast					
5009	Sacramento Basin	6.7	8.7	11	8.7	1.7	2.2	2.7	2.2
5010	San Joaquin Basin	690	850	1,000	850	190	230	270	230
5011	Central Coastal	5.0	6.5	8.0	6.5	1.1	1.5	1.8	1.5
5013	Ventura Basin.	710	880	1,100	880	210	260	310	260
5014	Los Angeles Basin	620	760	890	760	150	190	220	190
	Aggregated total	**2,100**	**2,500**	**2,900**	**2,500**	**580**	**680**	**780**	**680**
				Region 3–Colorado Plateau and Basin and Range					
5020	Uinta-Piceance Basin	240	320	400	320	78	100	130	100
5021	Paradox Basin	53	66	79	66	17	20	25	21
5022	San Juan Basin	380	530	690	530	100	140	180	140
	Aggregated total	**710**	**910**	**1,100**	**910**	**210**	**260**	**320**	**260**
				Region 4–Rocky Mountains and Northern Great Plains					
5028	North-Central Montana	60	73	87	73	16	19	23	19
5031	Williston Basin	1,100	1,300	1,600	1,300	370	460	560	460
5033	Powder River Basin	740	890	1,000	890	210	260	300	260
5034	Big Horn Basin	330	400	480	400	90	110	130	110
5035	Wind River Basin	69	87	100	87	17	22	26	22
5036	Wyoming Thrust Belt	5.5	7.6	10	7.7	2.1	2.9	3.9	2.9
5037	Southwestern Wyoming	40	49	58	49	12	14	17	14
5038	Park Basins	0.84	1.2	1.5	1.2	0.25	0.35	0.46	0.35
5039	Denver Basin	300	380	470	380	82	100	130	100
5040	Las Animas Arch	23	29	35	29	6.9	8.6	10	8.6
	Aggregated total	**2,800**	**3,200**	**3,800**	**3,300**	**850**	**1,000**	**1,200**	**1,000**
				Region 5–West Texas and Eastern New Mexico					
5044	Permian Basin	8,600	11,000	13,000	11,000	2,700	3,300	3,900	3,300
5045	Bend Arch-Fort Worth Basin	1,000	1,300	1,500	1,300	300	370	440	370
	Aggregated total	**9,800**	**12,000**	**14,000**	**12,000**	**3,000**	**3,700**	**4,300**	**3,700**
				Region 6–Gulf Coast					
5047	Western Gulf	2,900	3,500	4,100	3,500	760	920	1,100	930
5049	East Texas Basin and Louisiana-Mississippi Salt Basins	1,500	1,800	2,100	1,800	400	480	570	480
5050	Florida Peninsula	3.5	4.7	5.9	4.7	1.3	1.7	2.2	1.7
	Aggregated total	**4,500**	**5,300**	**6,100**	**5,300**	**1,200**	**1,400**	**1,600**	**1,400**

Table 2. Estimated volume of oil that could be produced with carbon dioxide enhanced oil recovery (CO_2-EOR) and estimated mass of associated carbon dioxide (CO_2) that could be stored (retained) in existing reservoirs underlying onshore and State waters areas of the conterminous United States, aggregated by region and province.—Continued

[Estimates of volumes of oil that could be produced with CO_2-EOR are in millions of petroleum barrels (MMbbl), and estimates of the mass of associated CO_2 that could be stored (retained) are in millions of metric tons (Mt). P_5, P_{50}, and P_{95} are probability percentiles and represent the 5-, 50-, and 95-percent probabilities, respectively, that the true resource is less than or equal to the value shown; for more information on the percentiles, see table 1. The P_{50} (median) values may be less than mean values because most output distributions are right skewed. Values are reported to only two significant figures, and mean entries may not sum to totals because of rounding. A four-digit code identifies the USGS-specific province. Resources in Alaska (Region 1), Hawaii, and federally owned offshore areas were not assessed]

Province number	Province name	Oil produced with CO_2-EOR (MMbbl)				CO_2 retention with CO_2-EOR (Mt)			
		P_5	P_{50}	P_{95}	Mean	P_5	P_{50}	P_{95}	Mean
				Region 7–Midcontinent					
5053	Cambridge Arch-Central Kansas Uplift	410	530	670	540	110	140	180	140
5055	Nemaha Uplift	660	870	1,100	870	190	250	320	250
5058	Anadarko Basin	890	1,200	1,500	1,200	270	350	440	350
5059	Sedgwick Basin	150	200	260	200	44	59	76	59
5060	Cherokee Platform	550	740	960	750	150	200	260	200
5061	Southern Oklahoma	500	690	910	690	140	200	260	200
5062	Arkoma Basin	48	64	83	65	14	19	25	19
	Aggregated total	**3,500**	**4,300**	**5,100**	**4,300**	**990**	**1,200**	**1,500**	**1,200**
				Region 8–Eastern					
5063	Michigan Basin	220	290	370	290	72	94	120	95
5064	Illinois Basin	84	110	140	110	23	29	37	29
5067	Appalachian Basin	98	120	150	120	39	49	59	49
	Aggregated total	**420**	**520**	**640**	**530**	**140**	**170**	**210**	**170**

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