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COAL RESOURCES OF ILLINOIS

M. E. Hopkins and J. A. Simon

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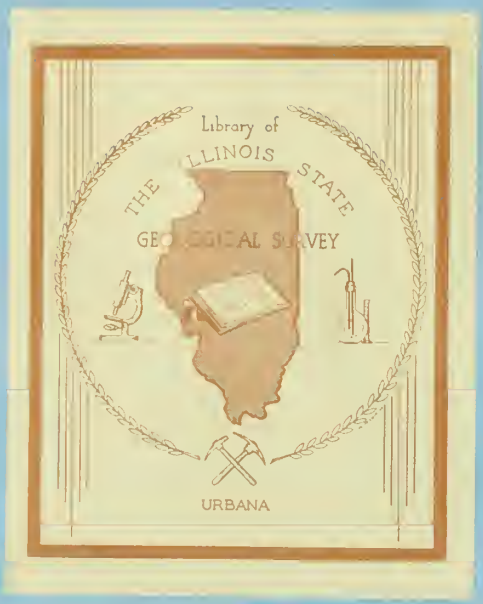

COAL RESOURCES OF ILLINOIS*

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COAL RESERVES IN ILLINOIS

Illinois is blessed with abundant coal, the fuel that at present represents the nation's best hope of becoming more self-sufficient in energy production in the future. Coal-bearing Pennsylvanian rocks underlie about 65 percent of the state of Illinois (36,806 out of a total of 56,400 square miles), appearing in all or parts of 86 of the state's 102 counties (fig. 1).

Compared to the other states, Illinois is in an enviable position in regard to coal reserves (table 1). It has the largest reserves of bituminous coal of any state and is surpassed in total reserves only by North Dakota and Montana, which have large quantities of lower rank lignite and subbituminous coals. Although large quantities of reserves in the western states lie at shallow depths, a significant amount are coals that lie too deep for strip mining but still would be difficult to mine by underground methods.

Long-term and continuing studies of Illinois coal reserves by the Illinois State Geological Survey have amassed a fund of data on Illinois coal reserves that is extremely detailed and comprehensive. An estimate of Illinois coal reserves was published in 1952 and has been supplemented by more recent material for various parts of the state. Coal reserves have been estimated for 79 Illinois counties (Cady et al., 1952; Clegg, 1961, 1972; Hopkins, 1968; Reinertsen, 1964; Searight and Smith, 1969; Smith, 1957, 1958, 1961, 1968; Smith and Berggren, 1963). In October 1973, 46 mines were operating in the state—21 underground and 25 strip mines. Preliminary figures show Illinois produced about 61,314,107 tons of coal in 1973.

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*From a paper presented at the First Annual Illinois Energy Conference at the University of Illinois at Chicago Circle, June 13-15, 1973.

TABLE 1—ESTIMATED REMAINING COAL RESERVES OF THE UNITED STATES BY RANK, SULFUR CONTENT, AND STATE ON JANUARY 1, 1965 (10^6 short tons)

Coal rank and state	Sulfur content (%)									
	0.7 or less	0.8 - 1.0	1.1 - 1.5	1.6 - 2.0	2.1 - 2.5	2.6 - 3.0	3.1 - 3.5	3.6 - 4.0	Over 4.0	Total
BITUMINOUS COAL										
Alabama	889.2	1,189.3	5,421.7	5,182.8	458.8	417.4	-	-	18.6	13,577.8
Alaska	20,287.4	1,100.0	-	-	-	-	-	-	-	21,387.4
Arkansas	-	-	1,128.4	293.1	154.0	-	40.3	-	-	1,615.8
Colorado	25,178.3	37,237.2	-	-	-	-	-	-	-	62,415.5
Georgia	-	76.0	-	-	-	-	-	-	-	76.0
Illinois††	-	-	1,808.0	-	1,139.5	17,871.9	36,264.0	62,130.0	20,542.6	139,756.0
Indiana	197.5	173.0	3,645.2	4,248.8	3,543.4	4,110.5	10,872.8	5,105.9	2,944.0	34,841.1
Iowa	-	-	-	-	-	-	117.1	-	6,405.4	6,522.5
Kansas	-	-	519.9	519.7	1,038.7	2,070.6	4,148.0	8,287.3	4,153.8	20,738.0
Kentucky										
West	-	-	1,119.6	162.0	336.3	3,793.6	12,759.3	13,643.3	5,081.3	36,895.4
East	13,639.9	8,491.9	2,286.8	1,658.8	1,158.3	2,154.4	24.7	-	-	29,414.8
Maryland	-	-	-	124.6	191.8	208.2	378.6	56.4	220.4	1,180.0
Michigan	-	-	-	-	-	-	-	205.0	-	205.0
Missouri	-	-	-	-	-	-	6,456.7	20,669.2	51,634.1	78,760.0
Montana	51.2	218.2	205.0	397.2	400.0	175.0	40.0	27.0	591.0	2,104.6
New Mexico	5,212.0	5,474.0	-	-	-	-	-	-	-	10,686.0
North Carolina	-	-	-	-	-	110.0	-	-	-	110.0
Ohio	-	611.0	369.0	2,110.2	2,750.4	7,810.5	9,785.3	10,148.2	8,439.4	42,024.0
Oklahoma	250.6	772.2	825.0	368.1	-	-	577.2	19.1	490.6	3,302.8
Oregon	-	14.0	-	-	-	-	-	-	-	14.0
Pennsylvania	44.0	1,154.4	7,624.4	12,424.9	19,689.5	9,995.6	5,287.6	1,150.5	580.6	57,951.5
Tennessee	3.3	160.9	715.9	258.7	178.2	190.5	219.7	43.8	68.5	1,839.5
Texas	-	-	-	-	7,978.0	-	-	-	-	7,978.0
Utah	8,551.4	13,584.0	-	1,524.9	-	-	-	-	3,997.7	27,658.0
Virginia	1,981.5	6,077.5	1,637.1	-	123.9	-	-	-	-	9,820.0
Washington	898.9	672.1	-	-	-	-	-	-	-	1,571.0
West Virginia	20,761.0	26,710.6	21,819.7	13,290.6	8,496.1	2,491.8	3,147.4	5,949.2	-	102,666.4
Wyoming	6,222.2	6,596.6	-	-	-	-	-	-	1.1	12,819.9
Other states	-	616.0	-	-	-	-	-	-	-	616.0
Total	104,168.4	110,928.9	49,125.7	42,564.4	47,636.9	51,400.0	90,118.7	127,434.9	105,169.1	728,547.0
Percent of total	14.3	15.2	6.7	5.8	6.5	7.0	12.4	17.5	14.4	100.0
SUBBITUMINOUS COAL										
Alaska	71,115.6	-	-	-	-	-	-	-	-	71,115.6
Colorado	13,320.8	4,908.7	-	-	-	-	-	-	-	18,229.5
Montana	94,084.4	36,728.0	0.5	1,303.7	-	-	-	-	-	132,116.6
New Mexico	38,735.0	12,000.0	-	-	-	-	-	-	-	50,735.0
Oregon	87.0	87.0	-	-	-	-	-	-	-	174.0

TABLE 1- *Continued*

Coal rank and state	Sulfur content (%) 0.7 or less	0.8 - 1.0	1.1 - 1.5	1.6 - 2.0	2.1 - 2.5	2.6 - 3.0	3.1 - 3.5	3.6 - 4.0	Over 4.0	Total
SUBBITUMINOUS COAL (Continued)										
Utah	-	-	150.0	-	-	-	-	-	-	150.5
Washington	3,693.8	500.0	-	-	-	-	-	-	-	4,193.8
Wyoming	35,579.7	72,315.6	-	-	-	-	-	-	8.6	107,903.9
Other states	-	4,047.0	-	-	-	-	-	-	-	4,047.0
Total	256,616.3	130,586.3	150.0	1,303.7	-	-	-	-	8.6	388,665.4
Percent of total	66.0	33.6	0.1	0.3	-	-	-	-	-	100.0
LIGNITE										
Alabama	-	-	20.0	-	-	-	-	-	-	20.0
Arkansas	280.0	70.0	-	-	-	-	-	-	-	350.0
Montana	60,214.5	24,141.6	2,660.9	-	-	464.7	-	-	-	87,481.7
North Dakota	284,129.1	34,987.3	31,581.6	-	-	-	-	-	-	350,698.0
South Dakota	-	2,031.0	-	-	-	-	-	-	-	2,031.0
Texas	-	-	6,902.0	-	-	-	-	-	-	6,902.0
Washington	-	116.6	-	-	-	-	-	-	-	116.6
Other states	-	42.0	-	-	-	-	-	-	-	42.0
Total	344,623.6	61,388.5	41,164.5	-	-	464.7	-	-	-	447,641.3
Percent of total	77.0	13.7	9.2	-	-	0.1	-	-	-	100.0
ANTHRACITE										
Alaska	2,101.0	-	-	-	-	-	-	-	-	2,101.0
Arkansas	-	-	-	145.5	286.3	-	-	-	-	431.8
Colorado	-	90.0	-	-	-	-	-	-	-	90.0
New Mexico	-	6.0	-	-	-	-	-	-	-	6.0
Pennsylvania	12,211.0	-	-	-	-	-	-	-	-	12,211.0
Virginia	335.0	-	-	-	-	-	-	-	-	335.0
Washington	5.0	-	-	-	-	-	-	-	-	5.0
Total	14,652.0	96.0	-	145.5	286.3	-	-	-	-	15,179.8
Percent of total	96.5	0.6	-	0.9	2.0	-	-	-	-	100.0
Grand total	720,060.3	302,999.7	90,440.7	44,013.6	47,923.2	51,864.7	90,118.7	127,434.9	105,177.7	1,580,033.5
Percent of total	45.6	19.2	5.7	2.8	3.0	3.3	5.7	8.0	6.7	100.0

Source: National Air Pollution Control Administration Pub. No. AP-52, 1969.

* Coal in seams at least 14 inches thick and less than 3000 feet deep in explored areas. Approximately one-half of these reserves is considered recoverable.

† Illinois data are for 1966.

* See Gluskoter and Simon (1968) for modification of low-sulfur coal reserves for Illinois.

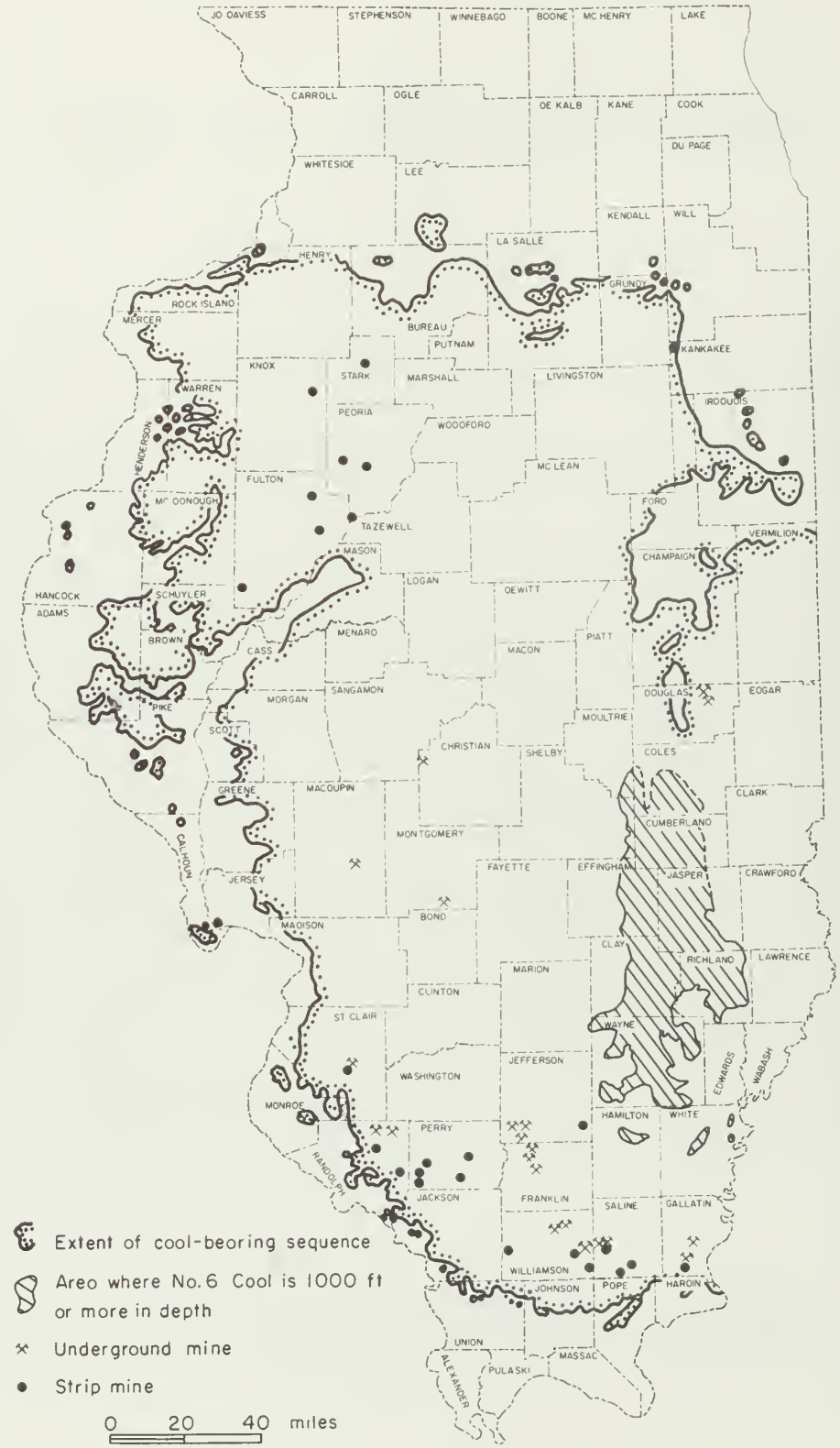

Fig. 1 - Operating coal mines as of October 1973. (Source: Illinois Department of Mines and Minerals.)

The latest estimate of reserves of coal in the ground is 148,172,540,000 tons (table 2). Included are coals more than 28 inches thick if they are more than 150 feet deep, and more than 18 inches thick if they are less than 150 feet deep. Thinner coals are not included in the reserves. This estimate is based on data developed in Cady's 1952 study and on additional information derived from exploratory drilling conducted in recent years. It makes no deduction for coal mined since the later reports were published. The new information has significantly increased the estimated reserves—more coal has been added to the reserves than has been removed by coal mining since 1952, at which time reserves were estimated (Cady, 1952) at more than 137 billion tons.

In Illinois, about 14 percent of our total coal reserves is found in seams lying less than 150 feet deep (table 2), and much of that coal is economically strippable with present equipment. The remaining coal reserves that have been mapped lie between 150 and 1500 feet deep, the deeper reserves occurring in the deepest part of the Illinois Basin in Cumberland, Jasper, Richland, Clay, and Wayne Counties (fig. 1).

Changing technology and economic conditions determine how thick a coal must be to be considered commercially minable at any given time, and these factors vary in different parts of the state at any one time. For example, although relatively little coal as thin as 18 inches has been mined in Illinois, one major strip mine in the state is now mining coal that will average only slightly more than 18 inches. Furthermore, although it is technologically possible, very little strip mining in the state has yet removed more than 100 feet of overburden, but what thickness of overburden will ultimately be practical to mine in Illinois has not yet been clearly defined. Although some coal no more than 30 inches thick has been mined underground, such operations have generally been very small. In years past, sizable underground operations have mined coal 3 to 4 feet thick, but the coal mined in present large-scale operations is generally thicker.

An important aspect of Illinois coal reserves data compiled by the Illinois Geological Survey is the detail in which they are given. Thicknesses recorded for each county are now making it possible to estimate current reserves of given minimum thicknesses above the 18-inch and 28-inch minima we mentioned previously. On a statewide basis, for example, if 54 inches were the minimum thickness specified, total in-ground reserves would be reduced by 50 percent, because only 50 percent of all Illinois coal reserves are estimated to be 54 inches or more thick.

For many years various agencies estimating reserves have assumed that 50 percent of the coal is lost or rendered unminable in underground mining. Although individual mines now generally exceed 50 percent recovery, the estimate is still valid when counties or larger areas are considered, for in Illinois only oil pool areas heavily drilled for oil and gas have been excluded from reserves estimates. Many surface features (cities, towns, superhighways, and similar areas) will also render coal unavailable for underground mining. There are, of course, several other factors that must be considered in determining minability of coal, including mining conditions and a variety of economic factors.

Technology designed to increase recoverability, with due regard to minimizing environmental damage, should be encouraged. The coal left in the ground in mined areas constitutes a loss of an important source of energy.

TABLE 2—REMAINING COAL RESERVES IN ILLINOIS BY COUNTY AND COAL SEAM*
(Thousands of tons)

County	Danville (No. 7)	Herrin (No. 6)	Springfield-Harrisburg (No. 5)	Summum (No. 4)	Colchester (No. 2)	De Koven	Davis	Rock Island (No. 1)	Misc. coals	Total	Percent strippable	Total strippable coal
Adams					625,241					625,241	99.0	619,275
Bond		2,451,950	299,867		2,092				2,472	2,756,381		
Brown					386,496					386,496	100.0	386,496
Bureau	424,110	649,427			1,221,789					2,295,326	19.7	452,400
Calhoun					15,015					15,015	100.0	15,015
Cass		55,884	49,049		452,957					557,890	43.9	244,903
Champaign	181,884									181,884		
Christian	61,454	3,556,511	1,336,119						86,660	5,040,744		
Clark	316,655	11,848	511,149						379,885	1,219,537		
Clay		916,819	702,311							1,619,130		
Clinton		3,236,433	552,248							3,788,681		
Coles	312,112		44,046							356,158		
Crawford	211,152	571,817	929,166						743,174	2,455,309	2.0	49,388
Cumberland		162,249	171,260						2,384	335,893	0.7	2,384
De Witt			173,619							173,619		
Douglas		726,829	11,011						10,061	747,901		
Edgar	950,564	721,363	441,330						878,904	2,992,161		
Edwards		684,316	1,031,565							1,715,881		
Effingham		622,072	1,164,351						1,248	1,787,671	0.1	1,248
Fayette	296,023	2,773,953	159,646						1,995	3,231,617	0.1	1,995
Franklin		2,213,231	1,977,951			362,147	507,878		64,989	5,126,196	0.1	2,949
Fulton	58,882	255,218	785,188	5,448	1,319,301			5,458		2,429,495	87.3	2,120,797
Gallatin		1,151,820	1,317,417			651,697	858,038		6,892	3,985,864	6.0	237,754
Greene		97,274		25,199	583,496					705,969	84.7	597,922
Grundy				42,578	844,353					886,931	40.1	356,077
Hamilton		2,611,967	2,192,953			3,557	5,336			4,813,813		
Hancock					29,828					29,828	100.0	29,828
Hardin						1,177	2,421			3,598		
Henderson					53,111					53,111	100.0	53,111
Henry	58,878	260,289			668,819			76,660		1,064,646	58.4	621,265
Jackson		236,551	218,494						257,749	712,794	54.9	391,321
Jasper		1,861,661	1,415,200							3,276,861		
Jefferson		2,848,713	2,442,508						29,417	5,320,638	0.6	29,417
Jersey	10,482	71,256			197,789					279,527	78.9	220,461
Kankakee				36,055	87,052					123,107	21.9	27,016
Knox	2,523	257,066	648,929		803,634			57,806		1,769,958	89.5	1,583,379
La Salle	489,782	217,085			1,452,571					2,159,438	13.0	280,420
Lawrence	223,427	1,186,698	985,024						555,780	2,950,929		
Livingston	512,624	125,369			2,351,608					2,989,601	1.7	49,226
Logan			2,589,660							2,589,660		
Macon		162,928	1,689,960							1,852,888		
Macoupin	15,510	3,972,492	43,026	32,328	1,632,416		126,363		697,334	6,519,469	4.2	275,605
McDonough					584,320					584,320	100.0	584,320

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TABLE 2 - *Continued*

County	Danville (No. 7)	Herrin (No. 6)	Springfield-Harrisburg (No. 5)	Summum (No. 4)	Colchester (No. 2)	De Koven	Davis	Rock Island (No. 1)	Misc. coals	Total	Percent strippable	Total strippable coal
McLean	603,370		316,337		296,406					1,216,113		
Madison		1,943,928			660,361		4,675		8,015	2,616,979	23.5	615,350
Marion		1,218,246	748,495							1,966,741		
Marshall	337,384	9,749			858,033					1,205,166	9.6	116,023
Mason			23,271							23,271		
Menard			1,593,985		23,755					1,617,740	33.5	541,378
Mercer					17,859			69,248		87,107	80.3	69,982
Monroe		13,676	4,970							18,646	36.1	6,726
Montgomery	24,972	3,743,720	523,812	85,909	558,844		133,353		513,415	5,584,025		
Morgan		621,765	18,021	22,531	1,322,351					1,984,668	41.7	827,615
Moultrie		355,524								355,524		
Peoria	282,537	1,070,432	1,321,268		440,025					3,114,262	69.8	2,174,236
Perry		2,294,358	440,324							2,734,682	40.4	1,106,041
Piatt			10,698							10,698		
Pike					144,401					144,401	100.0	144,401
Putnam	197,035	78,876			467,893					743,804		
Randolph		516,396	185,965							702,361	64.8	455,029
Richland		1,191,832	932,509						5,192	2,129,533	0.2	5,192
Rock Island								62,133		62,133	67.6	42,000
St. Clair		2,536,106	621,565							3,157,671	39.6	1,249,123
Saline	78,422	1,361,979	993,694	6,885	7,768	698,270	1,142,516		3,178	4,292,712	12.7	545,410
Sangamon		2,194,896	3,331,618		280,804				4,086	5,811,404	7.2	418,366
Schuyler			113,393		606,151					719,544	100.0	719,544
Scott		6,120			253,499					259,619	87.3	226,609
Shelby	125,267	1,183,577	304,861						90,944	1,704,649	5.0	84,569
Stark	57,703	442,507			25,781					525,991	100.0	525,991
Tazewell	4,152	69,687	129,386		202,528					405,753	37.0	150,005
Vermilion	1,712,155	702,569							44,521	2,459,245	10.0	245,924†
Wabash		575,908	880,534						158,473	1,614,915	9.8	158,473
Warren			809		369,414			39,000		409,223	98.4	402,665
Washington		3,462,823	650,598							4,113,421	0.2	7,958
Wayne		2,349,795	2,274,301							4,624,096		
White		2,364,131	2,248,345			13,823	17,204			4,643,503		
Will					21,623					21,623	100.0	21,623
Williamson	57,022	823,044	946,090	2,648		754,702	634,300		188,155	3,405,961	19.1	651,820
Woodford	38,560		144,770		990,850					1,174,180		
Total	7,644,641	65,802,733	42,642,666	259,581	20,860,234	2,485,373	3,432,084	310,305	4,734,923	148,172,540	14.0	20,746,025

* Totals include coal seams 28 inches or more thick in all classes of reliability, as defined in Illinois State Geological Survey Bulletin 78 (Cady et al., 1952). Strippable coals include coals 18 inches or more thick under 150 feet or less overburden. These totals do not include coal produced or rendered unminable since the date of each resource study.

† Not based on detailed study.

In evaluating coal reserves of any area, how the reserves are defined is of major importance. In Illinois, for example, if a minimum thickness of 54 inches for all types of mining (about 50 percent of total reserves mapped to date) and the figure of 50 percent recovery were accepted, only about 25 percent of the nearly 148 billion tons of coal would be estimated as recoverable.

Whatever assumptions may be made for estimating recoverable coal reserves, Illinois compares very favorably with all other states having bituminous coal reserves because of its generally thicker, more continuous, and relatively flat-lying seams.

Acknowledgments

Much of the statistical data used in the preparation of this report was gathered from the Illinois State Department of Mines and Minerals Annual Coal Reports and from the Minerals Yearbooks of the U.S. Bureau of Mines. A more detailed report covering much of the same subject material was submitted in February 1970 by Jack A. Simon as testimony before the Illinois Commerce Commission. The present report brings the data of this earlier report up to date and discusses the relation of coal in Illinois to current problems, particularly those related to the current energy shortage.

COAL QUALITY

Rank

Illinois coals are all of high-volatile bituminous rank. The rank for each coal increases from northwest to southeast, ranging from high-volatile C (the lowest rank of bituminous coal) in northwestern Illinois, through high-volatile B in the central and southern parts of the state, to high-volatile A in extreme southeastern Illinois (Cady, 1935; Damberger, 1971). Natural moisture contents range from about 20 percent in the northwest to about 5 percent in the southeast. Heating value (on an as-received basis) of Illinois coal ranges from about 10,500 to more than 13,000 Btu per pound, with the older coals of any area generally having higher heating values than younger coals. No systematic variation in ash content has been discerned. Most coals that are being or have been mined are reported to contain between 5 and 15 percent ash (as-received basis), with an average of about 11 percent.

Sulfur Content

The sulfur content of coal has recently assumed great importance as regulations concerning air quality have limited the use of high-sulfur coals. Sulfur occurs in coal in three forms: *organic sulfur*, which occurs in the organic compounds in the coal; *pyritic sulfur*, which is found as iron sulfides (FeS_2) that may be finely disseminated in the coal in microscopic grains, or

found in nodules, in lenses, in bands, and perhaps on cleat (fracture) faces; and *sulfate sulfur*, which normally occurs in relatively minor amounts in fresh coal.

Total sulfur in Illinois coals has been reported to vary between 0.5 and 6.0 percent (dry basis), with occasional samples having a higher sulfur content. The average total sulfur content of 473 face-channel samples from Illinois mines reported by Gluskoter and Simon (1968) was 3.57 percent. They also reported an average of 1½ times as much pyritic sulfur as organic sulfur in the same coals. Face-channel samples, excluding mineral bands over three-eighths of an inch thick, are believed to approximate the coal seam after moderate preparation.

Coals in certain well defined areas of Illinois have a significantly lower sulfur content than coals in the rest of the state, a condition than can be related geologically to variations in the roof strata immediately overlying the coal. Most of the relatively high-sulfur coals (those with 3 to 5 percent sulfur on a dry basis) are overlain by either black shale, limestone, or fossiliferous shale, all of which have at least one thing in common—they contain animal fossils that indicate they were deposited in marine waters. Conversely, every important known occurrence of Illinois coal that has a significantly low sulfur level is overlain by nonmarine gray shale in which plant fossils predominate. The gray shale separates the coal from the overlying marine unit, usually black shale or limestone. A fairly sharp change in sulfur content normally occurs between areas with marine roof and those with nonmarine roof. When the gray shale exceeds 20 feet thick, the total sulfur content of the coal is normally less than 2.5 percent and commonly averages about 1.5 percent. The nonmarine shale is usually associated with a river-laid sandstone unit that replaces the coal in a long, sinuous band, or "sandstone channel."

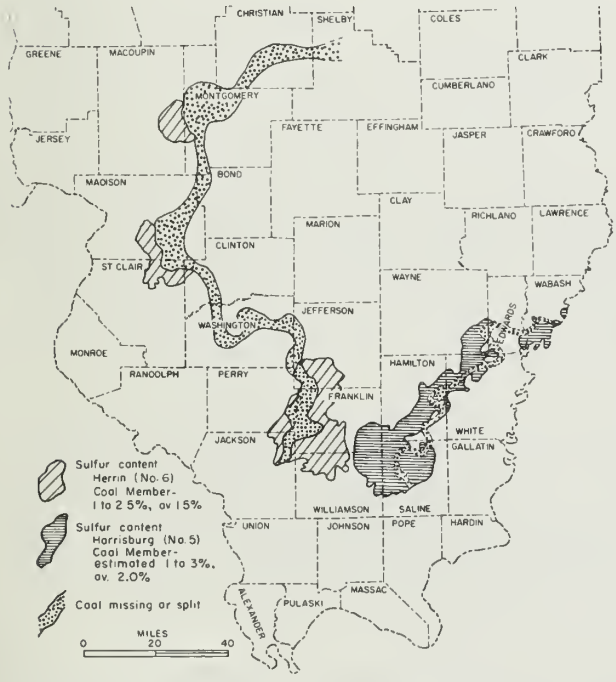


Fig. 2 - Low-sulfur coal areas in Illinois that have been mapped.

Areas of low-sulfur coal have been mapped (Gluskoter and Simon, 1968; Hopkins, 1968) and are shown in figure 2. Total reserves (i.e., total in ground) in these areas for the Herrin (No. 6) Coal and the Harrisburg (No. 5) Coal Members amount to 4.8 billion tons, or 3.2 percent of the total reserves of the state (table 3). About 65 percent of the coal in the so-called "Quality Circle" low-sulfur area, principally parts of Williamson, Franklin, and Jefferson Counties, has been mined out, and the remainder is under development by five large underground mines. Most of the production goes to the metallurgical coke market. Other areas of low-sulfur Herrin Coal are the "Troy Area," lying principally in Madison and St. Clair Counties, and the "Hornsby Area" in east-central Macoupin County. In

TABLE 3—ILLINOIS LOW-SULFUR RESERVES IN GROUND

Coal	County	Millions of tons
Herrin (No. 6) (< 2.5% S, av. 1.5%, dry basis)	Clinton	23
	Franklin	307
	Jackson	37
	Jefferson	580
	Macoupin	396
	Madison	245
	Perry	35
	St. Clair	381
	Williamson	59
	Total	2,063
Harrisburg (No. 5) (< 2.5% S, av. ∿ 2%, dry basis)	Edwards	54
	Franklin	243
	Hamilton	563
	Saline	627
	Wabash	262
	Wayne	89
	White	626
	Williamson	274
	Total	2,738
	Total Illinois low-sulfur reserves	4,801*

* 3.23 percent of total coal reserves of Illinois.

these three areas slightly more than 2 billion tons of coal in the ground contains an estimated average of 1.5 percent total sulfur. The Troy and Hornsby areas are not being mined at present, although the Troy area has been mined in the past.

Less is known about the average sulfur content of the low-sulfur Harrisburg (No. 5) Coal, but it is thought that the belt extending from Mt.Carmel in Wabash County to Harrisburg in Saline County contains about 2.7 billion tons of coal with an average sulfur content of about 2.0 percent; some of the coal contains as little as 1.0 percent sulfur. This low-sulfur coal area has been mined only in Saline County, where it has been extensively worked. A new mine has just begun production in this low-sulfur coal in Wabash County.

Low-sulfur coals occur in other less well known areas in Illinois, but their extent is either relatively small or not enough data are available to permit their delineation. However, no additional large occurrences of minable low-sulfur coals are likely to be found, particularly in the better known minable seams, because the relatively abundant subsurface data reveal no extensive areas of coal under nonmarine gray shale, the geologic indicator of low-sulfur coal.

The 1970 production of coal in Illinois is shown in table 4, according to sulfur content. Nearly 27 percent of the coal contained less than 2.5 percent sulfur, whereas more than 73 percent of the coal exceeded 2.5 percent sulfur.

IMPORTANCE OF COAL TO ILLINOIS

Coal is by far the largest mineral resource in Illinois and it has the highest annual mineral production value. With the present energy shortage facing this country, judicious use of this important commodity, with due regard for environmental quality, is vital.

Coal production (fig. 3) in Illinois in 1972, from 59 mines in 22 counties, totaled 65,521,394 tons and was about equally divided between surface and strip mines. This was the largest production since 1948, following which year production declined to a low point in 1954. Since 1961, the trend of the state's coal production has been generally upward, although some fluctuation has occurred in recent years.

The 1972 coal production had a value of more than 402 million dollars (at $6.14 per ton) and constituted almost 50 percent of all Illinois mineral production (fig. 4). Petroleum, the second most valuable mineral resource in Illinois, had a value of more than 121 million dollars in 1972 (figured at $3.47 per barrel), or 14.9 percent of the state's total mineral production value.

The value of a basic raw material to the economy is only partially expressed by its actual value. Basic raw materials generate or support other industries that convert the raw material to consumable products. Also involved are the various industries that provide materials and services to the basic industry and to the people employed. Coal, for instance, is by far the most important single commodity carried by our railroads, both in tonnage and in revenue.

PRODUCTIVITY AND EMPLOYMENT

Illinois mines, among the most productive in the world, are large and highly mechanized. Illinois mines (both strip and underground) have

TABLE 4—ILLINOIS COAL PRODUCTION BY SULFUR RANGE AND CUMULATIVE TOTALS AT EACH RANGE*

Sulfur content (%)	Tons	Cumulative tons	Total tons (%)	Cumulative % of total tons
1.0 - 1.49	8,823,114	8,823,114	13.8	13.8
1.5 - 1.99	3,997,656	12,820,770	6.3	20.1
2.0 - 2.49	4,162,803	16,983,573	6.5	26.6
2.5 - 2.99	14,508,072	31,491,645	22.8	49.4
3.0 - 3.49	17,610,333	49,101,978	27.6	77.0
3.5 - 3.99	8,751,686	57,853,664	13.7	90.7
4.0 and over	5,936,555	63,790,219	9.3	100.0

*Source: Midwest Coal Producers Institute (1970).

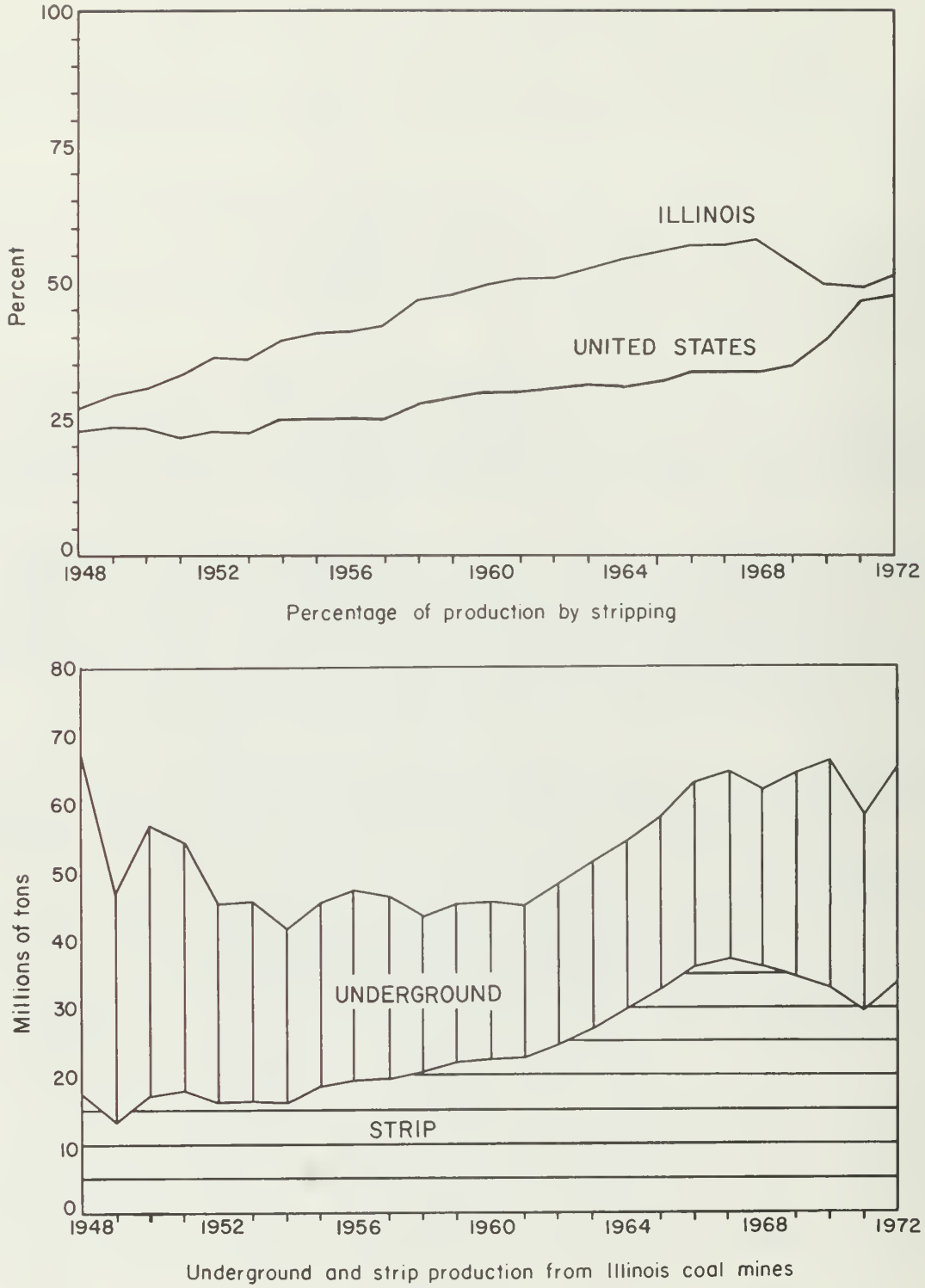


Fig. 3 - Illinois maintains a good balance between strip and underground mining. In the nation as a whole, strip mining has steadily increased.

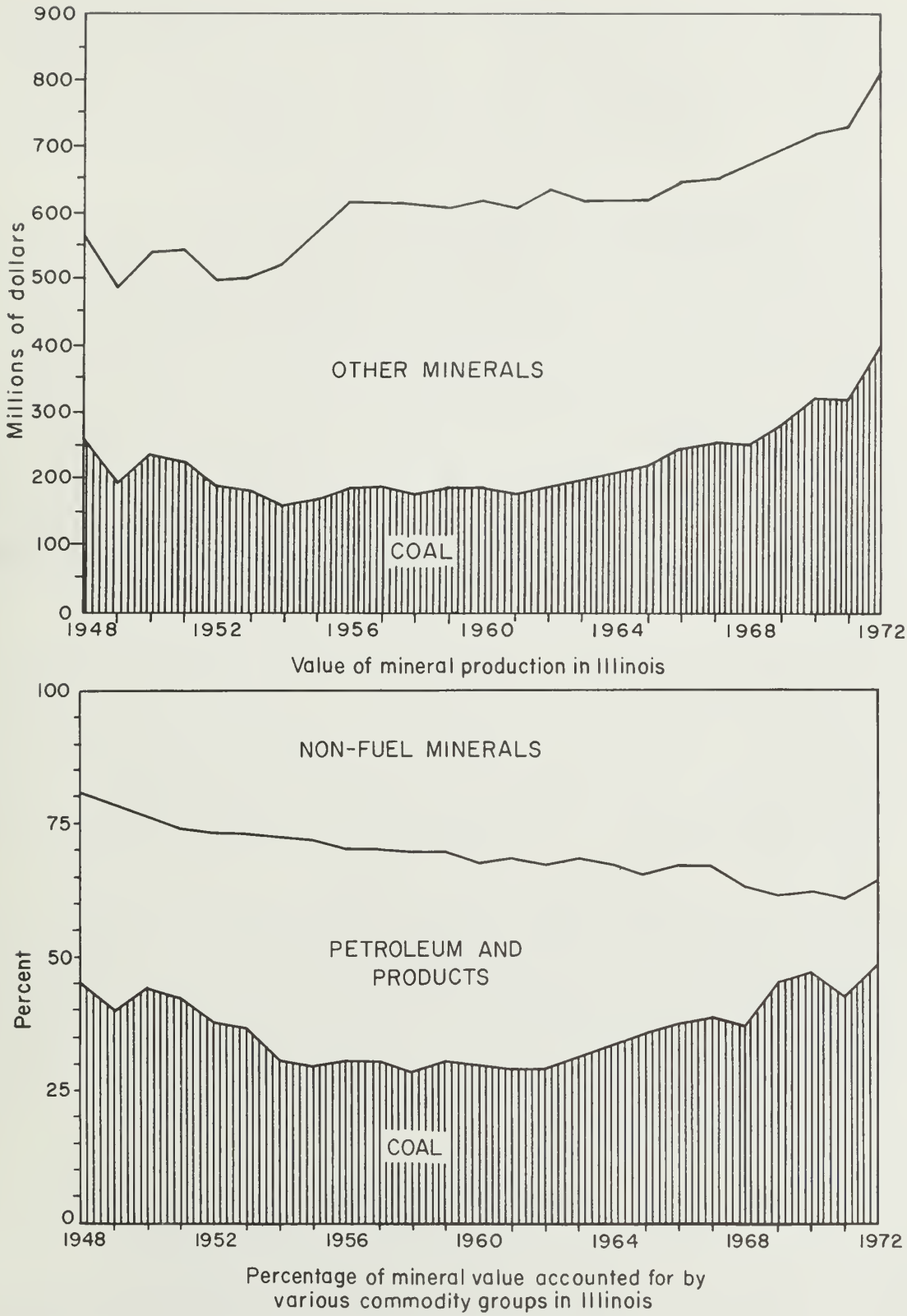
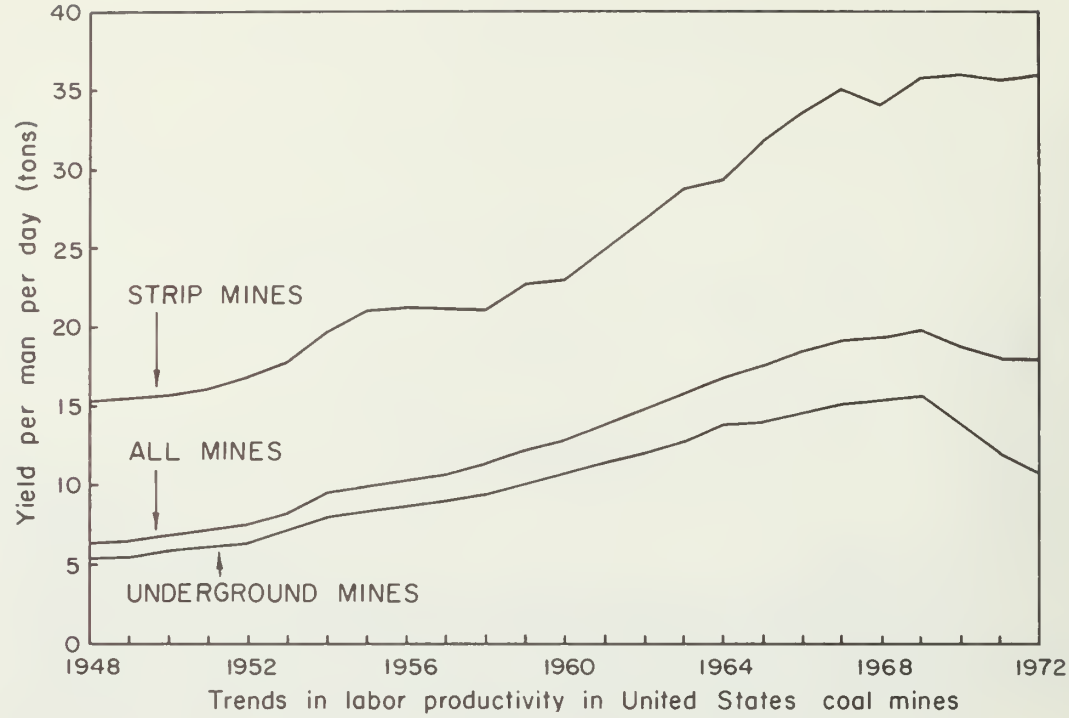


Fig. 4 - Coal is the most important mineral commodity produced in Illinois. (Source: U. S. Bureau of Mines Minerals Yearbooks.)



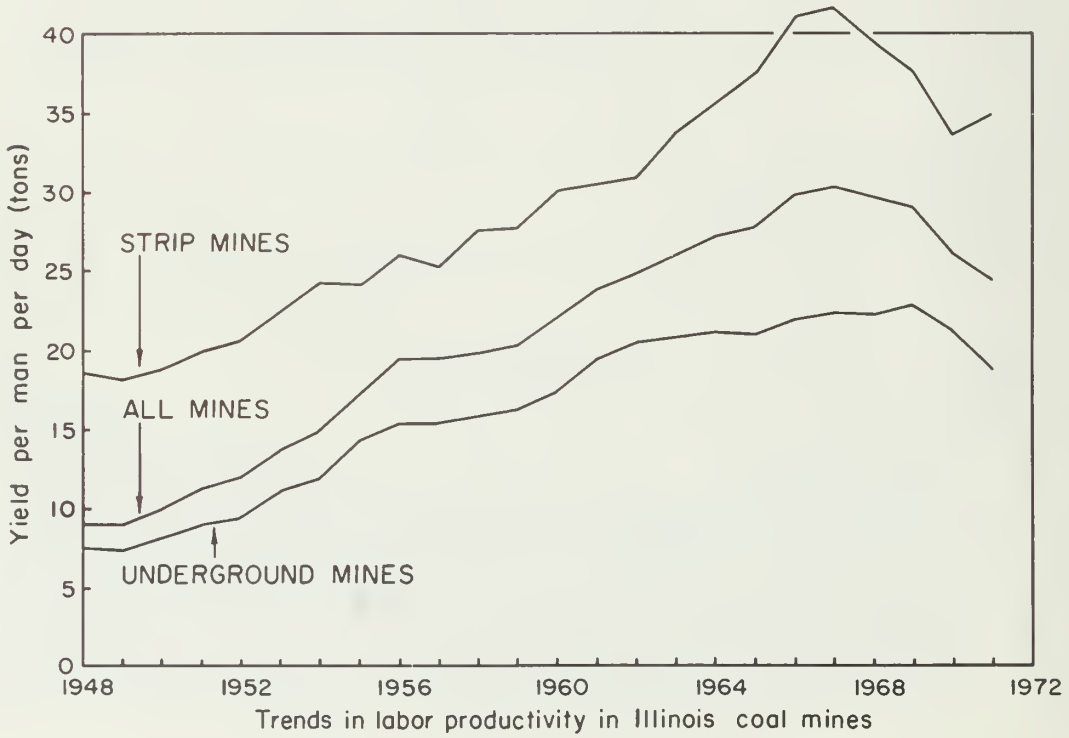


Fig. 5 - Illinois has consistently led the United States as a whole in productivity per man in both strip and underground mining. (Source: U.S. Bureau of Mines Minerals Yearbooks.)

consistently been ahead of the national average in productivity per man (fig. 5). Only during 1971 and 1972 has the national average for strip mine labor productivity exceeded that in Illinois. The decline is probably related to such factors as the enactment in 1967 of a new reclamation law and to the increasing depth of overburden in Illinois mines. Illinois strip mine productivity per man-day declined in 1968 but rose again in 1971.

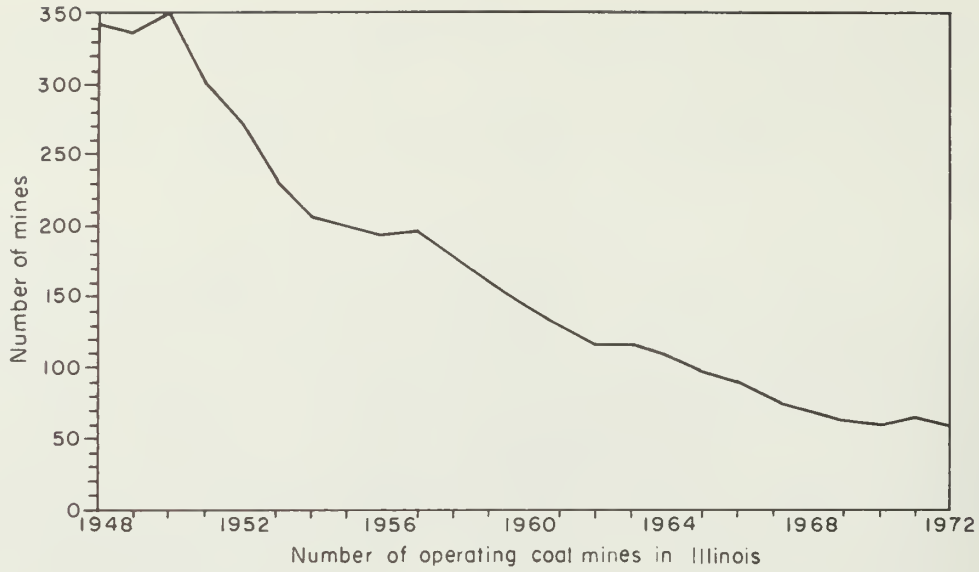
The over-all reduction in productivity per man in Illinois and throughout the country has two causes, both of which arose at about the same time. First, the increasing awareness of the need for protection of the environment diverted manpower from mining to activities such as strip mine reclamation, acid-water treatment or containment facilities, and the prevention of continued exposure of refuse material to the environment, adversely affecting productivity. Second, the Health and Safety Act of 1969 affected production in underground mines. A steady increase in productivity for many years had culminated in the highest productivity reported for the country as a whole, 15.61 tons per man per day in 1969. The rate dropped nationally to 12.03 in 1971 and is expected to be below 12 for 1972. In Illinois, productivity of underground mines has dropped from almost 23 tons per man-day in 1969 to slightly less than 19 in 1971, although Illinois underground mines still have the highest productivity per man-day of all the coal-producing states. Strip mine productivity has more or less leveled off for the nation as a whole, but has dropped considerably for Illinois.

Illinois mines are large producers, averaging over 1.1 million tons per mine for the year 1972 (fig. 6). The average mine size (measured in output) has increased rapidly in Illinois, especially since 1958, and the number of mines has consequently declined markedly from 350 mines in 1950 to the present 48. The national average has increased only slightly. In 1971 there were some 5,149 coal mines in the country—only 64 of them in Illinois. These 64 mines, constituting only 1.2 percent of the total number of mines in the United States, accounted for 10.6 percent of the total production, attesting to the efficiency of this industry in Illinois.

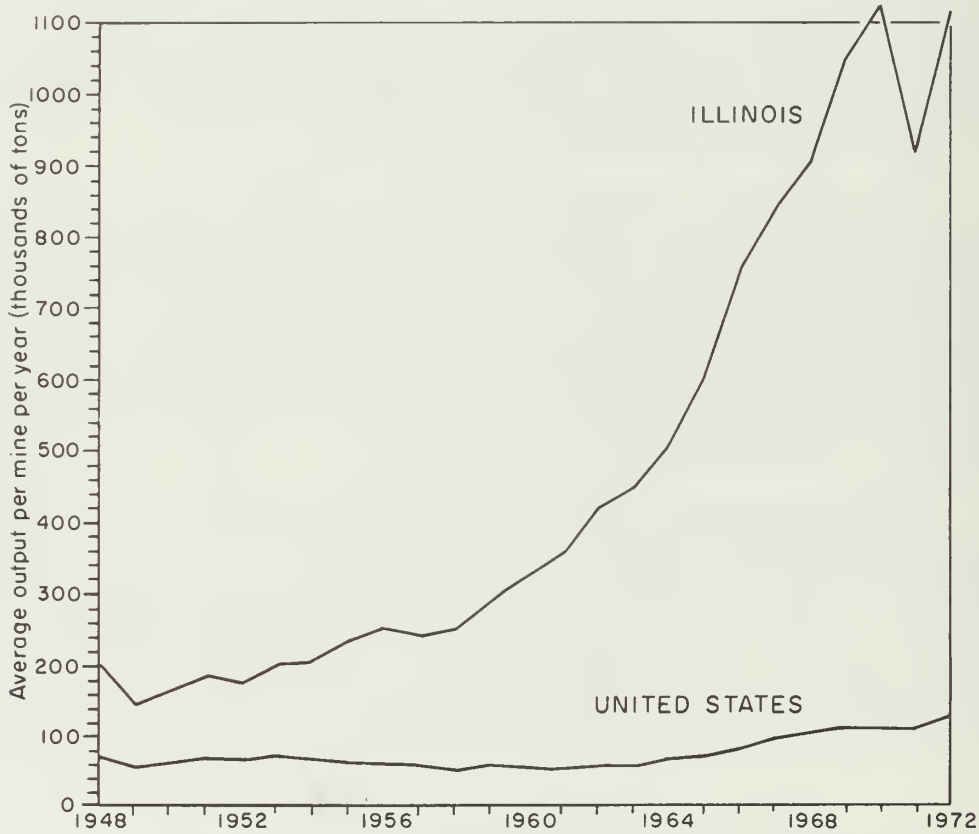
In 1972 the total number of men directly employed in the coal mining industry in Illinois was 11,237. Of these, 7,870 were employed by underground mines and 3,367 by strip mines. Mining activities employ men in 22 counties; distribution of the 11,237 employees by county is shown in figure 7. Three concentrations of mining occur—in western Illinois where operation is principally by surface methods, in west-central Illinois where three very large underground mines are located, and in southern and southwestern Illinois, the largest area, where both underground and strip mining methods are employed.

USES OF ILLINOIS COAL

Most projections for the future use of energy in the United States point to a substantial increase in the need for coal, for the generation of electrical power now and conversion to gas or liquid fuels later. Table 5 is one such projection (Dupree and West, 1972), and many of the others are similar (Risser, 1960). This projection forecasts a need for almost one billion



Number of operating coal mines in Illinois



Trends in average output for the coal industry in Illinois and the United States

Fig. 6 - Because many of the smaller mines in Illinois have been closed, the average output per mine in Illinois has increased markedly, far more dramatically than the average for the United States as a whole. (Source: U.S. Bureau of Mines Minerals Yearbooks.)

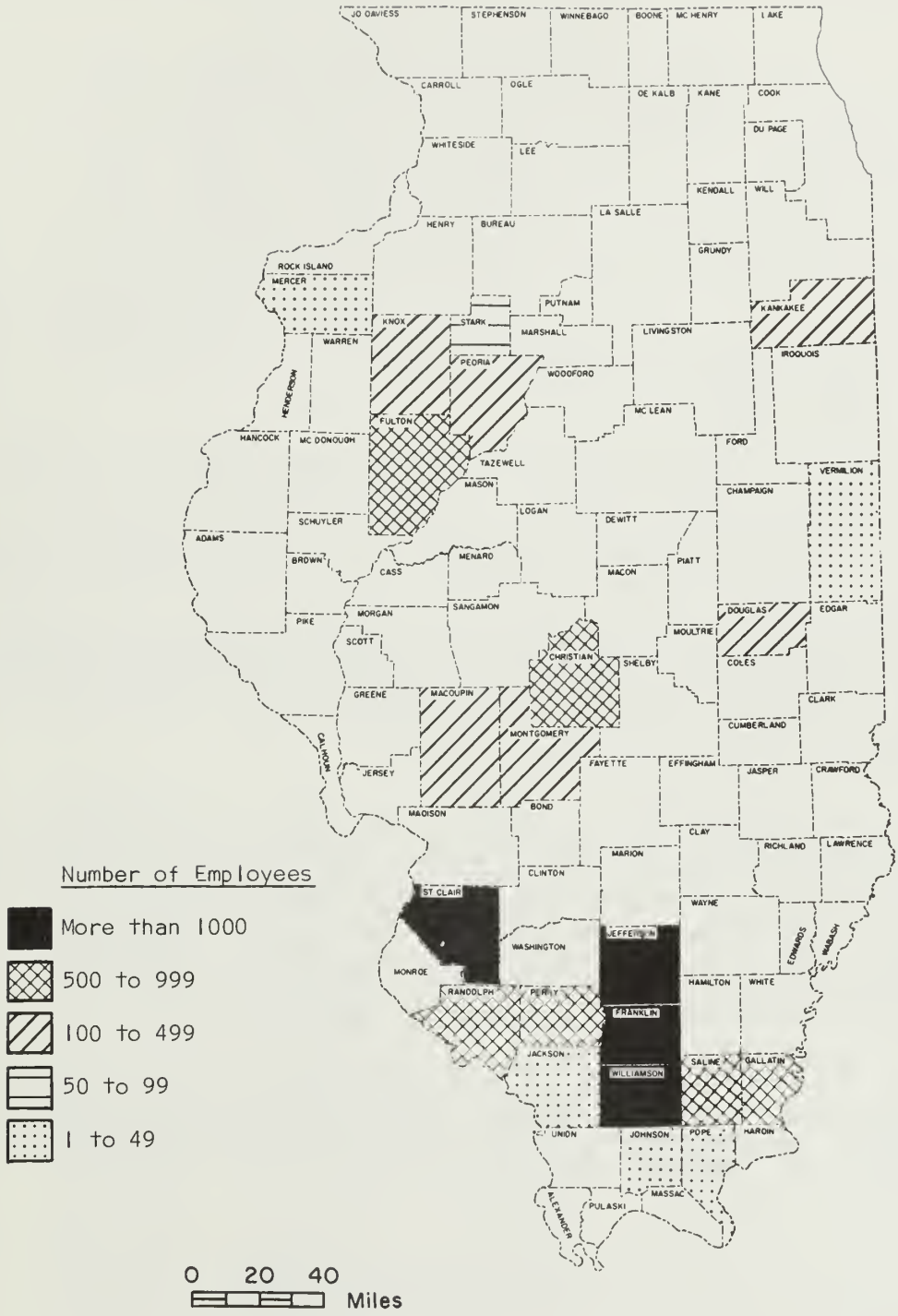


Fig. 7 - Pattern of employment in the Illinois coal industry, by counties, 1972. (Source: Illinois Department of Mines and Minerals 1972 Coal Report.)

TABLE 5—PROJECTED DEMAND FOR U.S. COAL BY POWER-CONSUMING SECTORS*
(millions of tons)

Coal supply	1971†	1975	1980	1985	2000
Household and commercial	14.6	12	11	4	—
Industrial	164.6	169	175	190	247
Electrical generation	331.6	384	460	613	755
Synthetic gas	—	—	19	86	308
Export	58.0	71	75	87	108
Total	568.8	636	740	980	1,418

* Source: Dupree and West, 1972.
† Actual figures.

tons of coal in 1985 and almost 1½ billion tons in 2000. U.S. production in 1971 was only 569 million tons; in 1972 it was 595 million tons.

In 1972 more than 32 million tons of coal, 25 million from Illinois, were consumed in Illinois for the generation of electrical energy (tables 6 and 7), almost 77 percent of all coal used in the state. The amount is projected to increase substantially as the demand for electrical energy continues to soar (Risser, 1970). Much of the increased demand for electricity will be met by electricity generated by nuclear energy, but, even if the development of nuclear capacity progresses as hoped, a substantial increase in coal consumption will still be needed.

At present, two principal sources supply steam coal for Illinois power plants, the Illinois Basin mines (including those of Indiana and western Kentucky) and the western subbituminous mining area in Wyoming and Montana, from which about six million tons are reportedly coming into the Chicago area annually. The western coal is low-sulfur coal, and, although of lower heating value than midwestern or eastern coals, is becoming increasingly important in the central part of the United States. Several new power plants will be using this coal in Texas, Oklahoma, Kansas, and other states.

A large percentage of low-sulfur coal produced in Illinois is used by steel companies for blending with higher rank coals to produce metallurgical coke. The coal with the lowest sulfur content produced from the relatively low-sulfur coal mines is generally committed to this market.

SOME COAL-RELATED PROBLEMS

Sulfur Emission

Illinois faces several problems related to its most abundant energy resource (Risser, 1973a,b). One immediate problem is that present and proposed

state and Federal regulations on emissions of sulfur dioxide prohibit the use of most Illinois coal unless most of the sulfur it contains is removed.

Although the Illinois Geological Survey has done extensive research to determine the possibility of reducing the sulfur content of coal and has achieved substantial reductions in total sulfur, no methods have been devised to lower the sulfur to the level that proposed regulations require (Helfinstine et al., 1971 and *in press*; Deurbrouck, 1972). Pyritic sulfur, which makes up about 60 percent of the total sulfur in our coals, is the most amenable to reduction by conventional gravity techniques of coal cleaning, but, even when the coal is reduced to relatively fine sizes (minus three-eighths of an inch), generally only about half of the pyritic sulfur is removable (about one-third or less of the total sulfur in the coal). There is some variation in the "cleanability" of Illinois coals, but, since a significant portion of total sulfur is organic, only a very small portion of Illinois coal can be cleaned to 0.7 percent total sulfur—the approximate level that regulations will require.

Extensive research has been conducted throughout the country on methods of removing sulfur dioxide and cleaning stack gases from large units, such as those found in power plants. Some processes are currently undergoing full-scale plant tests in Illinois, as well as in a number of other states.

TABLE 6—ILLINOIS CONSUMPTION OF BITUMINOUS COAL FROM ALL PRODUCING DISTRICTS, INCLUDING ILLINOIS, IN THE UNITED STATES*
(net tons)

Year	Electric utilities	Coke plants	Commercial and domestic	Industrial and misc.	Total
1960	19,134,000	2,948,000	6,570,000	10,053,000	38,705,000
1961	19,182,000	2,774,000	5,696,000	9,827,000	37,479,000
1962	20,380,000	2,874,000	5,803,000	10,202,000	39,259,000
1963	20,924,000	2,798,000	5,288,000	10,076,000	39,086,000
1964	22,995,000	3,309,000	4,809,000	10,353,000	41,466,000
1965	25,180,000	3,608,000	4,558,000	11,010,000	44,356,000
1966	27,808,000	3,626,000	4,263,000	10,685,000	46,382,000
1967	29,497,000	3,449,000	4,074,000	9,690,000	46,710,000
1968	28,221,000	3,069,000	3,312,000	8,863,000	43,465,000
1969	30,393,000	3,713,000	3,077,000	8,061,000	45,244,000
1970	29,453,000	3,688,000	2,591,000	6,579,000	42,311,000
1971	27,930,000	3,347,000	1,871,000	5,141,000	38,289,000
1972	32,294,000	3,243,000	1,415,000	5,076,000	42,028,000

* Source: U.S. Bureau of Mines Mineral Industry Surveys, Annual and Quarterly Distribution Reports.

TABLE 7—ILLINOIS CONSUMPTION OF BITUMINOUS COAL FROM ILLINOIS MINES*
(net tons)

Year	Electric utilities	Coke plants	Commercial and domestic	Industrial and misc.	Total
1960	14,974,000	499,000	3,078,000	8,289,000	26,840,000
1961	16,439,000†		2,526,000	8,082,000	27,047,000
1962	16,720,000	755,000	2,558,000	8,437,000	28,470,000
1963	17,670,000	801,000	2,316,000	8,513,000	29,300,000
1964	19,706,000	922,000	2,203,000	8,565,000	31,396,000
1965	22,115,000	1,170,000	1,959,000	8,903,000	34,147,000
1966	25,058,000	1,513,000	1,889,000	9,113,000	37,573,000
1967	26,825,000	1,468,000	1,831,000	8,386,000	38,510,000
1968	25,539,000	1,200,000	1,362,000	7,618,000	35,719,000
1969	26,622,000	1,538,000	1,141,000	7,102,000	36,403,000
1970	25,688,000	1,618,000	1,015,000	5,657,000	33,978,000
1971	22,204,000	1,424,000	723,000	4,189,000	28,540,000
1972	25,329,000	1,288,000	630,000	4,084,000	31,331,000

* Source: U.S. Bureau of Mines Mineral Industry Surveys, Annual and Quarterly Distribution Reports.

† Mineral Industry Distribution Report for 1961 combines utilities coal consumption with coke and gas plant consumption.

The National Academy of Engineering/National Research Council, studied and reported on the abatement of sulfur oxide emissions from stationary sources in 1970. The report stated "...contrary to widely held belief, commercially proven technology for control of sulfur oxides from combustion processes does not exist [on a scale considered for demonstration or larger]." A recent report prepared for the Federal Interagency Committee on Evaluation of State Air Implementation Plans by the Sulfur Oxide Control Technology Assessment Panel (SOCTAP, 1973) indicated that technological problems in controlling sulfur dioxide emission would be solved sometime in 1974. However, not all task force members agreed with that optimistic projection.

Despite claims made by some manufacturers, prior to and since the NAE/NRC study, that their equipment could effectively remove sulfur dioxide, we feel the conclusion of the committee is still true. The level of work on this problem is such, however, that one or more successful processes for removing sulfur dioxide from flue gases will be developed soon. One process in Japan has been in successful operation on a full-scale plant for about a year. Various technical observers have reported that this operation does not meet U.S. needs, but some qualified observers have indicated the process could be applied. Close analysis of the scrubbing agent used, the nature of load, operation at full capacity, disposal of wastes, and costs will determine if the process can be used in the United States.

Whether the cost of any of the promising techniques will prevent their acceptance will be determined after technical feasibility has been demonstrated. It is unlikely that any single process will be applicable to all installations, and time will be required to design, manufacture, and install any device in the wide variety of plants to which it may be applicable.

Liquefaction and Gasification

Another major area of research in the past 10 years has been the liquefaction and gasification of coal. Extensive efforts on pilot-plant scale are being planned and conducted to produce gas of pipeline quality (about 1000 Btu per cubic foot). The relatively good mining conditions, the extensive reserves of relatively thick coals, the moderate water potential, the availability of pipelines, and the presence of underground gas storage facilities suggest that Illinois would be an ideal location for such developments. However, such gas, which is essentially sulfur free, will probably not be available much before 1980. Furthermore, the gas probably will be too expensive for electric power generation.

Conversion of coal to low-Btu gas at a power plant for on-site use is being planned in the United States. As the process would include the removal of sulfur from the gas, its successful development holds much promise for installations that could employ this technique, providing economics prove favorable.

Manpower

Many have recognized that if demands for coal to meet utility needs and to serve as a raw material for gas and liquid fuels increase greatly, the nation will find it difficult to obtain and train the highly skilled manpower required for modern coal mine operations, particularly for underground mining. The largest part of our Illinois reserves, as noted previously, must be mined by underground methods.

Because of the potential of this valuable resource for meeting future energy requirements, it is important that the trained manpower force we now have should not be allowed to disperse. The present trained corps of miners will be an essential nucleus for the much larger work force that will certainly be required before the end of the decade.

New Mines

One considerable problem related to obtaining fuel resources to meet our energy needs is the time factor involved in the planning, exploration, design, and construction of the new mines that will be needed. There appears to be a reluctance to invest in the opening of new mines in areas such as Illinois where permission to use high-sulfur coal may not be forthcoming in the near future. Lead times of at least from 2 to 4 years are required for construction of large strip mines, and 3 to 5 years are needed for construction of large underground mines. This required lead time and the present hesitancy to begin new mines will have an adverse effect on potential coal production in the next several years.

Alternate Strategies

An unpublished report of the Task Force for Sulfur Dioxide Control Technology, prepared in 1971 for the Illinois Institute for Environmental Quality, suggested strategies for improving ambient air quality in the immediate future, in case sufficient low-sulfur fuels are not available and until various sulfur dioxide control processes have been perfected. The procedures include:

1. Stock piling of *available* low-sulfur fuels for use *only* when meteorological conditions are adverse, and use of available higher sulfur fuels during periods when weather conditions permit wide dissemination of gases.

2. Shut-downs or reduced operations of plants for which low-sulfur fuels may not be available, even on emergency basis, when meteorological conditions are adverse.

3. Use of tall stacks, which, while not reducing total emissions, can reduce level of concentration in ambient air.

4. Shift of power generation from stations where meteorological conditions are adverse to other stations that have favorable conditions.

In closing, we cannot ignore the place of other fuel resources, including oil, natural gas, and nuclear energy. It is our firm belief, however, that future competition among fuels will be relative to *where* each fuel will be used, rather than *what* fuel will be displaced. In the near- and long-term future, we shall need to draw on *all* of our available fuel resources. While nuclear energy will be used increasingly for generation of electricity, we agree with others that there will also be a greatly increasing demand for coal, at least to the end of the century.

We have vital energy resources in Illinois. It is hoped that we can use them wisely and well.

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