Independent Statistics & Analysis
U.S. Energy Information Administration

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Short-Term Energy Outlook Supplement: 2011 Outlook for Hurricane-Related Production Outages in the Gulf of Mexico

Highlights

- The National Oceanic and Atmospheric Administration's (NOAA) *Atlantic Hurricane Season Outlook*, released on May 19, 2011, predicts that the Atlantic basin likely will experience above-normal tropical weather activity during this year's hurricane season (June 1 – November 30).[1] NOAA projects that 12 to 18 named storms will form within the Atlantic Basin over the next 6 months, including 6 to 10 hurricanes of which 3 to 6 will be intense.[2]

- Based on the results of a simulation using the NOAA predictions for the level of hurricane activity, EIA estimates that median outcomes for shut-in production in the Federally-administered Gulf of Mexico as a result of disruptions during the 2011 hurricane season are 19 million barrels (bbls) of crude oil and 53 billion cubic feet (Bcf) of natural gas.

- Projections of shut-in production are highly uncertain. For example, there is a 70-percent probability that shut-in offshore production for the entire season will fall between 3.2 and 53.5 million bbls of crude oil and between 6.5 and 162 Bcf of natural gas. Intervals with a higher likelihood of encompassing the actual level of shut-in production would be even wider.

- EIA's simulation results indicate an 80-percent probability of offshore crude oil or natural gas production experiencing outages during the upcoming hurricane season that are equal to or larger than the production shut in during the 2010 hurricane season (about 4.3 million bbls of crude oil and 8.5 Bcf of natural gas).

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[1] http://www.cpc.noaa.gov/products/outlooks/hurricane.shtml

[2] A named storm generally refers to either a tropical storm or hurricane. An intense hurricane is one rated as Category 3, 4 or 5. A moderate hurricane is classified as either Category 1 or 2.

Impacts of the 2010 Hurricane Season on Crude Oil and Natural Gas Production

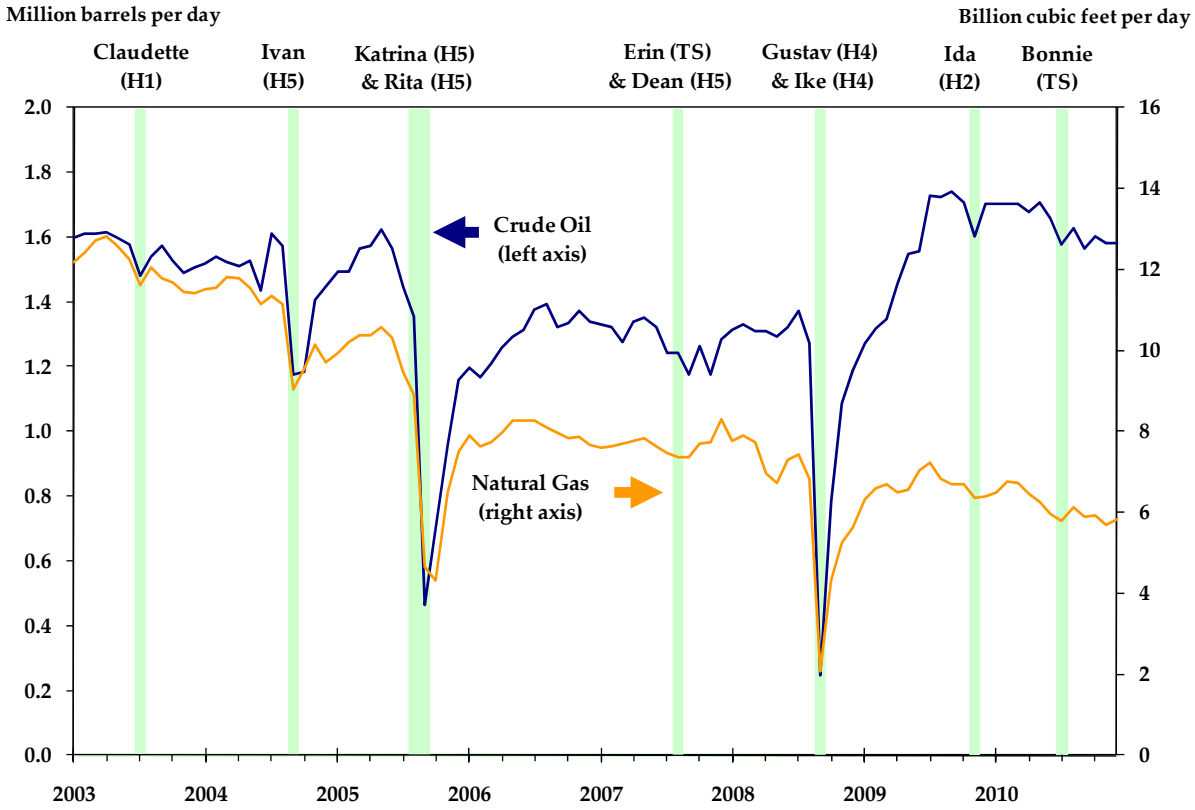
The Atlantic Basin experienced above-average hurricane activity during the 2010 hurricane season, consistent with NOAA's updated August 2010 *Outlook*. Nineteen named storms passed through the region, including 7 tropical storms and 12 hurricanes, of which 5 were classified as intense.[3]

Although hurricane activity in the entire Atlantic was above normal, the Gulf of Mexico was spared from the worst of the storms. Only one hurricane and two tropical storms threatened offshore energy production, and none of the storms passed within 400 miles of the center of the Gulf producing region. Thus, the impacts to crude oil and natural gas production were quite limited.

Hurricane Alex initially threatened offshore production in late June 2010, but as the storm reached hurricane strength it turned westward and made landfall near Tampico, Mexico. According to the Department of the Interior's Bureau of Ocean Energy Management, Regulation, and Enforcement (BOEMRE), a total of 1.04 million bbls of crude oil and 1.6 Bcf of natural gas were shut in by Hurricane Alex, representing about 2 percent and 1 percent of normal monthly Gulf crude oil and natural gas production, respectively. In late July, Tropical Storm Bonnie passed over Florida and entered the Gulf of Mexico. By the time it passed over the Gulf producing region, it had been downgraded to a tropical depression. BOEMRE reports that 3.26 million bbls of crude oil production (7 percent of the monthly normal level) and 6.3 Bcf of natural gas production (3 percent of the monthly normal level) were shut in by Bonnie. Figure 1 highlights the effect of some past tropical storms and hurricanes on crude oil and natural gas production in the Gulf of Mexico.

[3] NOAA had originally projected a relatively normal level of hurricane activity in its May 2010 *Outlook*, but the projection was revised in August to a likely range of 14 to 20 named storms, including 8 to 12 hurricanes.

Figure 1. Crude Oil and Natural Gas Production
Federal Offshore Gulf of Mexico, 2003-2010



Note: TS = Tropical Storm. H*n* = Category *n* hurricane.
Source: U.S. EIA and National Oceanic and Atmospheric Administration (NOAA).

Shut-in Production Outlook for the 2011 Hurricane Season

NOAA's *Atlantic Basin Hurricane Season Outlook*, which was released May 19, 2011, calls for a 65-percent chance of above-normal hurricane activity this season, a 25-percent chance of normal activity, and a 10-percent chance of below-normal activity. The *Outlook* indicates that 12 to 18 named storms likely will form within the Atlantic Basin, including 6 to 10 total hurricanes of which 3 to 6 will be intense. The projection of above-normal tropical weather activity in the entire Atlantic implies a greater likelihood for shut-in production in the Gulf of Mexico.

Seasonal hurricane-related disruptions to crude oil and natural gas production are difficult to forecast, primarily because of the uncertainty involved in predicting both the intensity of severe weather and the affected locations. Discussion of production outages in the face of such uncertainty requires analysis not just of the expected impact but also the probabilities inherent in various scenarios. EIA's projections for

shut-in production during the 2011 hurricane season were derived using Monte Carlo simulation techniques, which involve running numerous simulated hurricane seasons assuming random variations from NOAA's storm forecast and historical experience of storm-related outages. Sampling distributions for seasonal shut-in crude oil and natural gas production were compiled using the results of the simulations. These sampling distributions can be used to summarize the expected level of shut-in production, but they also illustrate the uncertainty of the projections by outlining the probabilities of various outage scenarios.

The Monte Carlo simulation used for this analysis consisted of two steps: first, EIA simulated the number of severe storms passing through the Gulf of Mexico, and, second, it simulated an estimate of shut-in production was developed for each simulated storm. The number of tropical storms, moderate hurricanes, and intense hurricanes passing through the Gulf of Mexico was modeled using information contained in NOAA's *Atlantic Basin Hurricane Season Outlook*. The *Outlook*'s projected ranges for the entire Atlantic compare with a seasonal average of 11.8 named storms, 6.4 hurricanes, and 2.7 intense hurricanes during NOAA's baseline period of 1981-2010. During the same period, the Gulf of Mexico region experienced an average of 3.9 named storms including an average of 1.9 hurricanes of which 0.7 were intense.[4] EIA's simulation assumed that the likelihood of the number of each type of storm passing through the Gulf of Mexico could be modeled as a Poisson distribution.[5] The assumed mean of each distribution was calculated by multiplying the average number of each type of Gulf storm by the ratio between the midpoints of NOAA's projected seasonal range for the number of each type of storm and the average number of storms in the Atlantic Basin.

The second step of the Monte Carlo simulation involved modeling the shut-in production caused by each simulated tropical storm or hurricane and aggregating the values to calculate a cumulative seasonal outage. EIA's model simulated the proportion of shut-in production relative to normal monthly production based on how tropical storms and hurricanes affected production in the past, where "normal" is defined as the average monthly production during the January-to-May period preceding each year's hurricane season. Simulating the relative level of shut-in production allowed the model to reflect the declining trend in Gulf natural gas production and the deepwater drilling moratorium enacted last year, which has

[4] The Gulf of Mexico is defined for this report as the area within the rectangle bounded by 18°N – 31° N latitude and 81° W – 98° W longitude. The mean number of storms was calculated by EIA using NOAA's HURDAT database.

[5] A Poisson distribution expresses the probability of a given number of discrete events occurring during a fixed time period with an assumed average rate of occurrence.

limited growth in offshore production. Simulated relative shut-in percentages were then multiplied by the average of EIA's estimates of monthly Gulf crude oil or natural gas production during January to May of 2011 to calculate a simulated level of cumulative shut-in production caused by each storm.

Table 1. Shut-in Production as a Percentage of Normal Monthly Production by Type of Weather System, 1995-2010

	Crude Oil		Natural Gas	
	Mean	Std Dev	Mean	Std Dev
Tropical Storm	1.13%	1.69	0.67%	0.85
Moderate Hurricane [a]	3.32%	4.81	2.10%	3.09
Intense Hurricane [b]	28.44%	39.36	25.03%	35.64

Notes: [a] Category 1 or 2. [b] Category 3, 4, or 5. Std Dev = standard deviation.
Source: EIA calculations.

The simulated relative outage for each storm was assumed to be normally distributed, with a mean and standard deviation as shown in Table 1. These percentage outage statistics were calculated from EIA's estimates for the amount of production shut in by each storm over the period 1995-2010 (see Table A1 in the Appendix). The mean relative outages illustrate how weather-related production impacts increase dramatically with the severity of the storm. The mean value for intense hurricanes was skewed by the 100 million bbls of crude oil and 500 Bcf of natural gas cumulative production shut in by Hurricanes Katrina and Rita during 2005. The large standard deviation values imply that extreme events such as Katrina and Rita are relatively rare. For this analysis, any negative simulated shut-in values were assumed to represent zero production impact.

EIA conducted 10,000 random draws of the Monte Carlo simulation to build sampling distributions of seasonal shut-in crude oil or natural gas production within the Gulf of Mexico. Crude oil outages and natural gas outages were simulated separately. Table 2 summarizes the expected levels of seasonal production outages derived from the sampling distributions along with the estimated probabilities of various shut-in production scenarios. The extreme skewness or asymmetry of the two sampling distributions is evident in the large difference between the mean and median values. The mean value of a sampling distribution represents the simple average of all possible outcomes. The median value is that outcome which has an equal probability, 50 percent, of either falling below or exceeding the outcome value.

For crude oil, the median level of simulated cumulative shut-in production is 19 million bbls, in contrast to a mean of 27 million bbls. For natural gas, the median shut-in production level is 53 Bcf, in contrast to the mean of about 78 Bcf. This skewness occurs because the simulation allows for the possibility of another hurricane

season like 2005. Table 2 also shows the median outages for a simulated "normal" season in which the assumed mean values for Poisson distributions modeling the occurrence of each type of storm are equal to their average historical values over the period 1950-2010. EIA's projected median outages of 19 million bbls of crude oil and 53 Bcf of natural gas for the 2011 hurricane season are about three times the simulated outages expected during a normal hurricane season.

Table 2. Simulated Cumulative Seasonal Shut-in Production

Crude Oil (million barrels)		Natural Gas (billion cubic feet)	
Mean 2011 seasonal outage	26.7	Mean 2011 seasonal outage	77.9
Median 2011 seasonal outage	19.3	Median 2011 seasonal outage	52.9
Median normal seasonal outage	6.2	Median normal seasonal outage	14.4
2011 Outage Scenario Probabilities		2011 Outage Scenario Probabilities	
P(No Shut-In)	0.0150	P(No Shut-In)	0.0134
P(> 25 MMbbl Shut-in)	0.4310	P(> 100 Bcf Shut-in)	0.3230
P(> 50 MMbbl Shut-in)	0.1710	P(> 200 Bcf Shut-in)	0.0890
P(> 100 MMbbl Shut-in)	0.0180	P(> 300 Bcf Shut-in)	0.0180

Notes: MMbbl = million barrels, Bcf = billion cubic feet. More complete scenario probability tables are shown in Tables A2 and A3 in the Appendix.
Source: EIA calculations.

The sampling distributions derived from the Monte Carlo simulation also allow an analysis of other possible outage scenarios besides the median value. Table 2 lists some of the probabilities of exceeding certain levels of shut-in production during the upcoming season. More complete scenario probabilities are shown in Tables A2 and A3 in the Appendix, along with comparable probabilities during a normal season.

The probability of the Gulf producing region experiencing some positive level of shut-in production (i.e., outages greater than zero) is very high, exceeding 98 percent. Conversely, the likelihood of seasonal shut-in production falling below 25 million bbls of crude oil or 100 Bcf of natural gas this year is 57 percent and 68 percent, respectively. During the 2010 season, Gulf of Mexico energy producers shut in a cumulative total of 4.3 million bbls of crude oil and 8.5 Bcf of natural gas at some point. The Monte Carlo simulation results indicate that the likelihoods of experiencing similar disruptions or worse during the upcoming season are 79 percent for crude oil and 81 percent for natural gas, which are nearly double the probabilities expected during a normal season.

It is important to stress the uncertainty surrounding EIA's forecast of shut-in production. The simulated cumulative probability distribution functions can be used to construct various "likely" ranges for production outages in the Gulf of Mexico. For example, there is a 70-percent probability that shut-in offshore production for the

entire season will fall between 3.2 and 53.5 million bbls of crude oil and between 6.5 and 162 Bcf of natural gas. Both of the ranges are wide, and constructing intervals with a higher likelihood would widen the range even further.

The seasonal outage probability distributions simulated in this analysis are conditioned upon NOAA's projections of the number of storms expected to form within the Atlantic Basin. Long-range forecasts of hurricane activity are highly uncertain, especially with regards to activity within specific regions. As the hurricane season progresses and more information about actual outcomes is collected, there will likely be a need to revisit estimates of the likelihood of the various levels of shut-in production.

Appendix

Table A1. Shut-in Production Caused by Gulf of Mexico Tropical Storms and Hurricanes, 1995-2010

			Reported and Estimated Shut-in Production [b]			
		Maximum	Crude Oil		Natural Gas	
Name	Date	Category [a]	MMbbl	% of Normal	Bcf	% of Normal
Allison	Jun 1995	1	0.62	2.2	0.33	0.1
Dean	Jul 1995	0	0.19	0.7	4.03	1.0
Erin	Aug 1995	1	1.53	5.4	15.45	3.9
Gabrielle	Aug 1995	0	0.49	1.7	4.94	1.2
Jerry	Aug 1995	0	0.07	0.2	0.68	0.2
Opal	Oct 1995	4	2.09	7.3	24.30	6.1
Roxanne	Oct 1995	3	1.46	5.2	17.39	4.3
Dolly	Aug 1996	1	0	0.0	0	0
Josephine	Oct 1996	0	0.82	2.7	7.76	1.9
Lili	Oct 1996	2	0.63	2.1	5.99	1.4
Marco	Nov 1996	0	0	0.0	1.75	0.4
Danny	Jul 1997	1	0.99	3.1	6.31	1.5
Charley	Aug 1998	0	0	0.0	0	0
Earl	Sep 1998	2	3.76	9.9	27.47	6.4
Frances	Sep 1998	0	0.79	2.1	5.74	1.3
Georges	Sep 1998	2	7.69	20.3	56.14	13.1
Hermine	Sep 1998	0	1.34	3.5	9.75	2.2
Mitch	Nov 1998	0	1.48	3.8	0.04	0.0
Bret	Aug 1999	4	1.72	4.4	5.67	1.3
Harvey	Sep 1999	0	0.76	1.9	5.17	1.2
Irene	Oct 1999	1	0.28	0.7	3.95	0.9
Beryl	Aug 2000	0	0	0.0	0.85	0.2
Gordon	Sep 2000	1	0	0.0	0.50	0.1
Helene	Sep 2000	0	0	0.0	0.35	0.1
Keith	Oct 2000	1	0.42	1.0	0	0
Allison	Jun 2001	0	0.99	2.2	7.15	1.7
Barry	Aug 2001	0	2.39	5.2	11.95	2.8
Chantal	Aug 2001	0	0.38	0.8	1.91	0.4
Gabrielle	Sep 2001	0	0	0.0	0	0
Michelle	Nov 2001	4	1.09	2.4	8.63	2.0

See notes at end of table. *Table continued on next page*

Table A1. Shut-in Production Caused by Gulf of Mexico Tropical Storms and Hurricanes, 1995-2010, continued

Name	Date	Maximum Category [a]	Reported and Estimated Shut-in Production [b] Crude Oil MMbbl	Crude Oil % of Normal	Natural Gas Bcf	Natural Gas % of Normal
Bertha	Aug 2002	0	0	0.0	0	0
Edouard	Sep 2002	0	0.01	0.0	0.03	0.0
Fay	Sep 2002	0	0.22	0.5	1.34	0.3
Hanna	Sep 2002	0	0.28	0.6	1.69	0.4
Isidore	Sep 2002	3	4.50	9.2	27.50	7.1
Lili	Oct 2002	4	9.90	20.2	61.50	16.0
Bill	Jul 2003	0	0.07	0.0	0.61	0.2
Claudette	Jul 2003	1	1.27	2.7	8.04	2.2
Erika	Aug 2003	1	0.01	0.0	0.33	0.1
Grace	Aug 2003	0	0.00	0.0	0.08	0.0
Henri	Sep 2003	0	0.39	0.8	1.88	0.5
Larry	Oct 2003	0	0.16	0.3	0	0
Bonnie	Aug 2004	0	0.70	1.5	4.10	1.2
Charley	Aug 2004	4	0.56	1.2	3.27	0.9
Frances	Sep 2004	0	0.06	0.1	0.12	0.0
Ivan	Sep 2004	5	38.01	82.8	150.71	42.3
Jeanne	Sep 2004	1	0.09	0.2	0.34	0.1
Matthew	Oct 2004	0	0.01	0.0	0.11	0.0
Arlene	Jun 2005	0	0.58	1.3	3.43	1.2
Bret	Jun 2005	0	0.03	0.1	0.20	0.1
Cindy	Jul 2005	1	0.31	0.7	1.68	0.6
Dennis	Jul 2005	4	5.30	11.7	23.25	7.6
Emily	Jul 2005	4	0.24	0.5	1.58	0.5
Gert	Jul 2005	0	0.02	0.0	0.09	0.0
Jose	Aug 2005	0	0.16	0.3	0.83	0.3
Katrina	Aug 2005	5	30.25	64.8	155.33	50.5
Rita	Sep 2005	5	70.48	150.5	361.91	116.2
Stan	Oct 2005	1	0.69	1.5	4.13	1.3
Tammy	Oct 2005	0	0.06	0.1	0.37	0.1
Wilma	Oct 2005	4	8.05	17.3	43.54	13.9
Alberto	Jun 2006	0	0.14	0.4	0.22	0.1
Barry	Jun 2007	0	0.09	0.2	0	0
Dean	Aug 2007	5	0.44	0.4	0.44	0.2
Erin	Aug 2007	0	0.00	0.0	0.02	0.0
Humberto	Sep 2007	1	1.35	5.9	2.47	1.0
Ten [c]	Sep 2007	[c]	2.83	7.1	7.81	3.3

See notes at end of table.

Table continued on next page

Table A1. Shut-in Production Caused by Gulf of Mexico Tropical Storms and Hurricanes, 1995-2010, continued

			Reported and Estimated Shut-in Production [b]			
		Maximum	Crude Oil		Natural Gas	
Name	Date	Category [a]	MMbbl	% of Normal	Bcf	% of Normal
Dolly	Jul 2008	2	0.14	0.4	1.42	0.6
Edouard	Aug 2008	0	0.13	0.3	11.23	4.8
Gustav	Sep 2008	4	38.94	97.7	219.92	95.5
Ike	Sep 2008	4	21.53	54.0	121.60	52.8
Claudette	Aug 2009	0	0.30	0.7	6.22	3.3
Ida	Nov 2009	2	1.38	2.9	4.60	2.2
Alex	Jun 2010	2	1.04	2.1	1.62	0.8
Bonnie	Jul 2010	0	3.26	6.8	6.32	3.2
Hermine	Sep 2010	0	0	0	0	0

Source: Storm information from NOAA. Shut-in production from BOEMRE shut-in statistics reports for available storms, otherwise EIA estimates (see *The 2007 Outlook for Hurricane Impacts on Gulf of Mexico Crude Oil & Natural Gas Production* for estimation methodology <http://www.eia.gov/emeu/steo/pub/pdf/2007_hurricanes.pdf>)

Notes: [a] 0 = Tropical storm. 1-5 = Category n hurricane.

[b] MMbbl = million barrels. Bcf = billion cubic feet. Normal production defined as average monthly production during the January to May period preceding the given hurricane season.

[c] Storm was classified as a tropical depression.

Table A2. Simulated Probabilities for Exceeding Various Levels of Seasonal Shut-in Gulf of Mexico Crude Oil Production

	Probability of Shut-in Production	
> Million Barrels	2011 Season	Normal Season
0	98.5%	94.7%
0.5	97.3%	91.0%
1	95.3%	86.6%
1.5	93.3%	81.5%
2	90.8%	76.6%
2.5	88.1%	72.4%
3	85.9%	68.7%
3.5	83.4%	64.8%
4	81.1%	61.7%
4.5	79.1%	58.7%
5	76.8%	56.0%
6	73.3%	51.1%
7	69.9%	47.1%
8	67.3%	44.2%
9	64.9%	42.0%
10	62.8%	40.1%
11	60.9%	38.5%
12	59.4%	37.1%
13	58.0%	35.7%
14	56.5%	34.4%
15	55.2%	33.5%
16	54.1%	32.4%
17	52.7%	31.4%
18	51.6%	30.5%
19	50.4%	29.5%
20	49.1%	28.6%
25	43.1%	23.6%
30	36.6%	18.6%
35	30.9%	14.7%
40	25.6%	11.4%
45	21.0%	8.5%
50	17.1%	6.5%
60	11.3%	3.6%
70	7.5%	2.0%
80	4.9%	1.0%
90	3.1%	0.7%
100	1.8%	0.4%

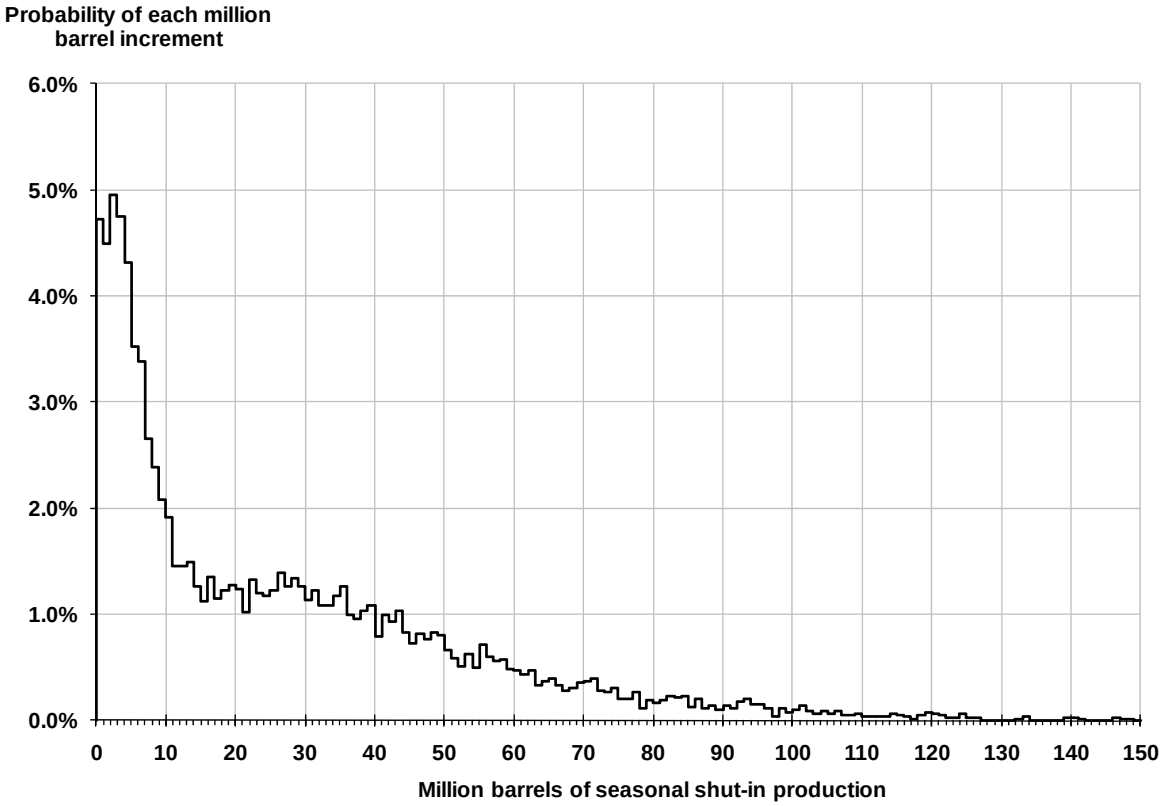
Source: EIA calculations.

Table A3. Simulated Probabilities for Exceeding Various Levels of Seasonal Shut-in Gulf of Mexico Natural Gas Production

	Probability of Shut-in Production	
> Billion Cubic Feet	2011 Season	Normal Season
0	98.7%	94.9%
1	97.5%	91.6%
2	95.8%	87.0%
3	93.5%	81.9%
4	91.2%	77.5%
5	88.5%	73.5%
6	86.1%	69.9%
7	84.0%	67.0%
8	81.8%	63.9%
9	79.8%	61.4%
10	77.9%	58.8%
15	70.3%	49.0%
20	65.0%	42.9%
25	61.5%	39.6%
30	59.0%	37.5%
35	57.0%	36.0%
40	55.0%	34.7%
45	53.2%	33.3%
50	51.2%	31.8%
75	41.6%	24.3%
100	32.3%	17.3%
125	24.1%	11.5%
150	17.4%	7.4%
175	12.5%	4.7%
200	8.9%	2.9%
225	6.1%	1.8%
250	4.0%	1.2%
275	2.8%	0.7%
300	1.8%	0.4%
325	1.3%	0.3%
350	0.8%	0.2%
400	0.4%	0.1%

Source: EIA calculations.

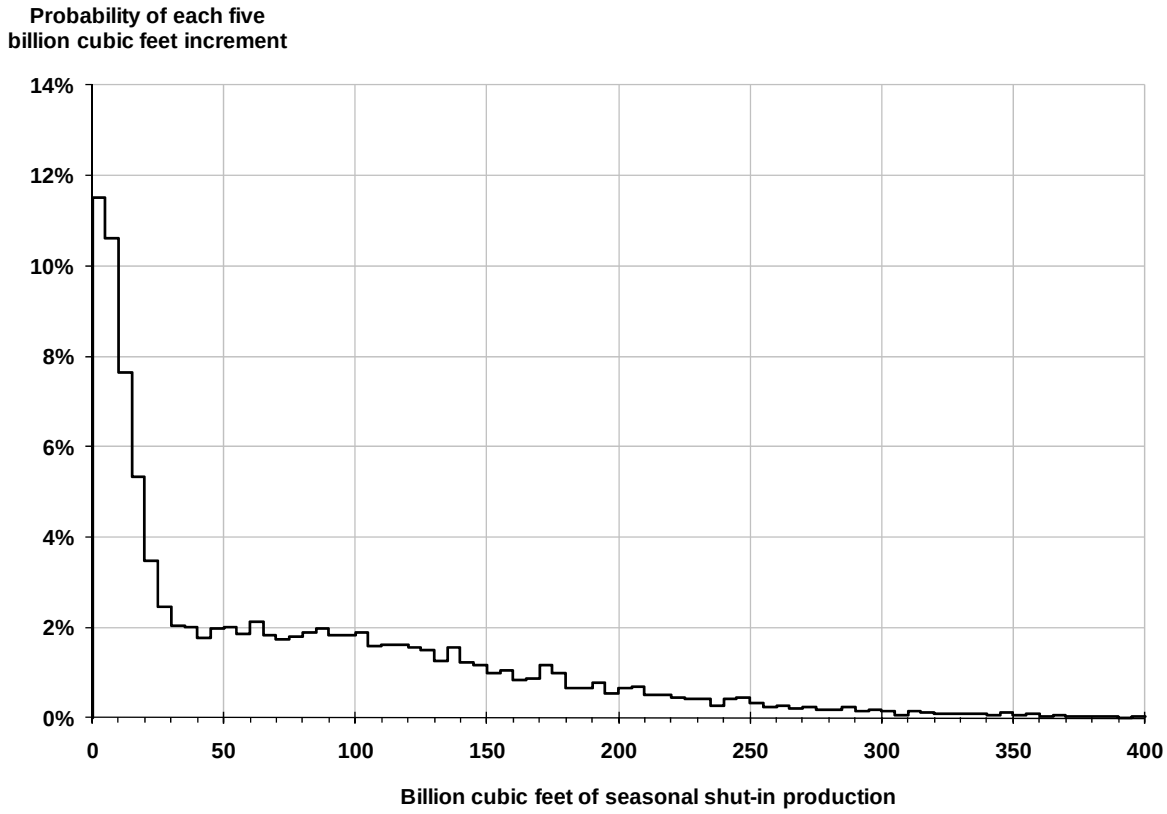
Figure A1. Simulated Probability Distribution Curve for Seasonal Gulf of Mexico Crude Oil Production Outages



Source: EIA calculations.

Note: Chart shows a histogram of the results of EIA's Monte Carlo simulation for shut-in crude oil production in the Gulf of Mexico. The probability of various ranges of shut-in production can be calculated by summing the probability values for each million-barrel increment within the range. The chart is not intended for projecting the probability of any single level of shut-in production, which is theoretically infinitesimal.

Figure A2. Simulated Probability Distribution Curve for Seasonal Gulf of Mexico Natural Gas Production Outages



Source: EIA calculations.

Note: Chart shows a histogram of the results of EIA's Monte Carlo simulation for shut-in natural gas production in the Gulf of Mexico. The probability of various ranges of shut-in production can be calculated by summing the probability values for each five billion-cubic-feet increment within the range. The chart is not intended for projecting the probability of any single level of shut-in production, which is theoretically infinitesimal.