CHAPTER 4

Federal Coal Resources

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Coal quality, geologic conditions, mining methods, and end uses of Federal coal are important factors that affect the development of individual Federal coal leases, and also the general development of coal resources in the Western United States. The following topics are discussed in this chapter:

- geographic location of Federal surface and underground coal reserves under lease and preference right lease applications (PRLAs) in the major Western coal regions;
- trends in Federal surface and underground coal production in the different regions;
- uses and market areas of coal from the major Federal coal States;
- quality of coal in the Western coal regions, and characteristics of major leased coal reserves and coalfields; and
- geologic conditions and mining methods in the major coal regions that are important in the development of Federal coal reserves.

Location of Leased Federal Coal Reserves

Leased Federal coal reserves are located in 14 States and in 5 of the 6 major coal regions of the United States (fig. 16). However, most Federal coal is located in two coal regions in the Northern Great Plains coal province and seven coal regions in the Rocky Mountain coal province (see fig. 17). * Federal leases in these two provinces include over 98 percent of the approximately 16.5 billion tons of recoverable coal presently under lease.

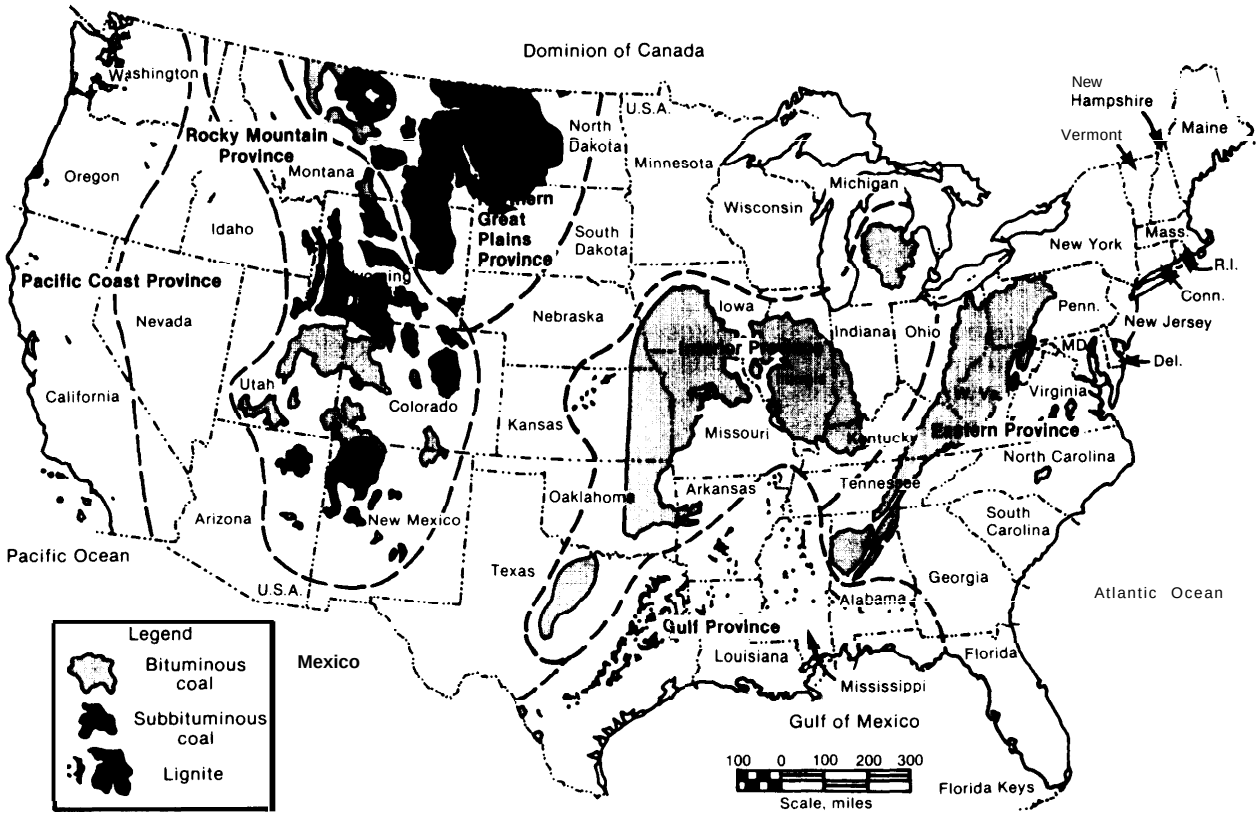
Three-quarters of the leased Federal coal reserves outside of the Northern Great Plains and Rocky Mountain coal provinces are contained in 46 leases in Oklahoma, which is geologically part of the Interior coal province. The remaining reserves (0.4 percent of the total under lease) are found in 17 leases in the States of Alaska, Alabama, California, Kentucky, Oregon, Pennsylvania, and Washington. Leases in these seven States were not analyzed by OTA. Leases in Oklahoma were evaluated by OTA and some data on this State is included in this chapter, but Oklahoma is discussed in less detail than the major Federal coal States of Colorado, Montana, New Mexico, North Dakota, Utah, and Wyoming.

The United States has several hundred billion tons of recoverable coal reserves, which are approximately evenly distributed between the Eastern and Western halves of the country.* These reserves are very large com-

*A number of different terms are used to describe areas in which coal deposits are located. Coal provinces cover a large geographic area where coal deposits have a relatively similar geologic and physiographic setting. The continental United States has six major coal provinces (see fig. 16). Coal provinces are usually divided into geologically distinct coal regions (or basins, where the geologic structure of the region is in the form of a basin) which also cover relatively large areas (generally hundreds of thousands to millions of acres) of coal-bearing rocks. Coal regions may be further divided into coal fields which generally cover areas of thousands or tens of thousands of acres, and identify specific deposits of minable coal, or a number of coal deposits with a similar geologic setting. Fig. 17 also shows the location and names of the major coal regions and fields in which Federal coal is leased.

*Various terms are used to describe quantity of coal. In-place resources (also called the resource or reserve base) include all coal deposits, regardless of depth, thickness, or economic recoverability. Minable resources represent the portion of the in-place resource that can be mined under present technology and economic conditions. Recoverable reserves refer to the amount of coal that can actually be recovered; this is always less than minable resources because some coal is lost during mining, and in some cases, some coal may be unavailable because of environmental and regulatory factors. Use of the term reserves in this chapter is synonymous with recoverable reserves. The demonstrated reserve base in the United States is estimated to be 475 billion tons (Demonstrated Reserve Base of Coal in the U.S. on Jan. 1, 1979, EIA, May 1981). An earlier OTA report has estimated recoverable reserves in the United States to total 283 billion tons (The Direct Use of *Coal* p. 63, OTA-E-86, April 1979). Experts differ in specific estimates of total recoverable reserves in the United States, but generally agree that it is on the order of several hundreds of billion tons or more.

Figure 16.—Generalized Coal Provinces of the United States



SOURCE U S. Bureau of Mines, adapted from USGS Coal Map of the United States, 1960

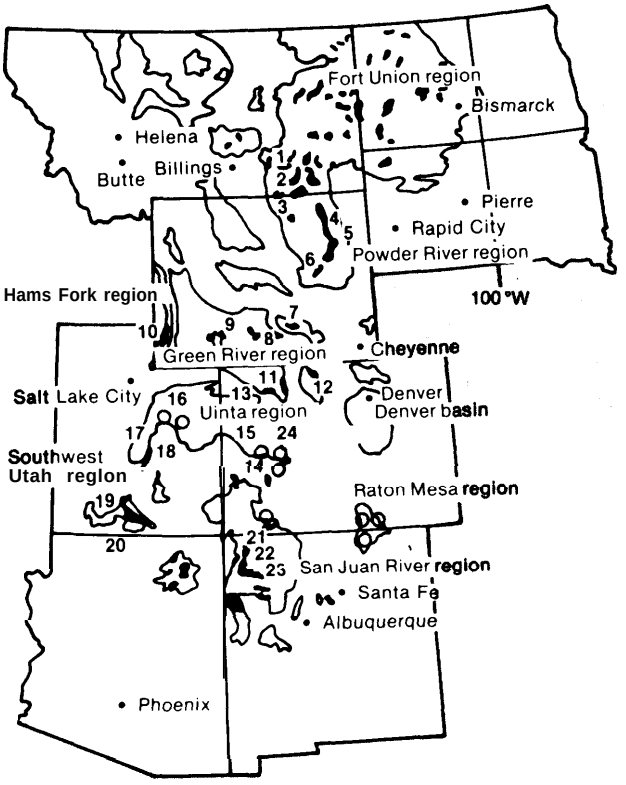
pared with the 820 million tons of coal produced in the United States in 1980. Slightly more than half of the recoverable reserves in terms of tonnage and slightly less than half in terms of heat content are found in the West. *

Federal coal leases are located primarily in six coal production regions in the West: Fort Union, Powder River, Green River-Hams Fork, Uinta-Southwest Utah, Denver-Raton Mesa, and San Juan River (see fig. 18). These coal production regions have been delineated along administrative boundaries of the Bureau of Land Management (BLM) for the purpose of implementing the new Federal coal management program and do not exactly coincide with geologic coal region boundaries. For example, the Danforth Hills coal field, which is geologically part of the Uinta coal region, is located within the Green River-Hams Fork production region. Also, some areas of the Uinta-Southwest Utah coal production region are geologically part of the San Juan River coal region. Unless coal production regions are specifically referred to (as in table 19), discussion in this chapter refers to geologic coal regions. *

*Coals in the West have generally a lower heat content than coals in the East (i.e., more coal must be burned to provide the same amount of energy). About 60 billion tons of underground subbituminous coal in the Powder River Basin of Wyoming and Montana cannot be economically mined now. (F. X. Murray (cd.), Where We *Agree:* Report of the National Coal Policy Project V.2 (Boulder, Colo.: Westview Press, 1978).) If this coal is subtracted from the reserve totals, the West's share of recoverable reserves according to heat content drops to approximately 40 percent of total U.S. reserves (National Research Council, Surface Mining: Soil, Coed and Society, Washington, D. C.: National Academy Press, 1981).

*There are a few Federal leases that are located in coal regions that are not included in the Federal coal production regions. These include two small leases in the Bighorn basin in

Figure 17.—Sketch Map Showing Major Coal Regions With Leased Federal Coal, and Generalized Location of Strippable and Metallurgical Coal Deposits



~ Area of coal reserves - Generalized location of strippable reserves O Major areas of metallurgical coal

Numbers show locations of major coal fields with leased Federal coal:

1. Colstrip
2. Decker
3. Buffalo
4. Powder River
5. Gillette
6. Glenrook
7. Hanna
8. Little Snake River
9. Rook Springs
10. Kemmerer
11. Yampa
12. North Park
13. Danforth Hils
14. Somerset
15. Book Cliffs (CO)
16. Book Cliffs (UT)
17. Wasatch Plateau
18. Emery
19. Alton
20. Kapalrowits Plateau
21. Fruitland
22. Bisti
23. Star Lake
24. Carbondale Coal Basin

SOURCE Base Map National Academy of Sciences, *Rehabilitation Potential of Western Coal Lands* (Cambridge, Mass Ballinger Press, 1974)

Continued from p. 60.

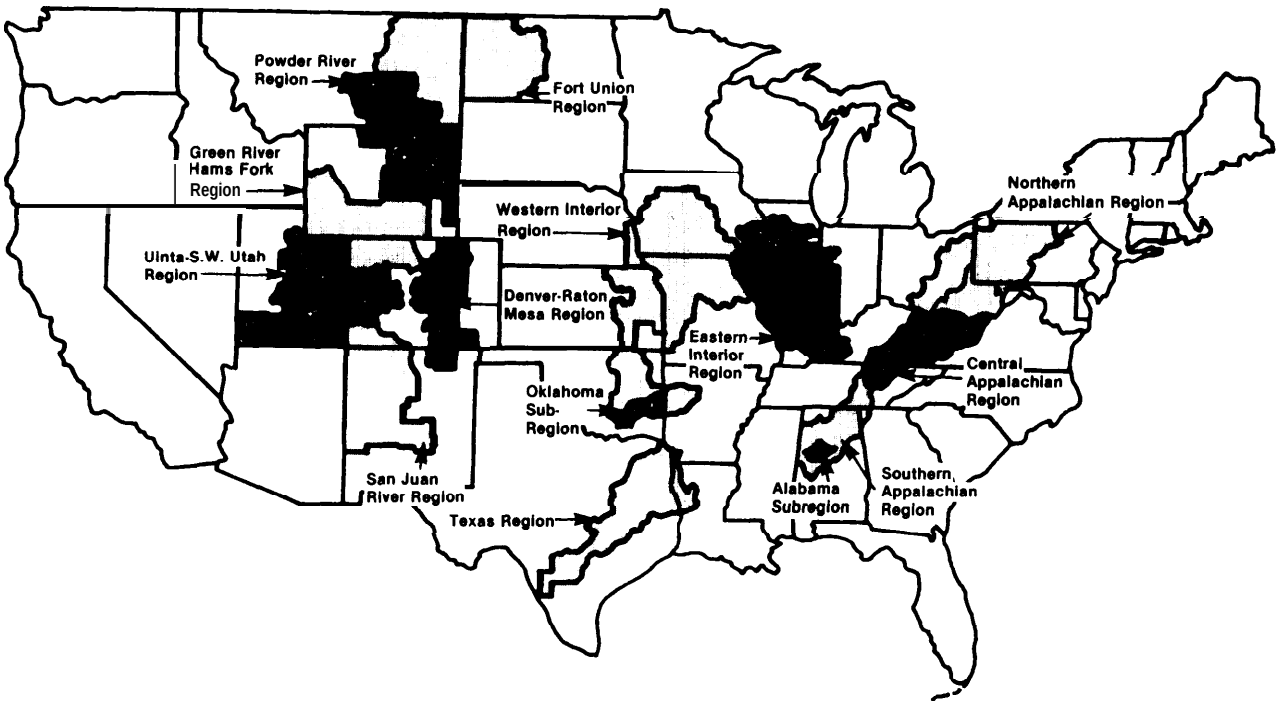
north-central Wyoming and one small lease in the Yellowstone region in southwestern Montana. Very small reserves are involved with these leases so these regions are not discussed in this chapter.

Coal reserves under Federal lease and PRLAs are unevenly distributed among the seven major Federal coal States (see table 20). Wyoming alone contains more than half (56 percent) of the reserves under lease, and Utah, the State with the next largest leased reserves has 20 percent of the total. Wyoming and Utah together contain more than three-quarters of the reserves under Federal lease. Wyoming also has the largest percentage of reserves under PRLA (43 percent), followed by New Mexico (26 percent) and Colorado (18 percent). These three States account for nearly 90 percent of the reserves under PRLA. Most Federal leased reserves are surface minable (1 1.3 billion tons, or 69 percent) as are most of the reserves under PRLA (3.6 billion tons, or 63 percent). The majority of leased reserves in Montana, New Mexico, North Dakota, and Wyoming are surface minable; most of the leased reserves in Colorado, Utah, and Oklahoma will have to be mined by underground methods.

Table 19 shows the distribution of Federal coal reserves under lease and PRLA by coal production region. The Powder River region in Montana and Wyoming, contains 59 percent of the leased reserves and the Uinta-Southwest Utah production region in Utah and Colorado contains 25 percent of the leased Federal reserves. The two regions combined contain 84 percent of the coal under lease.

The large amount of leased Federal coal reserves in the Powder River basin reflects the region's large reserves in thick flat-lying coal seams that can be easily surface mined and the high percentage of Federal coal ownership in the area. The thick seams in the Powder River basin can be mined at a substantially lower cost than other U.S. coal deposits. Federal coal leases are concentrated in the Uinta-Southwest Utah region because of its diversity of high-quality coals including metallurgical coal. The region is one of the oldest active mining areas in the West. The majority of reserves under lease in the Uinta-Southwest Utah region must be mined underground. The Green River-Hams Fork

Figure 18.–Coal Production Regions in the United States: Nov. 9,1979



Note: The boldface print indicates regions or subregions that have been officially designated as Federal Coal Productlon Regions.

SOURCE: U.S. Department of the Interior, *Federal Coal Management Report, Fiseal Year* 1979 (Washington, D.C.: U.S. Government Printing Office, 1980).

region of northwestern Colorado and southwestern Wyoming has a fairly even division between surface and underground minable reserves.

Of the total Federal reserves covered by PRLAs, 45 percent are located in the Powder River basin. The 2.4 billion tons of PRLA reserves in the Powder River basin include some 760 million tons that are recoverable only by underground or in situ methods. Consequently these underground reserves are unlikely to be developed commercially within the next 10 years. [1] If these underground PRLA reserves are excluded from the total reserves under PRLA, the Powder River basin still contains 35 percent of the total. The San Juan River region with 28 percent (32 percent if Powder River underground reserves are subtracted) and Denver-Raton Mesa region with 14 percent (or 16 percent) also have substantial amounts of reserves under PRLA.

[1] J. R. Boulding and D. Pederson Development and Production Potential of Undeveloped Federal Coal Leases and Preference Right Lease Applications in the Powder River Basin and Other Wyoming Coal Basins, final report (Washington, D. C.: Office of Technology Assessment, **1981).** PRLAs must have commercial quantities of coal to qualify for a lease. It is possible that in situ gasification may allow development of underground coal in the Powder River basin, but this technology is still experimental in nature, and is likely to be so until after 1984, which is the deadline for processing all PRLAs, Consequently, it is possible that areas under PRLA that include only underground reserves may not have leases granted.

Table 19.—Distribution of Recoverable Coal Reserves Under Federal Lease and Preference Right Lease Application by Major Coal Production Region

Coal production region	State	Number of leases[a]	Recoverable reserves (billions of tons)[b] Under lease			Preference right lease applications			FY79 Federal coal production (millions of tons)[f]	
			Surface	Underground	Total	Surface	Underground	Total	Surface	Underground
Fort Union	ND	17	0.25	0		0	0	0		
	MT	3	0.28	0		[e]	[e]	[e]	0.7	0
		20	0.53 (100%)*	0	0.53 (3%)**				(100%)	
Powder River	MT	15	0.83	0						
	WY	54	8.3	0.32		1.6	0.76	2.4	31.8	0
		69	9.1 (97%)	0.32 (3%)*	9.5 (59%)	(68%)*	(32%)*	(45%)**	(100%)*	
Green River-Hams Fork	WY	32	0.43	0.17						
	CO	56	0.46	0.57		0.08	0.22	0.30	11.6	0.7
		88	0.89 (55%)	0.74 (45%)	1.6 (10%)	(28%)	(72%)	(6%)	(94%)	(6%)
Uinta-Southwest Utah	UT	201	0.27	3.0						
	CO	61	0.01	0.78		0.09	0.38	0.48	0	9.0
		262	0.28 (7%)	3.8 (93%)	4.1 (25%)	(20%)	(80%)	(9%)		(100%)
Denver-Raton Mesa	CO	5	0.05	0.02						
	NM	4	– [c]	– [c]		0.68	0.06	0.74	0	0
		9	0.05 (71%)	0.02 (29%)	0.07 (<1%)	(91%)	(9%)	(14%)		
San Juan River	NM	25	0.27	0.06						
	CO	1	– [d]	– [d]		0.83	0.67	1.5	4.7	0.1
		26	0.27 (82%)	0.06 (18%)	0.33 (2%)	(55%)	(45%)	(28%)	(98%)	(2%)
Total		474	11.2 (70%)	4.9 (30%)	16.1	3.3 (61%)	2.1 (39%)	5.4 (100%)	48.8 (83%)	9.8 (17%)

*Numbers in parentheses represent percent of total reserves or production in the region.
**Numbers in parentheses represent percent of total reserves in all regions combined.
[a]AS OF SEPT 30, 1979, TOTALS DIFFER FROM TABLE 20 BECAUSE A FEW LEASES IN MONTANA AND WYOMING ARE LOCATED OUTSIDE OF THE PRODUCTION REGION BOUNDARIES AND BECAUSE A NUMBER OF LEASES WERE LET BETWEEN MID-1979 AND SEPTEMBER 1980.
[b]SOURCE. Automated Coal Lease Data System, Sept, 30, 1979, pages A-8 and A-14, U.S. Department of the Interior, Federal Coal Managemenf Report, Fiscal Year 1979 (Washington, D.C.: U.S. Government Printing Office, 1980). TOTALS FOR REGIONS ARE SLIGHTLY LESS THAN STATE TOTALS IN TABLE 20 BECAUSE A FEW LEASES IN MONTANA AND WYOMING ARE LOCATED OUTSIDE OF THE PRODUCTION REGION BOUNDARIES.
[c]Small reserves in New Mexico included in Colorado total to protect confidentiality of information.
[d]Small reserves in Colorado Included in New Mexico total to protect confidentiality of information.
[e]Small reserves in Montana not listed to protect confidentiality of information
[f]For fiscal year 1979, from page A-11 in USDI report cited in footnote b. Total is slightly less than in table 16 in ch. 3 because data is for fiscal year rather than calendar year.

Federal Coal Production

In 1979, 60,1 million tons of Federal coal were mined (and in 1980, 69 million tons), of which nearly 99.5 percent was produced in the six major Federal coal States of Colorado, Montana, North Dakota, New Mexico, Utah, and Wyoming. Figure 19 shows the trends in Federal coal production and total coal production from 1957 to 1979 in these six States.

Table 20.—Distribution of Recoverable Coal Reserves Under Federal Lease and Preference Right Lease Application by State

State	Number of leases[a]	Number of PRLA's[e]	Recoverable reserves under lease[b] (billions of tons)			Recoverable reserves under preference right lease application[b] (billions of tons)		
			Surface	Underground	Total	Surface	Underground	Total
Colorado	127	37	0.55 (28%)*	1.4 (71%)*	2.0 (12%)**	0.74 (71%)*	0.30 (29%)*	1.0 (18%)**
Montana	21	4	1.1 (100%)	0	1.1 (7%)	—[c]	—[c]	—[c]
New Mexico	29	28	0.27 *(82%)*	0.06 *(18%)*	0.33 (2%)	0.83 (55%)	0.67 (45%)	1.5 (26%)
North Dakota	20	0	0.25 (100%)	0	0.25 (2%)	0	0	0
Oklahoma	46	4	0.01 (6%)	0.19 (94%)	0.2 (1%)	[c]	—[c]	—[c]
Utah	204	25	0.27 (8%)	3.0 (92%)	3.3 (20%)	0.09 (26%)	0,27 (74%)	0.36 (6%)
Wyoming	101	74	8.8 (95%)	0.49 (5%)	9.3 (56%)	1.6 (66%)	0.8 (34%)	2.5 (43%)
Total	548	172	11.3 (69%)	5.1 (31%)	16.5 (100%)	3.6[d] (63%)	2.1[d] (36%)	5.7[d,e] (100%)

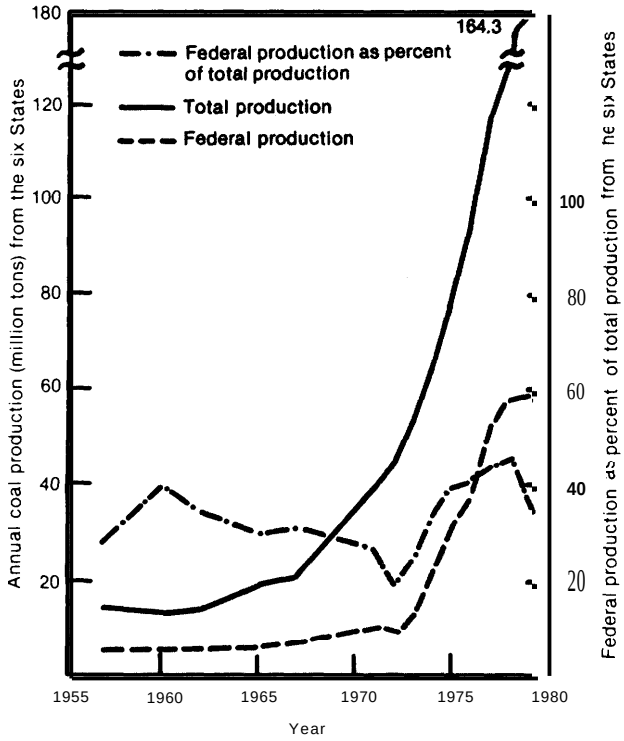
● Numbers in parentheses represent percent of total leased reserves in the State.
●● Numbers in parentheses represent percent of total reserves in all States.
[a]Includes all leases outstanding as of September 30, 1980, Seventeen leases with small reserves in Alaska, Alabama, California, Kentucky, Oregon, Pennsylvania, and Washington are not included in this table.
[b]SOURCE: Automated Coal Lease Data System, Sept. 30, 1979, pages A-7 and A-12, U.S. Department of the Interior, Federal Coal Management Report, Fiscal Year 1979 (Washington D.C.: U.S. Government Printing Office, 1960). NOTE THAT TOTALS HERE DIFFER SLIGHTLY FROM RESERVE FIGURES DISCUSSED IN CH. 3 AND CH. 6. FOR THE PURPOSE OF DISCUSSION IN THIS CHAPTER. THESE DIFFERENCES ARE NOT SIGNIFICANT.
[c]Reserves not shown due to confidentiality requirements.
[d]Includes 315.2 million tons of surface and 15.8 million tong of underground reserves in **eight PRLAs in Montana and Oklahoma.**
[e]**There are also four PRLAs** in Alaska with 0.1 billion tons of recoverable reserves. See table 10. Extent *and Location of PRLAs* in ch. 3.

Between 1957 and 1967 total production from these States ranged between 3.2 and 3.8 percent of total U.S. production, but production increased dramatically during the 1970's to 21 percent in 1979 and 24 percent in 1980. Federal coal production from these States during this same period ranged between 0.9 and 1.3 percent of total U.S. production and increased to about 8 percent in 1979 and 1980.

Figure 19 also shows the changes in percentage contribution of Federal coal to total coal production for these six States. Between 1960 and and 1972 the share of Federal coal production in the six States declined from about 40 percent to 20 percent. Since 1973 the percentage of Federal coal production has shown a general increase, although in 1979, even though total Federal production was more than eight times higher than in 1970, its percentage share of all production (36 percent) was less than in 1960. During the next decade, Federal coal production will probably increase at a higher rate than non-Federal coal production because of the large increases from the Powder River region, where most coal reserves are owned by the Federal Government.

The current trend in production of Western Federal coal is toward large surface or underground mines producing more than 1 million tons per year. In Utah and Colorado where underground mines are common, small- and medium-sized mines ranging from 200,000 to 1 million tons per year in capacity still represent a significant and vital share of active and planned mines. Several mines on Federal leases in the Powder River basin have planned capacities exceeding 20 million tons per year. Annual production from one of these mines will exceed the individual 1979 total production from Colorado, New Mexico,

Figure 19.—Annual Coal Production From the Six Major Federal Coal-Producing States in the West, 1957-79[a]



[a]The six States are Colorado, Montana, New Mexico, North Dakota, Utah, and Wyoming

SOURCE Data for 1957.77 from table 2-7, U.S. Department of Interior, *Final Environmental States Federal Coal Management Program* (Washington, D C U S Government Printing Office, 1979) 1978 data from table A-2, U S Department of In tenor *Federal Coal Management Report* Fiscal Year *1979* (Washington, D C U S. Government Printing Off Ice, 1980) 1979 data from table 16 ch. 3 of this report

North Dakota, or Utah (18.1 million, 15.1 million, 15.0 million and 11.8 million tons, respectively).

The trend toward large mines contrasts sharply with coal production from the period 1920 to 1960. Most of the leases issued during this period were to individuals or small mining companies that produced relatively small amounts of coal for domestic or local industrial consumption. For example, about half (65 out of 138) of the leases issued before 1960 produced coal at one time, but are no longer producing coal. Most of the production from these leases was from small underground mines, and sum total cumulative production from 59 of these leases was less than a million tons.[2] This is less than the annual production of typical new mines on Federal leases.

The last two columns in table 19 show the breakdown between Federal surface and underground coal producton from the different coal regions. Surface mines accounted for 48.8 million tons, or 83 percent of Federal production in 1979. Since only 70 percent of reserves under lease, and 61 percent of reserves under PRLA* are surface minable, present production is concentrated more heavily on leases with surface reserves than underground reserves. Many leases with large surface reserves in the Powder River basin were not producing coal in 1979, so the emphasis on development of surface reserves will probably continue over the next 10 years or so. However, full development of existing reserves will have to rely increasingly on more costly underground mining methods.

[2]Data from Automated Coal Lease Data System, Summary of Federal Leases—Oct. 1, 1979 prepared by the Bureau of Land Management for OTA, including cumulative production from each lease, and production in fiscal year 1979. Of the other leases issued between 1920 and 1960, 38 (27 percent of total) produced coal in 1979, and 35 (25 percent of total) never produced coal.

*Table 19 shows that only 61 percent of the reserves under PRLA are surface minable, but if the subbituminous underground reserves in the Powder River basin are subtracted. as discussed earlier, the percentage changes to 71 percent.

Coal Ownership Patterns

Production from Federal coal leases must also be understood in the context of the coal ownership patterns that exist in the West. From the time of the early settlement of the West until the late 19th century, Federal coal passed into non-Federal ownership under a variety of laws and procedures. Under the homestead laws passed in the early 1900's, the Federal Government retained ownership of the coal and other mineral rights in lands

patented to settlers. Passage of the Mineral Leasing Act of 1920 ended the era of disposal of Federal coal lands and established a leasing system for coal and other fuel and fertilizer minerals on Federal lands. The pattern of coal ownership in the West has been generally stable since then. * The major categories of non-Federal coal ownership are: Indian, railroad, State, and private (often called fee coal because the owner holds fee simple title to the coal).

Sixty percent is a figure that is commonly cited as the amount of coal resources controlled by the Federal Government in the West. This figure originates from estimates made by State BLM offices of Federal coal ownership in coal-bearing lands (i.e., geologic formations known to contain coal deposits) in the major Federal coal States (see table 21) and probably does not accurately reflect the percentage of Federal ownership of recoverable coal reserves. This is because: 1) coal deposits are not evenly distributed throughout areas of coal-bearing rocks, and 2) the percentage of Federal coal landownership varies between coal regions.

A closer approximation (but still not entirely accurate, as discussed later) of Federal ownership of coal resources can be obtained by looking at the percentage of Federal coal land ownership in known recoverable coal resource areas (KRCRAs). A KRCRA is an administrative and technical classification established by the U.S. Geological Survey to designate areas where the location and amount of minable coal deposits have been reasonably well-defined by geologic mapping and coal exploration. KRCRAs must be formally designated by publication in the Federal Register. Minable coal reserves are found outside KRCRAs, but generally there is less information available about the extent of the reserves and little or no commercial coal mining in these areas. Table 21 shows that the six major Federal coal States contain 116.7 million acres of coal-bearing lands, but that only 17.5 million acres (15 percent) had been included in KRCRAs as of March 1978.

Table 21 also shows that the percentage of Federal coal acreage varies considerably between States and coal regions. The percentage of Federal coal ownership in KRCRAs range from a low of 32 percent in North Dakota to a high of 90 percent in the Colorado portion of the Uinta region. Other KRCRAs with a high percentage of Federal coal ownership are the Wyoming portion of the Powder River basin (82 percent), the New Mexico portion of the San Juan region (82 percent) and Utah (85 percent).

Overall, the percentage of Federal coal ownership in KRCRAs in the six major Federal coal States is higher than the percentage of Federal ownership in coal-bearing areas (65 percent v. 52 percent). Furthermore, the DOI estimates that the Federal Government owns about 72 percent of the recoverable coal reserves in KRCRAs because of the high percentage of Federal coal ownership in the Powder River basin where coal seams are exceptionally thick. [3] However, Federal ownership of total recoverable coal reserves in the West is probably lower than this percentage for several reasons: 1) a number of Indian tribes control substantial amounts of coal reserves that are not included in KRCRAs* and 2) identification of KRCRAs has tended to focus on areas of high Federal coal ownership and active coal exploration or leasing interest. Identification of new KRCRAs may tend to be located in areas where the percentage of Federal coal ownership is lower (such as the Raton Mesa region). When all

*Further changes in coal ownership patterns are possible through exchanges of Federal and non-Federal coal, but the amounts of coal involved are relatively small compared to total leased reserves and the overall relationships among categories of coal ownership are likely to remain much the same. Exchanges are discussed in more detail in ch. 9.

[3] U.S. Department of Interior, Final Environmental Statement Federal Coal Management Program (Washington, D. C.: U.S. Government Printing Office, 1979), p. 2-5.

*Twenty Indian reservations in the West contain coal-bearing rocks and Indians control an estimated 15 percent of the strippable coal reserves in the United States (Council of Energy Resource Tribes, The Control and Reclamation of Surface Mining on Indian Lands, Washington, D.C.: CERT, Sept. 30, 1979). Indian reservations with significant amounts of minable coal reserves are: Craw and Northern Cheyenne in southeastern Montana, Fort Berthold in North Dakota, and the Hopi and Navajo in Arizona and New Mexico.

Table 21.—Federal Coal Ownership in Coal Regions and Known Recoverable Coal Resource Areas in the Six Major Federal Coal States

State/coal production region	Federal coal acreage[a] (million acres)	Total coal acreage (million acres)	Known recoverable coal resource areas[d] Federal coal (million acres)	Known recoverable coal resource areas[d] Total coal (million acres)
North Dakota	5.6(25)[b]	22.4	0.8(32)[e]	2.5(11)[f]
Montana/Fort Union			0.5(44)	1.2
Powder River			1.7(75)	2.3
Total	24.6(75)	32.8	2.2(64)	3.5(11)
Wyoming/Powder River			3.3(82)	4.0
Green River-Hams Fork			1.2(55)	2.2
Total	11.8(39)	30.5	4.5(73)	6.2(19)
Colorado/Green River-				
Hams Fork			0.3(68)	0.5
Uinta			0.5(90)	0.6
San Juan			0.2(59)	0.3
Denver-Raton Mesa[g]			0.1(20)	0.5
Total	8.7(53)	16.6	1.1(58)	1.9(11)
Utah/Uinta-Southwest Utah	4.1(82)	5.0	0.9(85)	1.1(22)
New Mexico/San Juan			1.8(82)	2,3
Raton Mesa[g]			0	0
Total	5.5(59)	9.4	1.8(82)	2,3(24)
Total (6 States)	**60.3(52)**	**116.7**	**11.3(65)**	**17.5(15)**
Total all States	**92.1 (61)**[c]	**150.2**	—	—

[a]*From table* 1-31 *U.S.* Department of the Interior, *Final Environmental Impact Statement, Proposed Federal coal Leasing program* (Washington, DC.: U.S. Government Printing Office, 1975). Figures are based on BLM State Office estimates.
[b]Numbers in parentheses indicate percent of total coal acreage in the State.
[c]This total includes 23.4 million acres (97 percent of total Coal acreage) of Federal coal in Alaska and 0.4 million *acres (4* percent of total coal acreage of Federal coal in Oklahoma).
[d]K_{nown} Recoverable coal Resource Areas defined as of March 1978, A few of these KRCRAs include small amounts Of Indian coal, but Indian coal within reservation boundaries (which include the majority of Indian coal reserves) is not included in KRCRAs.
[e]From table 2-5, U.S. Department of the Interior, Final Environmental Statement Federal Coal Management Program (Washington, D. C.: U.S. Government Printing Office, 1979), Totals may not add because of rounding. Numbers in parentheses Indicate percent of total KRCRA acreage in the State or region. Percentages may not match numbers in table because of rounding.
[f]Numbers in parentheses indicate percentage of total coal acreage in the State or region (the second column in table).
[g]Raton Mesa region did not include any areas designated as a KRCRA as of March 1978,

SOURCE: Office of Technology Assessment.

these factors are taken into consideration, Federal ownership of total recoverable reserves in the six major Federal coal States is probably somewhere between 50 percent and 60 percent.

Overall, the landownership patterns in the West are probably no more complex than those found in the East and Midwest, however, because Federal, State, and Indian lands generally cannot be sold, a coal operator cannot gain ownership or control of a potential mine area through purchase of the title to surface and mineral rights as he might in other regions. Consequently, a single mining unit in Western States will often include coal reserves of several different ownership categories to allow maximum recovery of the reserves and Federal and non-Federal coal reserves are frequently mined as part of the same operation. * For example in Campbell County, Wyoming, which has a high percentage of Federal coal, 16 out of 20 lease units involving Federal leases have non-Federal coal associated with them, Federal coal is in-

*Mining of coal held by a single owner is often possible and has been done in areas of mixed ownership, but in some cases recovery rates are reduced because mining operations cannot be designed for maximum efficiency.

terspersed with alternate sections (a section is a square mile and covers 640 acres) of railroad coal over hundreds of thousands of acres in the Fort Union region, the Montana portion of the Powder River region and the Wyoming portion of the Green River-Hams Fork region. This situation also exists in limited areas of the San Juan Basin in New Mexico. Mining in these areas usually involves both Federal and non-Federal coal. In parts of North Dakota, on the other hand, current development of lignite reserves is concentrated in areas where relatively small amounts of Federal coal are interspersed with State and private coal. The Crow and Northern Cheyenne tribes in southeastern Montana own large blocks of surface minable coal (estimated to exceed 5 billion tons) most of which can be mined without involving Federal, State, or private coal. About one-third of the 168 million tons of potential production capacity from the Montana Powder River basin involves only Indian coal.[4] All the major coal deposits in Arizona are located on the Navaho and Hopi Reservations, and all coal production in the State comes from those lands. The Navaho tribe also has important coal reserves in New Mexico. Current production of coal in New Mexico comes from Indian, Federal, State, and private land. Only one currently operating mine involves mixed ownership of Indian, Federal, and private coal.

[4]See table 65 of this report. See also tables 6.8, vol. 1 and A.4.3, vol. 2 of J. R. Boulding and D. Pederson, Development and Production Potential of Undeveloped Federal Coal Leases and Preference Right Lease Applications in the Powder River Basin and Other Wyoming Coal Basins, Final Report (Washington, D. C.: Office of Technology Assessment, 1981). Note that the 168 million tons per year production capacity cited here is higher than planned capacity for 1990; the 168 million tons figure is potential capacity in the post-1990 period. It does not depend on new leasing of Federal coal, but does depend on a number of factors including, for example, the building of the proposed Tongue River Railroad.

Coal Use and Market Areas

Table 22 summarizes current uses and market areas for coal produced in States with significant amounts of leased Federal coal. Possible new markets for Federal coal are discussed in chapter 5. By far the largest end use of coal for all States is steam electric generation. In Wyoming, North Dakota, and New Mexico, over 90 percent of all the coal mined is used by electric utilities. There is considerable flexibility in the quality of coal that can be used for new powerplants because a boiler can be designed to accommodate almost any coal. Existing powerplants have less flexibility because use of coal with heat content and sulfur and ash content significantly different from coal for which the boiler was designed often reduces its efficiency.

In contrast to the electric utility industry, the steel industry has much stricter specifications for its coal. Coke, which is made from metallurgical-grade coal, is used in the production of steel from iron ore. Metallurgical-grade coal generally requires a low sulfur and ash content and medium to low content of volatile matter, as well as other specific physical characteristics. Although low-sulfur and low-ash coal is found throughout the West, relatively few coal deposits have the other characteristics necessary for the production of coke. Colorado, Utah, New Mexico, and Oklahoma are the only Western States with significant commercial deposits of metallurgical-grade coal. Major deposits of high-grade metallurgical coals are found in portions of the Uinta region in Colorado and Utah and in the Raton Mesa region of Colorado and New Mexico. Smaller occurrences of metallurgical coal have been found in other areas of New Mexico and Montana (see fig. 17).

Other major industrial uses of coal in the West include cement and lime processing, sugar processing, other metals processing, and, in Wyoming, processing of the mineral

Table 22.—Uses and Market Areas of Coal From States With Significant Amounts of Leased Federal Coal

State	Utility	Percent use in 1979[a] Industrial/ commercial	Residential	In-State	out-of-State	Non-utility uses[b]	Out-of-State market area[c] Utility	Industrial
Colorado	**71.5**	**26.6**	1.9	55	*45*	CoKe for steel, cememt, sugar processing, metals processing, railroad.	**MW (IL, IN, 1A, MÚ,** NB), SC (TX, MS), W (AZ, NM, NV),	MW (IN, 1A, MI, MN, NB, TN, SD), SC (OK, TX)(W (CA, MT, NM, NV, OR, UT, WA)
Montana	96.0	4.0		11	*89*	Cement, sugar processing.	**MW (IL, IN, 1A, MI, MN, WI), SC (TX).**	MW (IL, 1A, MN, WI).
New Mexico. . .	94.0	6.0		6 0[d]	*40*	Cement, metals processing (copper), drilling mud, coke for steel (Raton Mesa),	**MW (MO), SC (TX).**	W (AZ, CA, TX)
North Dakota.	*93.4*	*6 6*		*75*	*25*	Sugar processing, leonardite, charcoal briquets.	MW (SD, MN)	MW (MN)
Oklahoma	*79.0*	*21.0*		*16*	*84*	Lime and cement (16% total) coke for steel (3% total)	MW. SC	MW, SC
Utah .	*73.3*	*24.9*	1.8	*47*	*53*	Coke for steel (about half non-utility use), cement, metals processing.	MW (IN, IL, MO, NB), SC (MS), W (NV, WA).	NW (IL, 1A), W (AZ, CA, CO, ID, MT, NV, OR, WA, WY).
Wyoming .	96.3	3.7		22	*78*	Trona processing, synthetic coke, cement, sugar processing.	MW (IL, IN, 1A, KS, MO, NB, OH, SD, WI), SC (AK, LA, OK, TX), W (CO).	MW (IL, 1A, MN, NB, SD,) SC (OK), W (CO, ID, MT, OR, UT, WA).

[a]percentage breakdown in use categories taken from Office of Technology Assessment State assessment and market survey reports. In-State/out-of-State Percentages calculated from U.S. Department of Energy, *Bituminous and Subbituminous Coal and Lignite Distribution, Calendar* Year *7979* (Washington, D.C.: U.S. Government Printing Office, April 1980).
[b]Non-utility uses compiled from Office of Technology Assessment State assessment and market survey **reports,** information from the Utah and Wyoming Geological Surveys and *Keystone Coal Industry Manual.*
[c]Conpiled **from DOE report cited** In **footnote a.**
[d]**Half of coal used in-State is used to generate electricity (about 30 percent of total coal production) that IS** exported **Out-Of .State**

SOURCE: Office of Technology Assessment.

trona. * Like utilities, most industrial users (other than steel manufacturing) use coal for heat rather than its physical and chemical properties. However, industrial users generally do not require large amounts of coal compared to utilities, so economies in transportation costs through the use of unit-trains cannot be realized. Because of this, high heat content is a premium for industrial and commercial users, and it is the coal regions that produce coal with the highest heat content (Green River-Hams Fork, Uinta and Oklahoma) that have the widest market areas for industrial uses of coal.**

All of the States that produce Federal coal have either a nearly even division between coal that is used in-State and out-of-State (Colorado and Utah) or export most of the coal that is produced in the State, either as coal (Montana, Oklahoma, and Wyoming] or as coal and electricity generated at mine-mouth plants (New Mexico and North Dakota). Table 22 also shows the current market areas for coal that is exported out-of-State. Wyoming has by far the largest market area of any Western State, with 1979 coal production for utility use going to 14 States and nonutility use to 13 States. In contrast, North Dakota has the most limited market area, because of the low heat content of the coal. Colorado and Utah are the Western States that produce significant amounts of coal for industrial uses (26.6 and 24.9 percent respectively) and the importance of this market is shown by the fact that coal from Colorado and Utah was shipped to more States for industrial uses than for utility uses (16 v. 10 States for Colorado, and 11 v. 7 States for Utah). Chapter 5 discusses the reasons for the differences in market areas between the States in more detail.

*Trona is a mineral that is refined to soda ash, which in turn is used in the production of glass, woodpulp and paper processing, and manufacture of other chemicals. Southwestern Wyoming contains the only known commercial deposits of trona in the world (Department of Economic Planning and Development 1975 Wyoming Mineral Yearbook, Cheyenne, Wyo.: DEPAD, 1976).

* *One notable exception to the premium on heat content is the mining of leonardite in North Dakota, Leonardite is a soft, earthy coal-like substance that results from the oxidation of lignite. It is a poor fuel (about 4,000 Btu/lb) but is useful as a soil conditioner, and for various industrial uses such as manufacture of oil well-drilling muds, water treatment and stains for wood-finishing.

Quality of Federal Coal Reserves

User needs related to coal quality have been discussed briefly in the previous section. Except for metallurgical-grade coal (where several additional physical and chemical characteristics are important), the primary parameters of coal quality that are of concern to coal users are: 1) heat content, 2) sulfur content, and 3) ash content.

Heat Content

The large majority of coal is used for its energy value, which is usually expressed as the number of British thermal units (Btu) per pound of coal. * Coals vary considerably in heat content, ranging from less than 5,000 Btu/lb for low rank lignites to more than 14,000 Btu/lb for bituminous and anthracite coals.* (See table 23.) This possible range in heat content of coal can make a substantial difference in the amount of coal that is used.

*A Btu is the quantity of heat required to raise the temperature of 1 lb of water 10 at, or near, its point of maximum density (39.1 °F).

*Coal deposits are classified into 13 different ranks based primarily on criteria involving heat content, volatile matter (coal constituents that are easily vaporized), and fixed carbon (what is left after all volatile constituents have been driven off when coal is heated in the absence of oxygen). Table 23 shows the standards for classification of coal by rank that have been established by the American Society for Testing and Materials (ASTM). Lignite and subbituminous coal are classified according to heat content calculated on a moist mineral-matter-free basis. Bituminous coals are classified based on both heat content and percent volatile matter in the coal. High-volatile bituminous coal (greater than 31 percent volatiles) are classified into three ranks based on heat content. Coal with less than 31 percent volatile matter are classified as low or medium-volatile coal irrespective of heat content, Anthracites have very low content of volatile matter (less than 8 percent), Heat contents reported in this chapter are on an as-received basis, which differ from the heat contents which would be used to rank the coal using ASTM procedures, because corrections have not been made to account for ash content (for lower rank coals) or ash and moisture content (for higher rank coals). The as-received heat content of a coal sample is lower than the heat content that is used to classify the sample according to rank.

Table 23.—Classification of Coals by Rank

Class	Group	Fixed carbon limits, in percent (dry, mineral-matter-free basis)		Volatile matter limits, in percent (dry, mineral-matter-free basis)		Calorific value limits, in Btu per pound (moist, mineral-matter-free basis)[a]		Agglomerating character
		Equal or greater than	Less than	Equal or greater than	Less than	Equal or greater than	Less than	
1. Anthracitic	1. Meta-anthracite	98			2			
	2. Anthracite	92	98	2	8			
	3. Semianthracite	86	92	8	14			Nonagglomerating.[b]
II. Bituminous	1. Low-volatile bituminous coal	78	86	14	22			
	2. Medium-volatile bituminous coal	69	78	22	31			
	3. High-volatile *A* bituminous coal	69		31		14,000[c]		Commonly, agglomerating.[d]
	4. High-volatile *B* bituminous coal					13,000[c]	14,000	
	5. High-volatile *C* bituminous coal					11,500	13,000	
						10,500	11,500	Agglomerating.
III. Subbituminous	1. Subbituminous *A* coal					10,500	11,500	Nonagglomerating.
	2. Subbituminous *B* coal					9,500	10,500	
	3. Subbituminous C coal					8,300	9,500	
IV. Lignitic	1. Lignite *A*					6,300	8,300	
	2. Lignite B,						6,300	

[a]Moist refers to coal containing its natural inherent moisture but not including visible water on the surface of the coal.
[b]If agglomerating, classify in low-volatile group of the bituminous class.
[c]Coals having 69 percent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of calorific value.
[d]It is recognized that there may be nonagglomerating varieties in these groups of the bituminous class, and there are notable exceptions in the high-volatile C bituminous group.

NOTE: This classification does not include a few coals, principally nonbanded varieties, which have unusual physical and chemical properties and which come within the limits of fixed carbon or calorific value of the high-volatile bituminous and subbituminous ranks. All these coals either contain less than 48 percent dry, mineral-matter-free fixed carbon, or have more than 15,500 British thermal units per pound, calculated on the moist, mineral-matter-free basis. Modified from American Society for Testing and Materials (1974).

SOURCE: P. Averitt *Coal Resources of the United* States, *January 1, 1974* U.S. Geological Survey Bulletin 1412 (Washington, D C.. U.S. Government Printing Off Ice 1975)

For example, a powerplant using lignite may burn more than twice as much coal as a powerplant using bituminous coal to produce the same amount of electricity. However, the most important concern of the user in relation to heat content is the cost per unit of energy in the coal (usually expressed as cents or dollars per million Btu) rather than the heat content itself. Thus, a low rank coal that has a lower delivered price per Btu in general compares favorably with a higher rank coal at a higher delivered price.

Sulfur and Ash Content

Sulfur content has become an important aspect of coal quality since passage of the Clean Air Act of 1970, which established limitations on sulfur dioxide emission from coal-fired powerplants. The effect of sulfur emission standards on the demand for Western coal is discussed in more detail in the following chapter on markets. Ash content may be a concern to users if its percentage reaches a level (generally greater than 15 percent) where ash begins to build up in boilers and reduce their efficiency. High ash content also increases the cost of ash disposal after the coal is burned. Boiler design must also take into account the physical and chemical properties of the sulfur and ash in the coal that is used. To some extent, sulfur and ash can be removed from coal before it is burned, however this process adds to the cost.

Variations in Coal Quality by Region

Coal ranks in the Northern Great Plains province fall within a fairly narrow range of lignite and subbituminous coals. In the Rocky Mountain coal province, on the other hand, the different coal regions have a considerable range of coal ranks. The Uinta-Southwest Utah region has the widest range of coal ranks, ranging from lignite to anthracite, although current production is entirely bituminous coal. The diversity of coal ranks in the Rocky Mountain province resulted from the fact that the processes promoting the formation of coal—heat and pressure—have operated with varying degrees of intensity over the geologic history of different deposits. The Northern Great Plains province, on the other hand, has had a relatively simple geologic history in which coal forming processes have generally not been very intense.

Table **24** summarizes some of the important coal quality characteristics of leased Federal coal and major coal fields with Federal leases. The location of these fields is shown in figure 17. The data shown for the Fort Union and Powder River regions shows the range of values for existing leases, whereas data for other coal regions is for the whole coal field, which is generally wider than the range for actual Federal leases in the field.

All coals in the Fort Union region are lignites, whereas Federal coal reserves under lease in the Powder River basin are primarily subbituminous coal. The leased coal in the Decker and Colstrip areas in Montana have higher heat contents than leased reserves in the Wyoming portion of the Powder River basin, but the Colstrip area also has higher sulfur contents. Leased reserves in the Wyoming portion of Green River-Hams Fork region are generally higher quality subbituminous coals [greater than 9,000 Btu/lb) and bituminous coals. Maximum sulfur content is higher than in the Powder River basin, but often coal from higher sulfur seams can be blended with low-sulfur coal to produce coal with acceptable levels of sulfur.

Major fields with leased Federal coal in Colorado and Utah contain mostly bituminous coals, except for the Alton field in southwest Utah which contains leased reserves of subbituminous coal. Leased reserves in the San Juan River region in New Mexico are mostly subbituminous coals with generally higher heat content than in the Powder River basin. There are leased Federal reserves of metallurgical-grade coal in the Uinta region in Colorado and Utah and the Raton Mesa region in Colorado and New Mexico. There are some reserves of lignite under Federal lease in the Denver region of Colorado, but total reserves leased in this area are small and not likely to be developed in the next 10 years.

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Table 24.—Coal Quality Characteristics of Federal Leases and Major Coaifieids With Federai Leases

State	Coal region	No. coal fields[a]	No. fields w/leased Fed. coal	Coal fields with significant concentrations of Federal leases	Quality characteristics of field/Federal leases[b] Ash percent	Sulfur percent	Heat content (Btu/lb)[c]
North Dakota	Fort Union	—	—	—	5.3-10.0	0.2-1.1	5,460-7,345
Montana	Fort Union	26	2	—[d]	5.7-6.7	0.3-0.5	6,660-6,740
	Powder River	36	4	Decker	3.7-22.1	0.3-0.5	9,100-9,650
				Colstrip	8.0-10.4	0.75-1.0	8,700-9,000
Wyoming	Powder River	12	8	Gillette	{4.8-12.6	0.3-0.5	7,500-8,600}
				Powder River	{		}
				Buffalo	12-30	—	6,500-7,500
				Glenrock	8-12	0.4-0.5	7,300-8,000
	Green River	8	4	Hanna	4.8-18.3	0.4-1.4	9,400-11,460
				Rock Springs	2.8-17.5	0.6-1.2	9,000-13,670
				Little Snake River	14.6	1.7	8,000
	Hams Fork	4	2	Kemmerer	5.3-7.0	0.4-0.6	8,500-9,600
Colorado	Green River	1	1	Yampa	3-20	0.3-1.8	9,800-12,600
	North Park	2	1	—[d]	2-19	0.2-1.6	6,500-11,300
	Uinta	8	8	Book Cliffs	5-23	0.4-1.7	9,800-13,600
				Danforth Hills	2-1o	0.3-1.4	10,100-12,000
				Somerset	3-11	0.5-0.8	10,000-13,500
	San Juan River	4	2	—[d]	3-27	0.5-1.3	9,400-14,700
	Denver	2	1	—[d]	4-45	0.2-1.1	3,600-10,800
	Raton Mesa	2	1	—[d]	5-22	0.4-1.3	10,200-13,900
Utah	Uinta	15	3	Book Cliffs	6-7	0.4-1.0	12,500-13,000
				Wasatch Plateau	6-7	0.6	12,200-12,700
				Emery	9-20	0.5-2.5	11,400-12,300
	Southwest Utah	4	2	Alton	9	1.1	9,600
				Kaiparowits Plateau	8-14	0.8-1.3	11,200-12,400
New Mexico	San Juan River	31	7	Fruitland	12.6-17,4	0.7-1.0	9,800-10,600
				Bisti	18.5	0.4-0.9	7,500-10,000
				Star Lake	15-20	0.4-0.7	9,400-10,200
	Raton Mesa	1	1	Raton	9-14	0.6	14,300

[a] *Number of* coalfields in each region identified from maps in Criteria for Detetmining viable *Mining* Properties of Exitsing *Federal Coal Leases in the Unitedd States, Final Report* prepared by Colorado School of Mines for the Office of Technology Assessment, March 1980, except for Montana which was taken from Montana Energy Advisory Council, Coal *Development Information Packet* (Helena, Mont.: Office of the Lieutenant Governor, 1974).

[b] Coal quality data for North Dakota, Montana and Wyoming represents range of characteristics of existing developed and undeveloped leases in each region; data for other States represents range for the whole coalfield. Data Sources: North Dakota, Montana, and Wyoming — Office of Technology Assessment State assessment reports; Colorado and Utah — Colorado School of Mines Report cited in footnote a; New Mexico — J. W. Shomaker, E. C. Beaumont and F. E. Kottiowski, *Strippable Low-Sulfur* Coal *Resources of the San Juan Basin in New Mexico and Colorado* (Socorro, N. Mex.: New Mexico Bureau of Mines and Mineral Resources, 1971).

[c] As-received values.

[d] Only small amounts of Federal reserves are under lease in these regions

SOURCE: Office of Technology Assessment.

A notable characteristic of all the Western coal fields with leased Federal reserves is their generally low-sulfur content. Only the Emery field in Utah has a maximum sulfur content greater than 2 percent. In contrast sulfur contents exceeding 2 percent are typical in the Midwest and Appalachia, except for West Virginia, which produces a significant amount of low-sulfur coal. Although many Western coal fields have coal seams that exceed 1 percent sulfur, mining is generally concentrated in seams that average less than this percentage. For example, a recent survey of mine expansions and proposed new mines by ICF, Inc., found that only 1 mine will produce coal with more than 1 percent sulfur[5] of 55 mines responding in the Powder River basin and southern Wyoming. All mines responding in the Rocky Mountain coal province will produce coal with less than 1 percent sulfur. In contrast, only 6 percent of the mines surveyed in the Midwest and 25 percent in northern Appalachia will produce coal with less than 1 percent sulfur. *

‘Percentages calculated from table 11, ICF, Final Report, Survey of United States *Coal* Mine Expansion Plans prepared for the Department of Energy (Washington, D. C,: ICF, Inc. August 1980). The percentage is calculated for only those mines for which coal quality information was reported, which ranged from 71 to 87 percent of all mines included in the survey for the different regions mentioned in the text,

*It should be noted that differences in sulfur content are slightly less when they are compared on a uniform Btu basis.

The same ICF mines survey shows that, except for the San Juan River region, ash content is also generally lower in the West than in the Midwest and Appalachia, although the differences are less than with sulfur. According to the ICF survey, all new mines and mine expansions in the Northern Great Plains and 88 percent of the mines in Utah and Colorado will produce coal with less than 10 percent ash. In the Midwest 68 percent and in northern Appalachia 65 percent of mine expansions and new mines involve less than 10 percent ash. The San Juan River region in New Mexico is the only area with leased Federal coal where ash content seems to be a significant coal quality factor. Eighty-five percent of the mines in the ICF survey from this area will produce coal with greater than 10 percent ash and most of these mines will produce coal that exceeds 14 percent ash. At mines in the San Juan River region of New Mexico, the coal is frequently cleaned to reduce ash before it is burned.

Continued from p. 72.

Because Western coal has generally lower heat content than coal from Appalachia and the Midwest, its effective sulfur content is higher than a comparison based on percentages would indicate. Table 12 of the ICF survey cited above compares mines according to pounds of sulfur per million Btu. In the Northern Plain, for example, 67 percent of the mines will produce coal with less than **0.83** lb sulfur per million Btu (coal less than this can comply with the 1970 new source performance standards with small amounts of sulfur reduction) compared to 30 percent of the mines in northern Appalachia. Western coal still has a lower sulfur content on the whole than Eastern coal, but the difference is not as great as sulfur percentage comparisons suggest.

In general, the quality characteristics of leased Federal coal reserves would not prevent development of the coal, based on user needs, provided the coal can be sold at a price that is competitive with coal produced from other mines or regions. There are a few exceptions to this generalization. All Federal leases in the Fort Union region and about 50 million tons per year potential production capacity from Federal reserves under lease and preference right lease application in the Wyoming Powder River basin are suitable only for onsite development because of low heat content. * Similar constraints for lease development exist for NERCO's Cherokee lease block in the Little Snake River field in southern Wyoming and several leases in the Denver region of Colorado.

The demand for metallurgical coal in the West is expected to remain relatively stable during the next decade because most coal currently produced is used at steel plants in the region. Production of metallurgical coal could increase slightly to meet expanded foreign exports. The availability of Federal and non-Federal coal from the metallurgical coal areas in the West is expected to meet demand in the foreseeable future.

*Forty-five million tons out of the 50 million tons are unlikely to be in production by 1991, but could come into production in the 1990's.

Geologic Conditions and Mining Methods

The diversity of geologic and topographic conditions in which coal is found in the West requires a variety of mining methods. This section describes the different geologic conditions in the West that affect the choice of mining methods and the ease or difficulty of mining coal. Chapter 11 describes in more detail the surface and underground mining methods that are currently used in the West and analyzes the potential for use of more advanced mining technologies.

Table 25 summarizes data on seam thickness and dip (the inclination of a coal seam expressed as degrees from the horizontal) in the major coal regions in which Federal coal is leased and the dominant mining methods and common mining problems encountered. The thickness and dip of a coal seam affect the ease and cost of mining. In most of these regions coal seams can be very thick. Two regions, the Powder River and Hams Fork, have single coal seams that exceed 100 ft. All other

Table 25.—Geologic[a] and Mining Characteristics of Major Federal Coal States

Coal production region	Coal thickness (ft)	Typical seam dip	Mining methods	Mining problems[b]
Fort Union (ND, MT)	2-37 (ND) 10-50 (MT)	Less than 30	Surface only[c]	Highwall stability
Powder River (MT, WY)	4-80 (MT) 10-220 (WY)	Less than 40	Surface only[c]	Highwall stability. Burned coal.
Green River-Hams Fork (WY, CO)	2-40 (CO) 5-110 (WY)	1-15° (CO) 10-50", some areas less than 6° (WY)	Surface and underground in Green River region; surface only in Hams Fork region at present.[c]	Steep dips create difficulties in Hams Fork and Hanna areas in Wyoming and subsidence from previous underground mining has been a problem in the Rock Springs area, Wyoming. No serious problems in Colorado because dips are generally less steep than in Wyoming.
Uinta-southwest Utah (CO, UT)	1-30 (CO) 3-25 (UT)	Less than 10" (Uinta) generally less than 70 but UP to 15" (SW Utah).	Mostly underground in Uinta region at present. No present production in southwest Utah, but both surface and underground possible.	Uinta area: some methane, floor and roof stability, faulting, steep dips (CO), sandstone dikes (CO), thick overburden (UT and CO), variable dips (UT), water (UT, CO), rugged terrain (UT, CO). Southwest Utah: discontinuous beds, burned coal, undulating roof, water, difficult terrain, splits and partings in coal.
Raton Mesa (CO, NM)	3-10 (CO) 6-13 (NM)	Less than 3"	Surface and underground.	Colorado: roof stability, igneous sills and dikes, some methane. New Mexico: no serious problems.
San Juan River (CO, NM)	1-40 (CO) 3-50 (NM)	Generally 2-6" up to 20°	Surface and underground in Colorado. Surface only in New Mexico at present, but underground possible in future.	Colorado: rugged topography. New Mexice: steep dips, faulting.
Oklahoma	1-7	Generally less than 3" but up to 80°	Surface and underground.	Steep dips, methane, abandoned workings, thin seams, undulating beds, faulting.

[a]*Data drawn primarily* from tabular summary of conventional coal mine development models, western U.S. in Criteria for Determining viable *Mining Properties On Existing Federal Coal Leases in the Western United States, Final Report* prepared by the Colorado School of Mines for the Office of Technology Assessment, March 1980. Some additional data on coal rank and seam dips comes from Summary *Geologic Description of the United States Coal Provinces and Coal Regions, Prepared from Existing Data,* prepared for Office of Technology Assessment by Earth Satellite Corporation, February 1980.

[b]Geologic and topographic conditions that make the process of mining difficult, as distinct from environmental regulations that may affect the mining process. Problems listed here do not occur at all mines in a region; individual mines will rarely have more than a few of the problems listed here, and many have none. Mining problems listed here were identified in *Criteria for Determining* Viable *Mining Properties on Existing Federal Coal Leases m the Western United States, Final Report,* prepared by the Colorado School of Mines for the Office of Technology Assessment, with some supplemental information obtained from the Office of Technology Assessment State assessment reports.

[c]There has been underground mining in the Fort Union, powder River and Hams Fork regions in the past, but such production is not expected In the near future. In the longer term, in situ gasification may result in the development of underground reserves in the Powder River Basin. Coal in the Hams Fork region has a higher heat content than the Powder River Basin, but steep dips make underground mining difficult, Hydraulic mining, which uses a jet of high-pressure water for cutting coal has been proposed for this region on an experimental basis. Hydraulic mining has been successfully used In Canada on coal seams with dips 25 to 50" (R. L Raines, "Underground Mining of Coal" *Mining Congress Journal,* February 1976, pp. 24-27,

SOURCE: Office of Technology Assessment.

regions have coal seams that range up to 30 to 50 ft, except Oklahoma and the Raton Mesa.

Thick coal seams are advantageous for surface mining because less overburden must be removed per ton of coal compared to the thinner coal seams (generally less than 6 ft) that are mined in the Midwest and Appalachia. On the other hand, in underground mines recovery of coal reserves is considerably decreased where coal seams exceed 10 or 12 ft in thickness, although full seam extraction of coal seams 20 to 30 ft thick is currently achieved in mines in France and Poland. However, the high costs of the methods used to achieve high recovery rates in thick coal seams has prevented use of these methods in the United States where underground coal mines must compete with inexpensive surface mined coal.

Coal seams in the West range from horizontal to vertical, but there are considerable regional differences in the typical dips of coal seams (see table 25). The Fort Union, Powder River, Raton Mesa, and San Juan River coal regions have generally flatlying beds which are easily surface mined. Difficulties may be encountered in the Colorado portion of the Raton Mesa region because of factors other

than dip (see table 25). The Green River and Southwest Utah regions and the Oklahoma portion of the Western Interior coal region are generally characterized by coal seams that dip less than 70, but some coal leases in the Rock Springs field in the Green River region and in Oklahoma have more steeply dipping beds that can create difficulties for mining. The Hanna field and the Hams Fork coal region in Wyoming typically dip more than 100, The dipping seams in the Hanna field, located in the northeast part of the Green River region (see fig. 17) present some of the most difficult surface mining conditions in the United States, and special methods of using draglines to handle overburden have been developed.

At this time, only surface mining methods are used to produce coal in the Powder River and Fort Union regions because thick seams and low heat content make underground mining economically unfeasible, In-situ gasification in the Powder River region may permit development of deeper coal beds (more than 500 ft of overburden) in the future. All production at present from the Hams Fork region in Wyoming and the San Juan River region in New Mexico is from surface mines, but several operators are planning or considering underground mining in these areas because the higher heat content of these coals makes it economically feasible to do so. Coal in the Uinta and Raton Mesa regions and the Colorado portion of the San Juan River region is currently mined by both surface and underground methods, Mining in the Utah portion of the Uinta region is almost entirely underground, and there is no mining in the Southwest Utah region at this time, although both surface and underground mining is possible.

Geologic conditions that make mining difficult are also very site specific, but there are definite regional differences in the extent to which problems can be expected to occur. The Fort Union, Powder River, and San Juan River regions generally have few, or minor mining problems, although highwall stability may be a problem locally in the Northern Great Plains. Steep dips in the Hams Fork Region and the Rock Springs and Hanna fields in the Green River regions of Wyoming create difficulties for both surface and underground mining as mentioned previously. In underground mines a variety of difficulties can be encountered in the Uinta, Southwest Utah, Raton Mesa regions and in Oklahoma. The number and relative importance of underground mining problems varies between these regions (see table 25) but include: methane hazards, roof and floor instability, dikes and intrusions in the coal, faulting, steep dips, thick overburden, variable dips, thin seams, undulating or discontinuous beds, splits and partings in coal, water, and burned coal.

Mining conditions found on Federal leases include almost the whole range of possible combinations that make mining easy or difficult. The Gillette field in northeastern Wyoming presents some of the most ideal mining conditions found anywhere, with thick, flat-lying coal seams under shallow overburden. Underground mining conditions on Federal leases in western Colorado and central Utah range from very favorable to very difficult, Among the most difficult underground mining problems that are sometimes encountered are: overburden that exceeds 3,000 ft, seam dips that approach 350, extreme fracturing and faulting in both the coal seams and the confining rock strata, and unstable floor and roof conditions. Chapter 11 examines in more detail geologic conditions as they affect underground mining methods.

Summary

Leased Federal coal reserves encompass a wide range of coal types, qualities, and geologic conditions for mining. This section summarizes some of the important points made in this chapter.

1. Federal coal leases are located in **14** States, but the vast majority of leased Federal coal reserves (98 percent) are located in six Western States: Colorado, Montana, North Dakota, New Mexico, Utah, and Wyoming. Coal reserves under lease and PRLA are very unevenly divided between these six States. Wyoming has by far the greatest reserves under lease and PRLA (56 and 43 percent respectively of total reserves under lease and PRLA in the six States). Wyoming and Utah together contain more than three-quarters of the reserves under Federal lease, and Wyoming, New Mexico, and Colorado contain nearly 90 percent of the reserves under PRLA. Most of the reserves under lease and PRLA (about 70 percent for both)* can be mined by surface methods, but a majority of the leased reserves in Colorado and Utah must be mined by underground methods.
2. Although the Federal Government owns approximately 60 percent of the coal reserves in the six major Federal coal States, production from Federal coal leases between 1957 and 1979 fluctuated between only 20 and 45 percent of total production. Since 1973 the quantity and percentage share of Federal coal production in these States has shown a general increase. However in 1979, even though total Federal production was more than eight times higher than in 1970, its percentage share of all production in the six States was less than in 1960. During the next decade, Federal coal production will probably increase at a higher rate than non-Federal coal production because of the large increases from the Powder River region where the Federal Government owns a large percentage of coal reserves.
3. The quality of coal reserves presently under lease and PRLA does not appear to impose any serious limitations for meeting the demand that is likely for Western coal over the next 10 to 15 years. Most leased reserves have low sulfur and ash content and are suitable for use by utilities, which constitute the single greatest user of Western coal. All Federal leases in the Fort Union region and about 50 million tons per year potential production capacity from Federal reserves under lease and PRLA in the Wyoming portion of the Powder River basin are probably suitable only for onsite development for power or synfuels plants because of their low heat content. (However, the majority of Federal reserves under lease are of sufficiently high quality to be exported out of the producing State.) The demand for metallurgical coal in the West is expected to remain relatively stable during the next decade and even when possible increases in demand for foreign export are considered, the availability of Federal and non-Federal metallurgical coal in the West appears to be adequate for the foreseeable future.

*Table 19 shows that only 61 percent of the reserves under PRLA are surface minable, but if the subbituminous underground reserves in the Powder River basin are subtracted, as discussed earlier, the percentage changes to 71 percent.