Changing Landscape of the Coal Mining Industry in the United States

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ABSTRACT

Coal has been a valuable natural resource in the United States throughout the country's history. European settlers began to use coal for heating in the late 1740s and, as energy demands increased, coal production climbed from 9.3 million tons in 1850 to 750 million in 1918. Eventually coal replaced wood as the primary energy source, and by the 1940s, coal was providing up to 75 percent of U.S. energy needs.

In the United States, bituminous coal was the first target of the coal mining industry. This changed between 1843 and 1868 when more anthracite began to be mined. Used in iron smelting, this cleaner and smokeless alternative became the preferred fuel in cities. However, limited anthracite resources could not fulfill increasing demand. The production of sub-bituminous coal began to slowly rise, and in 2010 it was greater than bituminous coal production. Until the 1950s, coal was mined primarily using underground methods. By the 1970s, however, the development of cheaper surface mining proved a viable alternative for the U.S. coal industry.

Over the last 10 years, coal production in the United States dropped 37 percent, from about 1.1 billion to about 702 million tons in 2017, and the number of active coal mines also declined. Coal consumption declined as a result of an increased supply of cheaper and cleaner natural gas, the growth of renewable energy sources, and enforced environmental regulations. Coal provided close to 60 percent of U.S. electricity in the mid-1980s, but only about 30 percent in 2017. While there were 606 coal-burning power plants in 2007, only 359 were operating in 2017, with the remainder closed because of aging infrastructure and stiffer environmental guidelines.

Coal mining is an industry in transition—new technologies and policies continually to reshape the energy landscape. With increased competition from other sources of energy, a steady decline in the number of coal-fired power plants, and increasing public perception of coal as a dirty fuel, the coal industry faces even more changes.

U.S. COAL IN THE WORLD CONTEXT

At the end of 2017, more than 1.03 trillion tons of coal reserves were estimated to remain in the world's coal basins (BP, 2018) (Table 1, fig. 1). Coal reserves in North America account for 25 percent of the world resource (fig. 2), and the United States, having the world's largest proven reserves (250.9 billion tons), accounts for 24.2 percent (Table 1, fig. 3).

According to data from BP, 5,276.04 million tons of coal were produced worldwide in 2017, a 2.7 percent increase after production fell for the previous three years (BP, 2018) (Table 2). This increase was, to a large extent, caused by a 3.6 percent increase in coal production in China, which in 2017 produced 2,446.08 million tons (BP, 2018). China is the largest coal producer in the world, followed by the United States and India (fig. 4). The Asia-Pacific region, with China, India, and Australia as leading coal producers, accounts for 71.7 percent of the world's output, compared to 10.8 percent from North America (fig. 5).

World coal consumption was 5,224.10 million tons in 2017, a level roughly maintained since 2011 (Table 3A, B). China is not only the largest producer of coal, it also uses the greatest amount of coal (fig. 6). Coal consumption in the United States has decreased over the last decade. Coal consumption trends follow those of coal production, with the Asia-Pacific region as the number one consumer (74.5 percent) (fig. 7). Although

world coal production has maintained a steady level over the last several years, coal's position as a world energy source fell to 27.6 percent in 2017, the lowest since 2004 (BP, 2018).

COAL IN THE UNITED STATES

In the United States, coal is found in a number of basins and varies in rank from lignite to anthracite (fig. 8). An estimate from the U.S. Energy Information Administration (EIA) shows that the demonstrated coal reserve base (DRB) in the United States was 430,900 million tons as of 2018 (EIA, 2018a). In comparison, 2018 BP data calculates 250,916 million tons of proven reserves (Table 1). The BP calculation takes into account property rights, land use conditions, and physical and environmental restrictions, and estimates that about 53 percent of the DRB would be available for mining (EIA, 2018a). Considering current (2019) U.S. coal production, reserves will last for more than 200 years (BP, 2018).

The history of coal mining in the United States dates back to the fourteenth century and the use of coal by the Hopi Indians for firing pottery and heating their homes (French and Hanes, 2006). The 1740s mark the first use of coal in Virginia by European colonists (EIA, 1992). At the beginning of the nineteenth century, almost all of the coal produced was bituminous, and only a small amount of anthracite was mined. However, anthracite

Figure 1. Map showing the major coal basins of the world. Compiled from Brownfield and others (2001); Karlsen and others (2001); Merrill and Tewalt (2008); Tewalt and others (2008); Trippi and Tewalt (2011); Jaireth and Huleatt (2012); Euracoal (2012).

Table 1. Total proven reserves at the end of 2017 (in million metric tons) (BP, 2018). CIS = Commonwealth of Independent States (Russian Commonwealth)

COAL RESERVES Million metric tons	Anthracite and bituminous	Sub-bituminous and lignite	Total	Share of total
US	220,800	30,116	250,916	24.20%
Canada	4,346	2,236	6,582	0.60%
Mexico	1,160	51	1,211	0.10%
Total North America	226,306	32,403	258,709	25.00%
Brazil	1,547	5,049	6,596	0.60%
Colombia	4,881	–	4,881	0.50%
Venezuela	731	–	731	0.10%
Other S. & Cent. America	1,784	24	1,808	0.20%
Total S. & Cent. America	8,943	5,073	14,016	1.40%
Bulgaria	192	2,174	2,366	0.20%
Czech Republic	1,099	2,541	3,640	0.40%
Germany	8	36,100	36,108	3.50%
Greece	–	2,876	2,876	0.30%
Hungary	276	2,633	2,909	0.30%
Poland	19,808	6,003	25,811	2.50%
Romania	11	280	291	♦
Serbia	402	7,112	7,514	0.70%
Spain	868	319	1,187	0.10%
Turkey	378	10,975	11,353	1.10%
United Kingdom	70	–	70	♦
Other Europe	1,108	5,172	6,280	0.60%
Total Europe	24,220	76,185	100,405	9.70%
Kazakhstan	25,605	–	25,605	2.50%
Russian Federation	69,634	90,730	160,364	15.50%
Ukraine	32,039	2,336	34,375	3.30%
Uzbekistan	1,375	–	1,375	0.10%
Other CIS	1,509	–	1,509	0.10%
Total CIS	130,162	93,066	223,228	21.60%
South Africa	9,893	–	9,893	1.00%
Zimbabwe	502	–	502	♦
Other Africa	2,756	66	2,822	0.30%
Middle East	1,203	–	1,203	0.10%
Total Middle East & Africa	14,354	66	14,420	1.40%

♦ Less than 0.05%

Table 1. (continued) Total proven reserves at the end of 2017 (in million metric tons) (BP, 2018). CIS = Commonwealth of Independent States (Russian Commonwealth)

COAL RESERVES Million metric tons	Anthracite and bituminous	Sub-bituminous and lignite	Total	Share of total
Australia	68,310	76,508	144,818	14.00%
China	130,851	7,968	138,819	13.40%
India	92,786	4,942	97,728	9.40%
Indonesia	15,068	7,530	22,598	2.20%
Japan	340	10	350	♦
Mongolia	1,170	1,350	2,520	0.20%
New Zealand	825	6,750	7,575	0.70%
Pakistan	207	2,857	3,064	0.30%
South Korea	326	–	326	♦
Thailand	–	1,063	1,063	0.10%
Vietnam	3,116	244	3,360	0.30%
Other Asia Pacific	1,326	687	2,013	0.20%
Total Asia Pacific	314,325	109,909	424,234	41.00%
TOTAL WORLD	718,310	316,702	1,035,012	100.00%

♦ Less than 0.05%

Figure 2. Distribution of proven coal reserves at the end of 2017 (BP, 2018). CIS = Commonwealth of Independent States (Russian Commonwealth).

Figure 3. Proven coal reserves in the top ten coal-producing countries at the end of 2017 (in million metric tons) (BP, 2018).

Table 2. Coal production from 2007 to 2017 (in million metric tons) (BP, 2018). Note: Commercial solid fuels only, i.e., bituminous coal and anthracite (hard coal), lignite and brown (sub-bituminous) coal, and other commercial solid fuels. Includes coal produced for coal-to-liquids and coal-to-gas transformations. Growth rates are adjusted for leap years. Recalculated into million metric tons from million tons of oil equivalent.

COAL PRODUCTION million metric tons	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Growth rate per annum			Share 2017
												2017	2016- 2017	2016- 2017	
US	781.62	793.66	719.18	733.18	739.62	688.66	666.12	675.22	597.66	487.62	519.82	6.9%	-4.7%	-4.7%	9.9%
Canada	49.98	49.84	46.34	49.56	49.70	49.70	50.54	50.26	45.22	44.52	43.54	-2.0%	-0.9%	-0.9%	0.8%
Mexico	10.22	9.66	8.54	10.22	13.16	10.36	10.08	10.22	9.66	8.54	7.70	-8.5%	-1.1%	-1.1%	0.1%
Total North America	841.82	853.16	774.06	792.96	802.34	748.86	726.74	735.70	652.54	540.68	571.06	5.9%	-4.4%	-4.4%	10.8%
Brazil	3.78	4.06	3.22	3.22	3.36	4.06	5.18	4.76	3.78	4.20	4.20	–	1.5%	1.5%	0.1%
Colombia	67.20	70.70	70.00	71.54	82.46	85.68	82.18	85.12	82.32	87.08	85.96	-0.9%	3.2%	3.2%	1.6%
Venezuela	7.00	5.18	3.36	2.66	2.66	1.96	1.26	0.84	0.84	0.98	0.42	-52.4%	-18.3%	-18.3%	♦
Other S. & Cent America	0.42	0.56	0.56	0.56	0.56	0.70	2.38	4.20	3.22	2.80	2.80	1.1%	17.6%	17.6%	0.1%
Total S. & Cent. America	78.26	80.50	77.14	77.98	89.04	92.26	91.00	94.92	90.16	94.92	93.52	-1.3%	2.4%	2.4%	1.8%
Bulgaria	6.72	6.86	6.44	6.86	8.68	7.84	6.72	7.14	8.26	7.14	7.84	10.3%	1.7%	1.7%	0.1%
Czech Republic	33.32	31.92	29.26	29.12	29.40	28.42	24.92	23.80	23.94	22.54	21.56	-3.8%	-3.9%	-3.9%	0.4%
Germany	76.16	70.14	64.96	64.26	65.38	66.92	63.14	61.74	59.92	55.72	55.44	-0.3%	-2.9%	-2.9%	1.0%
Greece	11.76	11.34	11.48	10.22	10.50	11.20	9.38	8.96	7.98	5.60	6.44	16.2%	-7.0%	-7.0%	0.1%
Hungary	2.52	2.38	2.24	2.24	2.24	2.24	2.24	2.24	2.10	2.10	1.82	-13.5%	-1.8%	-1.8%	♦
Poland	87.50	85.26	78.96	77.56	77.98	80.92	80.08	75.60	74.20	72.94	69.44	-4.4%	-2.6%	-2.6%	1.3%
Romania	9.66	9.80	9.24	8.26	9.38	8.82	6.58	6.16	6.58	5.88	6.58	12.1%	-4.2%	-4.2%	0.1%
Serbia	10.08	10.50	10.36	10.08	10.92	10.22	10.78	7.98	10.08	10.22	10.50	3.9%	n/a	n/a	0.2%
Spain	8.26	6.16	5.32	4.62	3.64	3.50	2.52	2.24	1.68	0.98	1.40	47.6%	-19.8%	-19.8%	♦
Turkey	20.72	23.38	24.36	24.50	25.06	23.80	21.70	22.96	17.92	21.70	29.12	34.8%	1.6%	1.6%	0.6%
United Kingdom	14.98	15.82	15.40	15.96	16.10	14.84	11.20	10.22	7.56	3.64	2.66	-27.0%	-13.6%	-13.6%	0.1%
Other Europe	21.70	21.98	22.12	22.40	22.40	20.16	23.38	21.56	19.46	17.50	17.50	-0.2%	-6.3%	-6.3%	0.3%
Total Europe	303.24	295.40	280.14	276.36	281.96	278.88	262.50	250.60	239.68	225.82	230.44	2.3%	-3.1%	-3.1%	4.4%
Kazakhstan	59.08	67.06	60.76	66.50	69.72	72.24	71.96	68.46	64.68	62.02	67.06	8.5%	0.7%	0.7%	1.3%

♦ Less than 0.05%

Table 2. (continued) Coal production from 2007 to 2017 (in million metric tons) (BP, 2018). Note: Commercial solid fuels only, i.e., bituminous coal and anthracite (hard coal), lignite and brown (sub-bituminous) coal, and other commercial solid fuels. Includes coal produced for coal-to-liquids and coal-to-gas transformations. Growth rates are adjusted for leap years. Recalculated into million metric tons from million tons of oil equivalent.

COAL PRODUCTION million metric tons	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Growth rate per annum		Share 2017
												2017	2006- 2016	
Russian Federation	200.90	208.60	198.38	211.40	220.64	235.62	242.34	247.24	260.96	271.60	288.82	6.7%	3.2%	5.5%
Ukraine	47.60	48.16	44.52	44.52	50.82	53.20	51.24	36.26	22.96	23.94	20.16	-15.6%	-7.1%	0.4%
Uzbekistan	1.40	1.26	1.40	1.40	1.54	1.68	1.54	1.68	1.54	1.54	1.54	4.2%	3.3%	♦
Other CIS	1.12	1.12	1.12	1.26	1.40	1.68	1.82	1.96	1.96	2.38	2.80	19.7%	9.4%	0.1%
Total CIS	310.10	326.20	306.32	324.80	343.98	364.42	368.90	355.60	352.10	361.34	380.52	5.6%	1.6%	7.2%
Total Middle East	1.54	1.40	0.98	0.98	0.98	0.98	0.98	0.98	0.98	1.12	1.12	-	-2.9%	♦
South Africa	193.76	197.40	195.58	201.74	200.48	205.24	203.42	207.48	200.06	199.36	200.20	0.7%	0.3%	3.8%
Zimbabwe	1.82	1.40	1.54	2.38	2.38	1.40	2.80	5.18	3.92	2.38	2.66	8.7%	2.5%	0.1%
Other Africa	1.12	1.12	0.98	1.26	1.54	6.02	7.14	8.12	8.40	7.56	13.44	77.3%	19.7%	0.3%
Total Africa	196.70	199.78	198.10	205.52	204.40	212.66	213.36	220.78	212.24	209.44	216.30	3.6%	0.6%	4.1%
Australia	317.80	327.88	339.50	350.84	343.14	372.26	400.12	428.26	428.96	430.78	416.36	-3.1%	3.4%	7.9%
China	2,015.02	2,088.52	2,153.06	2,331.42	2,592.38	2,622.90	2,652.44	2,609.88	2,555.84	2,367.96	2,446.08	3.6%	2.4%	46.4%
India	294.42	318.50	344.40	353.36	351.12	357.00	357.98	377.30	393.40	398.86	411.88	3.5%	3.7%	7.8%
Indonesia	178.92	198.24	211.40	226.94	291.48	318.36	391.58	377.86	380.80	376.32	380.24	1.3%	8.9%	7.2%
Japan	1.12	0.98	0.98	0.70	0.98	0.98	0.98	0.98	0.84	0.98	1.12	3.9%	-0.1%	♦
Mongolia	6.72	7.28	11.48	21.28	27.86	25.06	25.20	21.28	20.02	30.10	42.42	41.4%	18.2%	0.8%
New Zealand	4.20	4.20	3.92	4.62	4.34	4.20	4.06	3.50	2.80	2.38	2.52	2.2%	-7.1%	♦
Pakistan	2.38	2.52	2.24	2.10	1.96	1.96	1.82	2.10	2.10	2.52	2.52	-0.8%	0.2%	♦
South Korea	1.82	1.82	1.68	1.40	1.40	1.40	1.12	1.12	1.12	1.12	0.98	-8.0%	-4.7%	♦
Thailand	6.86	6.86	6.58	6.86	8.26	6.72	6.72	6.58	5.46	6.02	5.74	-4.5%	-2.3%	0.1%
Vietnam	33.32	31.22	34.58	35.14	36.54	33.04	32.20	32.20	32.62	30.24	29.82	-0.9%	-0.1%	0.6%
Other Asia Pacific	28.98	30.94	27.02	28.98	31.08	31.92	32.76	33.32	35.28	48.02	43.40	-9.2%	4.3%	0.8%
Total Asia Pacific	2,891.70	3,018.68	3,136.70	3,363.64	3,690.40	3,775.80	3,906.84	3,894.38	3,859.38	3,695.44	3,783.22	2.7%	3.2%	71.7%
TOTAL WORLD	4,623.36	4,775.12	4,773.44	5,042.24	5,413.24	5,473.72	5,570.46	5,552.96	5,406.94	5,128.90	5,276.04	3.2%	1.5%	100.0%

♦ Less than 0.05%

Figure 4. Coal production from 2007 to 2017 in the top ten coal-producing countries (in million metric tons) (BP, 2018).

Figure 5. Shares of coal production in 2017 (BP, 2018).

Table 3A. Coal consumption from 2007 to 2017 in North, Central, and South America, and Europe (in million metric tons) (BP, 2018). Note: Commercial solid fuels only, i.e., bituminous coal and anthracite (hard coal), lignite and brown (sub-bituminous) coal, and other commercial solid fuels. Excludes coal converted to liquid or gaseous fuels, but includes coal consumed in transformation processes. Differences between these world consumption figures and the world production statistics are accounted for by stock changes and unavoidable disparities in the definition, measurement, or conversion of coal supply and demand data. Growth rates are adjusted for leap years. Recalculated into million metric tons from million tons of oil equivalent.

COAL CONSUMPTION million metric tons	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Growth rate per annum		Share 2017
												2017	2006- 2016	
US	762.44	750.26	659.96	698.32	658.84	582.40	604.52	603.26	521.08	476.84	464.94	-0.067		8.9%
Canada	42.42	41.16	32.90	34.72	30.52	29.54	29.12	27.44	27.86	26.46	26.04	-0.056		0.5%
Mexico	15.82	14.14	14.42	17.78	20.58	17.92	17.78	17.78	17.78	17.36	18.34	5.6%	0.1%	0.4%
Total North America	820.68	805.70	707.28	750.82	709.94	629.86	651.56	648.48	566.72	520.66	509.32	-0.062		9.7%
Argentina	1.68	2.10	1.12	1.68	1.82	1.68	1.82	1.96	1.96	1.40	1.54	1.7%	2.1%	♦
Brazil	19.04	19.32	15.54	20.30	21.56	21.42	23.10	24.50	24.64	22.26	23.10	4.1%	2.2%	0.4%
Chile	5.74	6.16	5.60	6.30	8.12	9.38	10.50	10.64	10.22	10.36	9.38	-9.1%	8.0%	0.2%
Colombia	4.48	7.00	5.60	6.44	5.18	6.58	7.00	7.14	7.56	7.70	5.60	-27.6%	3.9%	0.1%
Ecuador	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Peru	1.40	1.26	1.12	1.12	1.12	1.26	1.26	1.26	1.12	1.40	1.40	-	2.2%	♦
Trinidad & Tobago	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Venezuela	0.14	0.14	0.28	0.28	0.28	0.28	0.28	0.28	0.14	0.42	0.42	-10.8%	1.7%	♦
Other S. & Cent. America	3.50	3.64	2.94	3.22	3.92	3.78	4.06	4.48	5.04	5.32	4.48	-14.0%	4.6%	0.1%
Total S. & Cent. America	36.12	39.62	32.34	39.34	42.00	44.24	48.02	50.26	50.68	48.86	45.78	-5.9%	3.7%	0.9%
Austria	5.46	5.32	4.06	4.76	4.90	4.48	4.62	4.20	4.48	4.20	4.48	5.0%	-2.9%	0.1%
Belgium	6.16	6.30	4.34	5.32	4.90	4.48	4.62	4.62	4.48	4.20	4.06	-0.065		0.1%
Czech Republic	29.96	27.58	24.78	26.32	25.76	24.36	24.08	22.40	23.24	23.24	22.40	-0.054		0.4%
Finland	9.80	7.42	7.56	9.52	7.70	6.30	7.00	6.30	5.32	6.16	5.74	-0.107		0.1%
France	17.92	16.94	15.12	16.10	13.72	15.54	16.24	12.04	11.76	11.48	12.74	11.4%	-4.1%	0.2%
Germany	121.38	112.14	100.38	107.94	109.62	112.70	115.92	111.44	110.18	106.12	99.82	-0.069		1.9%
Greece	12.32	11.62	11.76	11.06	11.06	11.34	9.80	9.38	7.84	6.16	6.86	11.7%	-6.4%	0.1%

♦ Less than 0.05%

Table 3A. (continued) Coal consumption from 2007 to 2017 in North, Central, and South America, and Europe (in million metric tons) (BP, 2018). Note: Commercial solid fuels only, i.e., bituminous coal and anthracite (hard coal), lignite and brown (sub-bituminous) coal, and other commercial solid fuels. Excludes coal converted to liquid or gaseous fuels, but includes coal consumed in transformation processes. Differences between these world consumption figures and the world production statistics are accounted for by stock changes and unavoidable disparities in the definition, measurement, or conversion of coal supply and demand data. Growth rates are adjusted for leap years. Recalculated into million metric tons from million tons of oil equivalent.

COAL CONSUMPTION million metric tons	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Growth rate per annum		Share 2017
												2017	2006- 2016	
Hungary	4.34	4.34	3.64	3.78	3.78	3.64	3.22	3.08	3.36	3.22	3.22	1.8%	-3.0%	0.1%
Italy	22.82	22.12	17.36	19.18	21.56	21.98	18.90	18.34	17.22	15.40	13.72	-0.146		0.3%
Netherlands	11.76	11.20	10.50	10.50	10.36	11.48	11.48	12.74	15.40	14.28	12.74	-10.4%	2.8%	0.2%
Norway	0.98	0.98	0.84	1.12	1.12	1.12	1.12	1.26	1.12	1.12	1.12	2.3%	2.0%	◆
Poland	78.26	77.28	72.52	77.14	77.00	71.68	74.76	69.16	68.18	69.30	68.18	-0.029		1.3%
Portugal	4.06	3.50	4.06	2.24	3.08	4.06	3.64	3.78	4.62	4.48	4.90	10.6%	-0.4%	0.1%
Romania	14.14	13.44	10.64	9.80	11.48	10.64	8.12	7.98	8.26	7.42	7.98	6.8%	-5.6%	0.2%
Spain	28.00	18.90	13.16	9.66	17.92	21.70	15.96	16.24	19.18	14.70	18.76	28.5%	-5.2%	0.4%
Sweden	3.78	3.36	2.66	3.50	3.50	3.08	3.08	2.94	2.94	2.94	2.66	-0.089		0.1%
Switzerland	0.28	0.28	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	-	-3.0%	◆
Turkey	41.30	41.44	43.26	43.96	47.46	51.10	44.24	50.54	48.58	53.90	62.44	16.3%	3.9%	1.2%
United Kingdom	53.76	49.84	41.72	43.26	43.96	54.60	51.80	41.72	32.48	15.68	12.60	-0.316		0.2%
Other Europe	55.30	55.02	51.66	53.76	57.26	51.66	52.22	48.58	49.56	49.42	50.54	2.6%	-1.2%	1.0%
Total Europe	522.06	489.02	440.02	458.92	476.28	486.22	470.96	447.02	438.34	413.14	414.96	0.7%	-2.2%	7.9%

◆ Less than 0.05%

Table 3B. Coal consumption from 2007 to 2017 in the Middle East, Commonwealth of Independent States (Russian Commonwealth, CIS), Africa, and Asia Pacific (in million metric tons) (BP, 2018). Note: Commercial solid fuels only, i.e., bituminous coal and anthracite (hard coal), lignite and brown (sub-bituminous) coal, and other commercial solid fuels. Excludes coal converted to liquid or gaseous fuels, but includes coal consumed in transformation processes. Differences between these world consumption figures and the world production statistics are accounted for by stock changes and unavoidable disparities in the definition, measurement, or conversion of coal supply and demand data. Growth rates are adjusted for leap years. Recalculated into million metric tons from million tons of oil equivalent.

COAL CONSUMPTION million metric tons	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Growth rate per annum		Share 2017
												2017	2006- 2016	
Azerbaijan	†	†	†	†	†	†	†	†	†	†	†	-	-15.0%	♦
Belarus	0.98	0.84	0.84	0.84	1.12	1.12	1.26	1.12	0.84	0.98	1.26	16.2%	1.9%	♦
Kazakhstan	43.54	47.32	43.26	46.76	50.82	53.06	52.50	51.80	47.88	47.46	50.68	7.0%	1.8%	1.00%
Russian Federation	131.46	140.98	129.08	126.70	131.60	137.76	126.70	122.64	128.94	124.88	129.22	3.8%	0.8%	2.50%
Turkmenistan	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ukraine	55.72	58.52	50.26	53.62	58.10	59.50	58.24	49.84	38.22	41.58	34.44	-0.2	-	0.70%
Uzbekistan	1.40	1.40	1.40	1.26	1.54	1.68	1.54	1.68	1.54	1.40	1.68	20.8%	2.1%	♦
Other CIS	1.12	1.54	1.26	1.26	1.40	1.96	1.96	2.38	2.52	2.24	2.66	16.0%	8.8%	0.10%
Total CIS	234.22	250.60	226.10	230.58	244.58	254.94	242.20	229.32	220.22	218.68	219.80	0.8%	-0.7%	4.20%
Iran	2.24	1.68	1.96	1.82	1.96	1.54	1.96	2.24	2.10	1.26	1.26	3.0%	-5.0%	♦
Iraq	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Israel	11.20	11.06	10.78	10.78	11.06	12.32	10.36	9.66	9.52	7.98	7.28	-0.115	-0.115	0.10%
Kuwait	†	†	-	†	†	-	0.42	0.28	0.28	0.28	0.28	-29.1%	57.7%	♦
Oman	†	†	†	†	†	†	0.14	0.14	0.14	0.14	0.14	-	-62.2%	♦
Qatar	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Saudi Arabia	0.14	0.14	†	0.14	0.14	0.14	0.14	0.28	0.14	0.14	0.14	-17.4%	-	♦
United Arab Emirates	0.14	0.42	0.42	0.98	0.56	1.96	2.52	2.80	2.38	2.10	2.24	1.7%	18.6%	♦
Other Middle East	0.14	0.28	0.28	0.42	0.56	0.70	0.70	0.84	0.56	0.56	0.56	-9.8%	12.7%	♦
Total Middle East	13.86	13.58	13.44	14.14	14.42	16.66	16.10	16.10	14.98	12.74	11.90	-	-0.067	0.20%
Algeria	1.12	1.12	0.70	0.42	0.42	0.42	0.28	0.28	0.14	†	†	-25.1%	-	♦
Egypt	1.12	0.98	0.84	0.70	0.56	0.56	0.56	0.56	0.56	0.28	0.28	4.2%	-15.5%	♦
Morocco	4.48	5.18	3.78	3.92	4.20	4.20	4.20	5.60	6.16	6.02	6.30	4.2%	1.0%	0.10%
South Africa	117.18	130.62	131.32	129.92	126.70	123.62	123.76	125.30	116.20	118.58	115.08	-2.7%	0.4%	2.20%

† Less than 0.05, ♦ Less than 0.05 %

Table 3B. (continued) Coal consumption from 2007 to 2017 in the Middle East, Commonwealth of Independent States (Russian Commonwealth, CIS), Africa, and Asia Pacific (in million metric tons) (BP, 2018). Note: Commercial solid fuels only, i.e., bituminous coal and anthracite (hard coal), lignite and brown (sub-bituminous) coal, and other commercial solid fuels. Excludes coal converted to liquid or gaseous fuels, but includes coal consumed in transformation processes. Differences between these world consumption figures and the world production statistics are accounted for by stock changes and unavoidable disparities in the definition, measurement, or conversion of coal supply and demand data. Growth rates are adjusted for leap years. Recalculated into million metric tons from million tons of oil equivalent.

COAL CONSUMPTION million metric tons	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Growth rate per annum		Share 2017
												2017	2006- 2016	
Other Africa	5.04	4.20	4.62	5.18	5.88	5.46	7.42	10.92	9.38	7.98	8.68	8.9%	5.1%	0.20%
Total Africa	128.80	141.96	141.40	140.14	137.76	134.40	136.08	142.66	132.44	132.86	130.34	-1.7%	0.5%	2.50%
Australia	73.78	76.86	74.34	69.16	67.34	63.14	60.20	59.64	61.46	61.04	59.22	-0.047		1.10%
Bangladesh	0.84	0.84	1.12	1.12	0.98	1.26	1.40	1.26	3.22	3.08	3.22	7.3%	16.6%	0.10%
China	2,217.88	2,253.02	2,360.12	2,448.46	2,665.46	2,698.92	2,756.74	2,736.30	2,679.60	2,644.74	2,649.64	0.5%	2.6%	50.70%
China Hong Kong SAR	10.50	9.66	10.08	8.68	10.36	10.22	10.92	11.34	9.38	9.38	8.82	-0.063		0.20%
India	336.00	363.02	393.12	406.56	426.44	462.00	493.92	542.90	553.42	567.84	593.60	4.8%	6.3%	11.40%
Indonesia	50.68	44.10	46.48	55.30	65.66	74.20	79.80	63.14	71.68	74.76	80.08	7.4%	6.3%	1.50%
Japan	164.78	168.42	142.24	161.98	153.44	162.12	169.68	166.74	166.60	166.32	168.70	1.7%	0.6%	3.20%
Malaysia	12.32	13.72	14.84	20.72	20.72	22.26	21.14	21.56	24.36	27.44	28.00	2.5%	10.4%	0.50%
New Zealand	2.38	2.94	2.24	1.96	1.96	2.38	2.10	2.10	1.96	1.68	1.68	5.2%	-6.1%	♦
Pakistan	7.56	8.40	6.86	6.44	5.60	5.60	4.48	6.58	6.58	7.84	9.94	26.2%	3.6%	0.20%
Philippines	7.56	8.96	8.54	9.80	10.78	11.34	14.00	14.84	16.24	16.38	18.34	12.0%	8.8%	0.40%
Singapore	†	†	†	†	†	†	0.42	0.56	0.56	0.56	0.56	-6.7%	56.0%	♦
South Korea	83.58	92.54	96.04	106.26	117.04	113.40	114.66	118.44	119.70	114.66	120.82	5.7%	4.1%	2.30%
Sri Lanka	†	0.14	0.14	0.14	0.42	0.70	0.70	1.26	1.68	1.82	1.96	5.4%	40.5%	♦
Taiwan	54.32	51.80	49.28	52.64	54.46	53.20	54.04	54.60	52.92	54.04	55.16	2.5%	0.4%	1.10%
Thailand	19.46	21.00	21.00	21.56	21.98	23.10	22.68	25.06	24.50	24.78	25.62	3.7%	3.7%	0.50%
Vietnam	8.82	16.66	15.68	20.44	24.22	22.54	24.08	29.12	36.68	39.62	39.48	-3.6%	17.3%	0.80%
Other Asia Pacific	26.18	28.70	23.24	22.68	18.48	19.46	15.68	17.78	17.08	25.62	27.16	6.2%	-1.7%	0.50%
Total Asia Pacific	3,076.64	3,160.50	3,265.22	3,414.04	3,665.62	3,745.70	3,846.50	3,873.10	3,847.62	3,841.60	3,892.00	1.6%	3.1%	74.50%
TOTAL WORLD	4,832.52	4,900.84	4,825.80	5,047.84	5,290.46	5,312.30	5,411.42	5,407.08	5,271.00	5,188.40	5,224.10	1.0%	1.3%	100.00%

† Less than 0.05, ♦ Less than 0.05 %

Figure 6. Coal consumption in the top ten coal-consuming countries from 2007 to 2017 in million metric tons (BP, 2018).

Figure 7. Shares of coal consumption in 2017 (BP, 2018).

Figure 8. Map showing the coal basins of the United States and coal ranks and properties. Modified from EIA (2018a) and Tewalt and others (2008).

Figure 9. U.S. coal production from 1870 to 2017. Modified from Dan Plazak (written communication, Jan. 2019), and EIA (2018b).

Figure 10. U.S. energy consumption. Data from EIA (2016, 2018c).

Figure 11. U.S. coal production by coal type from 1870 to 2016. Modified from Dan Plazak (written commun., Jan. 2019).

overtook bituminous coal mining between 1843 and 1868. But because of the high demand for coal and the limited deposits of anthracite in the United States, bituminous coal, which occurs in much larger deposits, became the dominant contributor after 1869. At about that time, coal overtook wood as the United States's main energy source. Coal production then rapidly increased, peaking at 680 million short tons in 1918 (fig. 9) when new bituminous coal fields in Ohio, Indiana, Illinois, West Virginia, Kentucky, and Alabama were discovered. Some of these fields were small, and coal occurred at shallow depths, so coal companies developed surface mining methods, which increasingly contributed to production totals (fig. 9). In 1930, a rapid decrease in coal production was due to the drop-in demand during the Great Depression. During World War II (1941 to 1945), U.S. coal production bounced back and slightly exceeded pre-Depression levels. Then around 1960, during a natural gas and petroleum boom, coal production again declined (fig. 10). That decline was followed by a large increase in coal production from the early 1960s through 2008, in response to an increasing demand for energy. After a record high in 2008 of more than 1,063 million tons, production began to drop drastically, decreasing to about 660.9 million tons in 2016 (EIA, 2018d). Less expensive shale gas, increased demand for clean energy sources (fig. 10), and new EPA rules regarding emission limits from coal-fired power plants and greenhouse gas pollution standards were factors responsible for this decline.

According to Energy Information Administration (EIA, 2018e), the United States produced 702 million metric tons of coal in 2017. We note that BP reports significantly lower U.S. production (519.82 million metric tons, Table 2; BP, 2018), which perhaps results from different estimating methods. In 2017, 14 percent of energy consumed in the United States was from coal, and coal accounted for 30 percent of U.S. electricity production (EIA, 2018f).

Because of the dominance of bituminous coal in U.S. coal production, trends of the total coal production (fig. 9) parallel changes in the coal of bituminous rank alone (fig. 11). Production of sub-bituminous coal began in the late 1960s and reached the production level of bituminous coal around 2007. The mining of lignite was also initiated around 1970; it gradually increased until 1990 and has since levelled off. Anthracite production was largest between 1910 and 1920, reaching almost 100 million tons, but since 1970 production has been minimal (fig. 11).

Of all the states, Wyoming produces the most coal; however, its 2018 production rate was much lower compared to its historic high in 2008 (fig. 12). West

Virginia, Pennsylvania, Illinois, and Kentucky, leading coal-producing states in the past, have also declined dramatically compared to their past maximum production. Similarly, Utah, New Mexico, Virginia, Colorado, Ohio, and Alabama all experienced greatly decreased coal production in relation to their historic highs. Some states (Texas, Indiana, Montana, and North Dakota) have maintained their levels of coal production, with some oscillations owing to, for example, long-term contacts or switching mining methods.

Although the most recent decline in U.S. coal production began around 2008, the number of coal mines has been decreasing since around 1981 (fig. 13). This decline has affected both surface and underground mining, as well as the number of coal processing plants. Environmental regulations, including the Coal Mine and Safety Act of 1969, the Surface Mining Control and Reclamation Act, and the Clean Water Act of 1977, contributed to the closing of some mines. These regulations also resulted in operators replacing or transforming older, smaller mines to larger mines. This became possible owing to the advent of larger, more efficient mining equipment and technologies. Mining costs also increased because of tighter regulations (EIA, 1992). More recently, more than half the mines operating in 2008 closed, a drop from 1,435 mines in 2008 to 671 mines in 2017 (fig. 14). As the demand for coal decreased, less efficient mines were the first to close, with most mine closures occurring in the Appalachian region. During that time, U.S. coal-fired power plants also declined in number; of 606 coal-burning power plants in 2007, 359 remained in 2017, with the rest closing because of aging infrastructure and stiffer environmental guidelines (EIA, 2018f).

In 2017, about 63 percent of electricity generated in the United States came from fossil fuels. Coal accounted for 39 percent in 2014, 33 percent in 2015, 30.4 percent in 2016, and 29.9 percent in 2017 (EIA, 2018j). In comparison, electricity generated from coal in Indiana accounted for 70 percent in 2017 (EIA, 2018h).

Employment in the coal mining industry peaked around 1920 with close to 900,000 workers (fig. 15). At present in the United States, employment is at its lowest point in coal production history, at about 53,000 in 2018 (EIA, 2018d). The number of fatalities in the U.S. coal mining industry declined from more than 3,000 a year (1907) to fewer than 100 annually in recent years (fig. 16). The decline after 1970 was primarily due to increased regulations and safety in the mines, a direct effect of the Coal Mine Health and Safety Act of 1969.

Before 1955, the number of people employed in the coal industry paralleled coal production trends, but later, between 1955 and 2008, employment depended on other factors such as technological advances and

Figure 12. U.S. coal production by state. Modified from EIA (2018b) and Indiana Coal Council (2018).

Figure 13. Number of U.S. coal mines and coal processing plants from 1979 to 2016. Modified from U.S. Department of Labor (2017).

Figure 14. Active U.S. coal mines in 2017 (EIA, 2018i).

Figure 15. U.S. coal production and coal mining industry employment from 1890 to 2018. Employment data modified from Dan Plazak (written commun., Jan. 2019) and Federal Reserve Board of St. Louis (2018). Beginning in 1973, the data includes office workers. Coal production modified from Dan Plazak (written commun., Jan.2019), and EIA (2018b).

Figure 16. U.S. coal mining fatalities from 1900 to 2017. Data from U.S. Department of Labor (2017).

Figure 17. U.S. coal production, consumption, export, and import. Data from EIA (2018g).

Figure 18. U.S. coal prices from 1949 to 2017. Modified from EIA (2011) and EIA (2018b, j).

productivity. Since 2008, the decline in employment again correlates with the decline in coal production and consumption (figs. 15, 17) as a response to the increased production of cheap natural gas and increasing public demand for clean energy (fig. 10). However, between 2016 and 2018 about 1,200 new jobs in coal mining industry were added, an increase of about 2.4 percent compared to 2016 (EIA, 2018i).

Despite its large coal reserves and high production total of 702 million tons in 2017 (EIA 2018g), the United States imported about 7.2 million short tons of coal that year, because some coal-burning power plants along the Atlantic and Gulf Coasts could buy imported coal cheaper than domestic coal (fig. 17). Imported coal came primarily from Colombia (78 percent) and Canada

(11 percent). The remaining 11 percent was from 13 other countries (EIA, 2018g).

The United States is a net coal exporter (fig. 17). Exports of American coal reached a record high of about 115 million tons in 2012, equal to about 12 percent of U.S. total coal production (EIA, 2018f). Coal exports decreased by half between 2012 and 2016 to about 55 million tons, but in 2017 increased again to about 88 million tons, about 13 percent of U.S. coal production. The United States exports mostly metallurgical coal used for steel production and steam coal for electricity generation. The biggest importers of U.S. coal in 2017 were India (11.8 percent), South Korea (9.7 percent), the Netherlands (9.7 percent), Japan (7.9 percent), and Brazil (7.8 percent) (EIA, 2018f).

Coal prices also fell since 2008, except for anthracite coal, which reached an average of \$93.17 per short ton in 2017 (fig. 18). The average price of U.S. coal was \$55.60 per short ton; 2019 prices in real dollar terms are not higher than those 40 years earlier.

In 2016, the new U.S. government administration promised to help the U.S. coal industry and coal-fired power plants, the biggest buyer of American coal, and bring coal-related jobs back. Between 2016 and 2018, about 1,200 new jobs in coal mining industry were added, an increase of about 2.4 percent, compared to 2016 (EIA, 2018d). The administration was also considering new greenhouse gas emission rules for power plants that would make it easier for states to keep coal-fired facilities operational. The plan would replace the previous administration's approach, which proposed a steady retirement of coal plants. Coal mining is an industry in transition as new energy sources, new technologies, and policies continually reshape the energy landscape. With increased competition from other sources of energy and a steady decline in the number of coal-fired power plants, the U.S. coal industry faces a future that is difficult to predict.

STATE-SCALE CHANGES IN COAL MINING: INDIANA

Indiana has been a coal mining state for close to 200 years and has experienced its own changes in the coal mining industry. Coal has been mined in Indiana since its discovery along the banks of the Wabash River in 1736 (Mastalerz and others, 2009). Records show that underground mining began in Indiana in the early 1830s, with production increasing steadily until 1910 (fig. 19). Around 1920, the demand for coal decreased, which, together with the declining marketability of Illinois Basin coal, resulted in a drop in production from underground operations (fig. 20). The relatively low heating value and high sulfur content of Indiana coal (compared to Eastern coal), as well as the relatively high salaries paid to unionized miners in Indiana and Illinois were among the factors that limited development of underground mining in Indiana during that period.

The events of World War I resulted in a brief doubling of coal production in Indiana. However, after 1923, newer non-union coal fields (in, for example, West Virginia) attracted consumers in Chicago as well as in Indiana and Illinois, causing a dramatic decline in Indiana's underground coal production to levels far below those just prior to the war (figs. 19 and 20). By the 1960s, limited resources of thick and laterally extensive coals needed for underground mining precluded the development of underground mining in Indiana, and,

since then, surface mining has dominated the industry (fig. 19).

The implementation of the Clean Air Act of 1970 and the introduction of sulfur-dioxide emissions standards for coal-fired utility boilers by the U.S. Environmental Protection Agency in 1971 affected both surface and underground mining in the entire Illinois Basin (fig. 21). Because of the relatively high sulfur content of Illinois Basin coals, including Indiana coals, many utilities opted to switch to low-sulfur Powder River Basin coals from Wyoming rather than install scrubbers to reduce emissions (EIA, 1992). In addition, the Surface Mining Control and Reclamation Act of 1977 increased the cost of coal production from surface mines. Although these environmental regulations and their consequences affected Indiana's mining, increasing energy demand and the installation of gas scrubbers to reduce emissions by utilities (in response to the 1990 Clean Air Amendments) contributed to the general upward trend in coal production till 1988 (fig. 21). From 1988 to 1994, the industry experienced a rapid drop in coal production; this was followed by a rapid increase, owing to increased production from underground mines in Indiana (figs. 19, 20). Surface mining gradually declined during that period. In 2017, coal production declined in Indiana. However, in 2018 the state produced a total of 33.512 million tons of coal (Indiana Coal Council, 2018)—evidence that Indiana's coal production was not dramatically affected by the shale gas boom. As expected, trends in Indiana coal production roughly echo those of Illinois and western Kentucky (fig. 21).

Approximately 57 billion tons of unmined coal reserves remain in Indiana, of which nearly 17 billion tons can be mined using current technology (Mastalerz and others, 2009). Of the mineable reserves, about 88 percent is recoverable by underground mining and 12 percent by surface mining methods. In 2018, 33.512 million tons of coal were produced in Indiana—16.5 million from underground mines and 17.0 million tons from surface mines. As of 2018, ten surface and five underground coal mines were operating in Indiana (Indiana Coal Council, 2018) (fig. 22), marking a declining trend in the number of surface mines since 2009 (fig. 23). In 2018, more than 50 percent of total energy and 70 percent of electricity in Indiana comes from coal (EIA, 2018h).

The surface mines having the largest coal production in Indiana are Bear Run Mine (Sullivan County) and Wild Boar Mine (Warrick County), both Peabody operations (Table 4). Out of five underground mines in operation in Indiana in 2018, the largest were Gibson South Mine (Gibson County Coal) and Oaktown Mine (Sunrise Coal) (Table 5).

Figure 19. Indiana coal production from 1879 to 2018. Data from U.S. Bureau of Mines (2018; data through 1972); Indiana Bureau of Mines (1973–1997); from Indiana Coal Council (1998).

Figure 20. Indiana coal production from underground and surface mines in percentages of contribution. Data from U.S. Bureau of Mines (2018; data through 1972); Indiana Bureau of Mines (1973–1997); Indiana Coal Council (1998).

Figure 21. Illinois Basin coal production from 1820 to 2018. Indiana data: U.S. Bureau of Mines (2018; data through 1972), Indiana Bureau of Mines (1973–1997), Indiana Coal Council (1998); Illinois data: EIA (2018b); Kentucky data: Kentucky Geological Survey (1790–2014), Kentucky Quarterly Coal Report (2018; data from 2015).

Figure 22. Location of active coal mines and mined-out coal areas in Indiana as of 2018. Numbers on the map correspond to Tables 1 and 2.

Figure 23. Number of Indiana coal mines from 1998 to 2018. Data from Indiana Coal Council (2018).

Table 4. Active surface coal mines in Indiana as of 2018. Map numbers on Figure 22. Data from Indiana Coal Council (2018).

INDIANA SURFACE COAL MINE PRODUCTION IN 2018				
Operator	Map number	Mine	Production (tons)	County
Liberty Mine, LLC	1	Liberty Mine	1,627,647	Warrick
Peabody Midwest Mining, LLC	2	Wild Boar	2,487,892	Warrick
	3	Somerville South	1,971,905	Gibson
	4	Bear Run	6,911,825	Sullivan
Solar Sources, Inc.	5	Antioch	1,309,960	Daviess
	6	Cannelburg	765,557	Daviess
	7	Shamrock	1,217,512	Dubois
Sun Energy Group, LLC	8	Hillsmeyer	156,631	Pike
Sunrise Coal, LLC	9	Ace in the Hole	351,967	Clay
United Minerals, Inc.	10	West 61	246,566	Warrick
TOTAL INDIANA SURFACE MINE PRODUCTION 2017			17,047,192	

Table 5. Active underground coal mines in Indiana as of 2018. Map numbers on Figure 22. Data from Indiana Coal Council (2018).

INDIANA UNDERGROUND COAL MINE PRODUCTION IN 2018				
Operator	Map number	Mine	Production (tons)	County
Gibson County Coal Co.	11	Gibson South	6,951,510	Gibson
	12	Gibson North	923,743	Gibson
Peabody Midwest Mining, LLC	13	Francisco	2,248,274	Gibson
Sunrise Coal, LLC	14	Carlisle	370,404	Sullivan
	15	Oaktown #1 and #2	5,971,752	Knox
TOTAL INDIANA UNDERGROUND MINE PRODUCTION 2017			16,465,683	

CONCLUSIONS

Despite having the world's largest reserves of coal, the U.S. coal industry is experiencing challenging times and faces an uncertain future. Currently containing 24.2 percent of the world's reserves, the U.S. contribution to world coal production and consumption is 10 percent and 9 percent, respectively. Although the coal mining industry has experienced considerable variations over its 200 year history in the United States, previous periods of decline were relatively short lived and were followed by the rejuvenation of the industry in response to increasing demands for energy. The most recent decline of the coal mining industry since 2008, manifested by drop in coal production, number of mines, and employment, may be of a more permanent nature. Over the last decade, not only has coal faced competition from other energy sources (fig. 10), but a growing understanding of the environmental problems stemming from the use of coal and stricter environmental regulations have contributed to the retirements of many coal-fired power plants.

Even with the recent changes in the U.S. mining industry, in 2017, 14 percent of energy consumed in the United States was generated from coal, and coal accounted for 30 percent of U.S. electricity production. Some states continue to rely heavily on coal; in Indiana more than 50 percent of the total energy and 70 percent of electricity comes from coal.

A recent decline in coal production, although experienced by the majority of coal-producing states, has affected individual states and coal basins differently. Indiana, in contrast to Illinois and western Kentucky, has been able to maintain its coal production at or above 30 million tons over the last two decades, partly because of increasing contributions from underground mines, which have compensated for the decline in surface mining. In 2018, coal production from underground mines in Indiana (17,047,192 tons) closely approached surface mine production of 16,465,683 tons. But even in Indiana, in today's energy climate, the coal industry needs technical innovations and new ideas to successfully continue forward and to play an important role in the U.S. economy.

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