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GEOLOGICAL SURVEY OF WYOMING

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Wyoming

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Despite growing concern over Federal coal leasing and prospecting policies, unparalleled growth is predicted for Wyoming's coal industry. Today's power plant demands and synthetic fuel and coke markets of the future suggest a fifteen-fold increase in annual production by the year 2000. Low mining costs and favorable mining conditions only accentuate this prognosis.

Already, Wyoming coal is sold or used in 17 states and British Columbia. In addition to power companies, it is used by the beet sugar, cement and synthetic coke industries, railroads, government, domestic and other miscellaneous users. Unit-trains streaming out of the state to power plants in Sioux City, Kansas City, and Chicago indicate the demand. Announced unit-trains will soon be going to Wisconsin, Colorado, and Texas. The unit-train to Avinger, Tex. in 1976 is the longest proposed unit-train coal haul in the US—1,483 mi. There are also rumors of potential contracts with Oklahoma and Arkansas power plants.

Wyoming coal is used in power plants because it can 1) supply fuel demands and 2) meet pollution standards. In the first case, the current "energy crisis" continues to reduce or eliminate oil and gas as alternative, clean, uninterruptible fuels for electric power generation. In the second case, high-sulfur coals of many states remain unacceptable since they fail to meet sulfur emission standards. Many utility companies, therefore, turned to the low-sulfur coals of the "Energy State."

While the need for low-sulfur coal will diminish with the perfection of sulfur-dioxide removal systems, coal demands will continue to grow as electrical energy consumption increases 7 to 8% per year. Coal is the only fuel in great enough supply to satisfy projected requirements. Wyoming's vast coal deposits will play an important role in supplying these national fuel needs. However, coal for power generation is viewed as a relatively short, 20- to 30-year boom, as nuclear power, char from conversion processes, and other more exotic energy sources are developed.

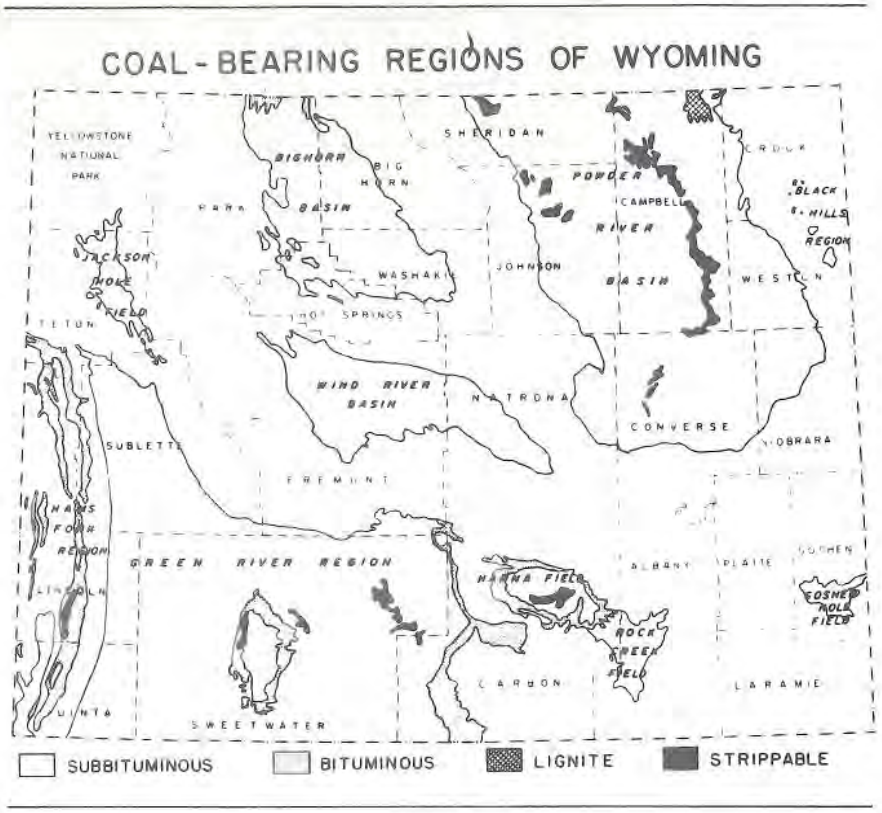
Conversion of coal to gaseous and liquid fuels promises to be the largest new outlet for Wyoming coal. Its subbituminous coals are well-suited for this use since they are more reactive than higher-ranked coals. Additionally, many individual coal deposits in the state exceed the 500 to 800 million tons of reserves required to sustain a conversion facility. This volume in a contiguous block has become increasingly harder to find outside the Rocky Mountain area. Mine-mouth facilities, which produce high-Btu, pipeline-quality gas or liquid fuels, are most suitable to the state since their products can be transported to markets through existing pipelines. Low-

Btu gas or "coal-gas" plants, on the other hand, are less suitable. Because these plants are best located at the point of use, their greatest potential in Wyoming lies in new, specially designed industrial power plants or in the conversion of existing facilities. Before the next century, conversion of coal to liquid and gaseous products should be the prime use for Wyoming coal.

Numerous oil, gas, power and coal companies have acquired extensive mineral holdings in Wyoming, ostensibly for conversion plant sites. Already, two Wyoming coal companies are participating with Conoco Methanation Co. in a commercial-scale, high-Btu gasification plant. Amax Coal Co. and Rocky Mountain Energy Co. joined Conoco and others in this venture. Rocky Mountain is also participating in FMC's COGAS venture in which a pilot gasification plant will be built. Although neither of these ventures plans to build its proposed plant in Wyoming, the plants could be used as prototypes for future Wyoming sites. Besides research on these more conventional surface plants, Rocky Mountain Energy Co. and the US Bureau of Mines are conducting tests on in-situ gasification in southeastern Wyoming. Similar in-situ uses of deep coals in the Powder River basin were suggested as long ago as the 1960s. Given the right set of circumstances, in-situ technology could open up enormous coal reserves too deep or costly to utilize any other way.

As coal's market swings from power generation to conversion, coke shortages and synthetic coke technology could stimulate the coking of Wyoming coal. Gunn-Quealy Coal Co. already manufactures synthetic coke suitable for reducing phosphate rock in electric furnaces. FMC Corp. is also making metallurgical-grade coke from Wyoming coal on a pilot-plant scale. Both synthetic cokes are produced from coals which are noncoking by conventional processes.

Mining costs and mining conditions in Wyoming complement development of its coal deposits. According to the state's Ad Valorem Tax Dept., coal mining costs ranged from 95¢ to $2.84 per ton in 1971. The average was $1.97. Low mining costs, coupled with the low rates of unit-train transportation, have made much of Wyoming's nearly 24 billion tons of strippable coal economical by current standards. Most of these strippable deposits are favorably situated in basinal areas of low relief. Coal beds frequently exhibit dips less than 10 deg, and range between 11 and 200 ft in thickness.



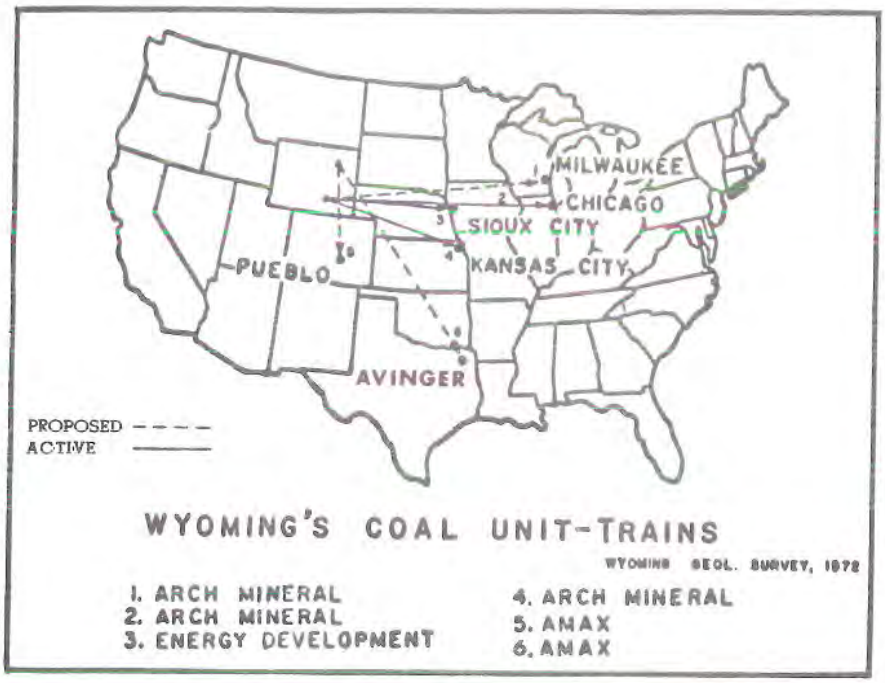
Wyoming coal producers are not without worries, however. Besides expected concerns over expensive health and safety regulations and new surface mining legislation, producers also are troubled with a 2½-year-old "moratorium" on Federal coal leasing and prospecting. Since nearly 72% of the coal in Wyoming is Federally owned, industry officials claim that the moratorium hinders the legitimate search for and development of reserves.

In 1972 the American Mining Congress expressed fears that this same measure could seriously handicap research and development of conversion technology. Late last year a Bureau of Land Management official suggested that the moratorium might continue for another three years. Without a reprieve, new contract proposals may be turned down by some Wyoming coal companies that do not have the necessary uncommitted reserves. Secretary Morton's newly announced short-term leasing policy may be this reprieve, at least for the companies that are already in production. The commitment of large reserves is essential to the future of both the electric power and synthetic fuel industries in Wyoming.

In a rapidly expanding energy market, the perfection of oil shale and tar sand extraction technology is unlikely to affect the pace of coal development. The coal industry of Wyoming faces an optimistic but challenging future as it strives to meet demands of power plants today and a new burgeoning conversion industry tomorrow.

Coal company profiles

Amax Coal Co., which is a subsidiary of American Metal Climax, Inc., opened the Belle Ayr open-pit mine near Gillette late in 1972.



CURRENT MARKETS FOR WYOMING COAL

The company's reserves in that area are 300 to 400 million tons. Over the next 20 years, 20 million tons of their 70-ft-thick, subbituminous Roland-Smith seam will be unit-trained to Public Service Co. of Colorado's Commanche plant in Pueblo. Another 25-year contract for 42.5 million tons is with Southwest Electric Power Co. Coal under this contract will begin its record 1,483-mi-long haul to Texas' first coal-fired power plant in 1976. Annual production from the Belle Ayr mine will increase from 2.5 million tons to as much as 6 million tons by 1978. Amax will mine with an 18- or 24-cu yd bucket on a Marion 295-C shovel. Its unit-train loading facility includes two 13,000-ton silos.

Arch Mineral Corp. is a joint venture of Ashland Oil Co. and Hunt Enterprises. Arch operates the Seminoe No. 1 strip mine on the 22-ft-thick No. 25 seam, and the Seminoe No. 2 strip on the 30-ft subbituminous Hanna No. 2 seam. Both mines are in the Hanna field of southeastern Wyoming. Each mine is expected to produce 2.5 to 3 million tpy. Arch presently sends coal to Chicago and Kansas City by unit-trains. The company has recently announced an 8-million-ton contract for shipment to Wisconsin, as well as another 5.5-million-ton contract to Commonwealth-Edison Co. in Chicago. Draglines, which include the largest in the state with a 62-cu yd bucket, are employed in overburden removal. Coal is then loaded with a 16-cu yd shovel and trucked in 100-ton haulers to the unit-train loading dock.

Best Coal Co.'s East Antelope strip mine along the northern border of Converse County is a one-man operation on the 40-ft-thick "D" seam. Annual production from the mine is less than 2,000 tons and goes to domestic users in Wyoming, Nebraska and South Dakota.

Big Horn Coal Co., which is a subsidiary of Peter Kiewit Sons, Inc., operates surface mines in the Monarch and Armstrong seams near Sheridan. These seams average 44 and 12 ft thick, respectively. In the Big Horn No. 1 open pit mine, overburden is removed by scrapers. Coal is then loaded by shovels and front-end loaders. Big Horn ships its coal from a conventional tipple to power plants in Nebraska, South Dakota, Colorado and Wyoming, as well as to domestic and industrial markets in British Columbia, Idaho, Washington and Montana. Annual production, which has been between 1.5 to 2 million tons, is expected to decrease in 1973.

Dusky Diamond Coal Co. is a wholly owned division of Dal Petroleum. After buying the Grass Creek mine in 1972, Dal announced plans to convert the 4,000 tpy deep mine into a 200,000 to 300,000 tpy strip mine. As an underground operation, the company mines 20 ft of a 40-ft seam by conventional methods. Dal estimates at least 12 million tons of reserves around the mine, which is near Grass Creek in Hot Springs County.

Energy Development Co. is a subsidiary of Iowa Public Service Co. Utilizing scrapers and a belt loader, Resources Exploration & Mining, Inc. operates the strip

mine in the 8- to 15-ft-thick Brook's seam for Energy. Annual production from this surface operation is around 400,000 tons. Energy also operates the Vanguard No. 1 deep mine on the 8-ft No. 65 bed. This mine uses the only continuous miners in Wyoming—Jeffrey Heliminers. Coal from Vanguard No. 1 is carried to a unit-train loading dock via a 3-mi-long covered conveyor belt. From there the coal is shipped to Sioux City. When the deep mine is fully developed, annual production should increase from the current 300,000 tons to an estimated 1 million. Energy is the only company in Wyoming simultaneously operating both a surface and underground coal mine.

Gunn-Quealy Coal Co., a subsidiary of Kemmerer Coal Co., has operated the 100,000-tpy Rainbow No. 7 deep mine near Rock Springs. This mine is scheduled to close as the Rainbow No. 8 mine comes on line this year. Rainbow No. 8 is on the bituminous, 4.5-ft-thick No. 7 seam and will be mined by conventional methods. Most of Gunn-Quealy's production will supply its new rotary-hearth synthetic coke plant, which is nearing completion.

Kemmerer Coal Co. is headquartered in Frontier, Wyo. Kemmerer mines nine subbituminous seams of the Adaville Formation by surface methods near Kemmerer. Tentative plans are to mine an additional eight seams. Seam thicknesses range from 6 ft to over 100 ft. Draglines, scrapers, shovels and front-end loaders are all used in its Sorensen and Elkol mines. All coal but that from the thick Adaville No. 1 seam goes to Utah Power & Light Co.'s nearby Naughton power plant. The Adaville No. 1 is retained as a commercial seam and is sold from the Elkol tipple. While Kemmerer's annual production for the power plant is 1.5 to 2 million tons, its Elkol tipple sells an additional 300,000 tons. Some Elkol coal is supplied to FMC Corp.'s pilot coke plant.

Medicine Bow Coal Co., a joint venture of Rocky Mountain Energy Co. and Arch Mineral Corp., was formed in October 1972. The company plans to strip 3 million tons

Remaining strippable subbituminous coal resources of Wyoming to Jan. 1, 1972 by coal-bearing region (Modified from USBM)

Coal-bearing region	Original strippable resource estimate to Jan. 1, 1968	Production and mining losses since Jan. 1, 1968	Remaining strippable resource to Jan. 1, 1972	Remaining recoverable strippable resource (80% recovery)
Powder River	21,262,400,000	15,190,211	21,247,209,789	16,997,767,832
Green River	1,151,100,000	34,483	1,151,065,517	920,852,414
Hams Fork	1,000,000,000	6,598,403	993,401,597	794,721,278
Hanna	313,000,000[1]	15,132,000[2]	297,868,000	218,294,400
Bighorn	3,000,000	0[3]	3,000,000	2,400,000
Total	23,729,500,000	36,955,097	23,692,544,903	18,934,035,924

[1] This approximation is based on a percentage of the original resource estimate. [2] This is strip mine production and mining losses since 1950. [3] Probably very little to no strippable tonnage has been removed.

Estimate of remaining coal resources of Wyoming to Jan. 1, 1972

Categories of original resources	Mapped and explored areas (0-3,000 ft of cover)	Mapped and estimate of unexplored areas (0-6,000 ft of cover)
Original resources[1]	136,891,430,000	545,710,000,000
Production from[2] strip mining	68,271,706	---
Production from[2] deep mining	382,994,559	---
Total production	451,266,265	451,266,265
Losses due to strip mining (20% lost)	13,654,341	---
Losses due to deep mining (50% lost)	382,994,559	---
Total production and mining losses	847,915,165	847,915,165
Remaining resources	136,043,514,835	544,862,084,835

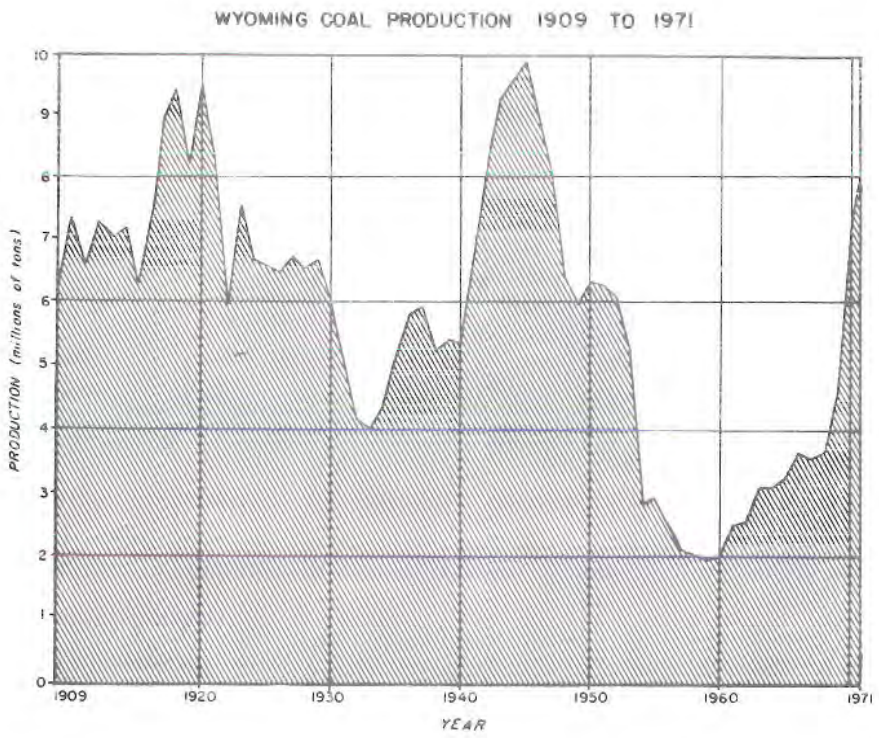
[1] Source: USGS and USBM. [2] Source: USGS, USBM and Wyoming State Inspectors of Mines.

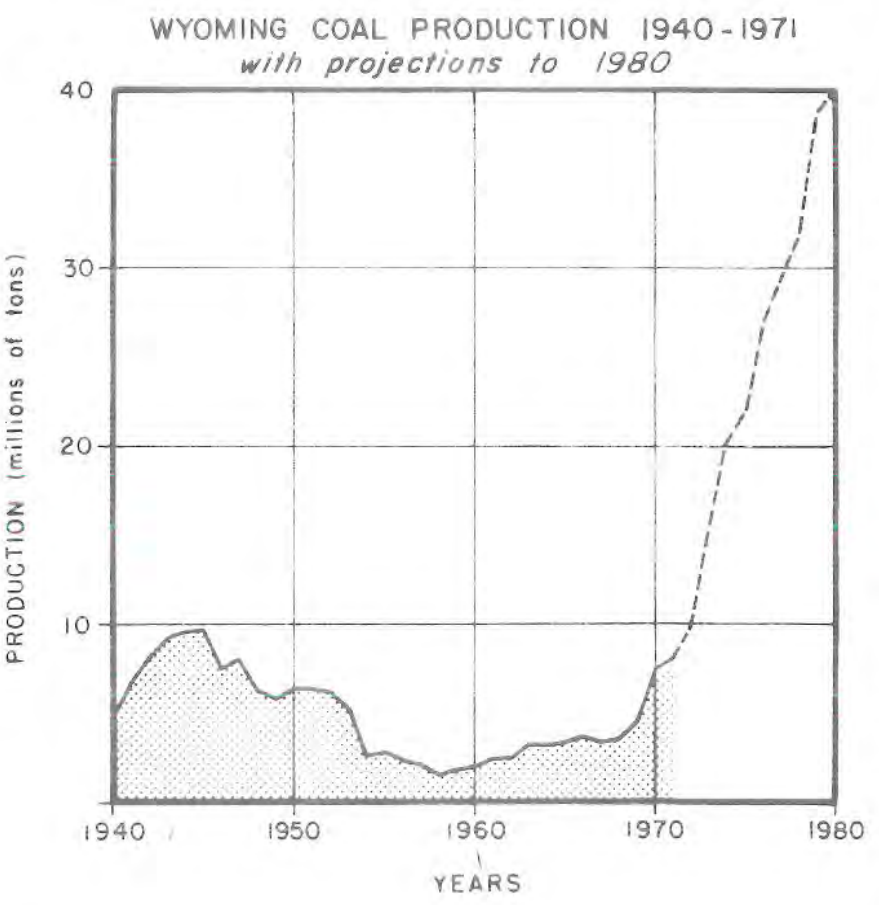
Estimated original in-place coal resources in Wyoming by major coal-bearing regions and rank

(millions of short tons)

Coal-bearing region	Bituminous[1]	Subbituminous[1]	Total
Powder River coal basin*	---	110,218.95	110,218.95
Green River coal region	9,904.84	6,051.04	15,955.88
Hams Fork coal region	3,197.68	1,676.86	4,874.54
Hanna coal field	73.44	3,843.52	3,916.96
Wind River coal basin	---	875.66	875.66
Bighorn coal basin	17.90	563.78	581.68
Rock Creek coal field	---	305.18	305.18
Jackson Hole coal field	---	121.49	121.49
Black Hills coal region	41.09	---	41.09
Total	13,234.95	123,656.48	136,891.43

Note: There has never been an estimate of the resources of the Goshen Hole coal field.
*This figure has been changed to reflect resources delimited since the original resource estimates that were calculated in 1950.
[1] Coal resources between 0 to 3,000 ft of overburden.





annually by 1974. Their mine will be in the Hanna field. Rocky Mountain Energy Co. alone has reserves in excess of 2 billion tons, much of which is in Wyoming.

Muddy Creek Mines Corp. of Riverton is the newest mining company in the state. Muddy Creek mine, which is a two-man surface operation, extracts a 17-ft seam. The coal is currently sold to domestic users in Fremont County. Strippable reserves are estimated at several million tons.

Pacific Power & Light Co.'s Dave Johnston Fuel Recovery Pit near Glenrock is a surface operation on both the 20-ft Badger seam and the underlying 31-ft School seam. Annual production is between 2 and 2.8 million tons. The 750-Mwe Dave Johnston power plant at Glenrock consumes all the tonnage mined. The company reports 150 million tons of reserves in the vicinity of the mine, as well as another 640 million tons in other areas of Wyoming. Pacific Power's dragline removes overburden with a 39- or 41-cu yd bucket. Power shovels load the coal into trucks; trucks dump it into cars on a private railroad, and a train then hauls it 15 mi to the power plant on the banks of the North Platte River.

Roncco Coal Co., Inc. is a two-man underground mine near Gebo in Hot Springs County. The mine follows a 6- to 9-ft seam down a 17 to 45 deg dip for 1,200 ft. Mining is by conventional methods and produces about 3,000 tpy.

Rosebud Coal Sales Co., which is a subsidiary of Peter Kiewit Sons, Inc., strips the Nos. 80 and 82 seams in the Hanna field. These seams average 20 and 9 ft, respectively. Annual production is about 1.5 million tons and is principally shipped to power plants in Colorado, Nebraska, Iowa and Illinois. Rosebud uses draglines, power shovels and trucks in its mining operation. They currently load from a conventional tipple.

Welch Coal Co. is a wholly owned subsidiary of Montana-Dakota Utilities. Welch operates a surface mine on the 16-ft-thick Monarch seam north of Sheridan. A scraper and power shovel annually produce about 20,000 tons,

which is used by the 12-Mwe Acme power plant some 10 mi away.

Wyodak Resources Development Corp., a subsidiary of Black Hills Power & Light Co., mines the 55- to 106-ft-thick Wyodak seam near Gillette by open-pit methods. The 600,000 to 700,000 tons mined each year supplies the Neil Simpson (27.68-Mwe) and Osage (35.5-Mwe) power plants in Wyoming, as well as two South Dakota plants. Wyodak mines with scrapers, loading shovels, dozers and front-end loaders.

Other companies anticipate or have confirmed future coal mining activities in Wyoming. Atlantic Richfield has announced plans to ship coal to a Nebraska power company in 1977. Reynolds Mining Corp. plans to mine coal near Buffalo to fuel a huge (possibly 3,500-Mwe) power plant for its proposed $2.2 billion uranium enrichment facility. Reynold's mining plans, however, hinge on AEC approval of its plant application.

Past production

Except for an 11-year interval after WW I, Wyoming's coal production for the years 1910 through 1945 remained above 6 million tons annually. After 1945, production plummeted to a record low of 1.6 million tons by 1958. This decline followed WW II and, more importantly, the railroad's change from steam locomotives to diesel engines. Low-sulfur fuel demands revived the state's coal industry in the 1960s. Production increased, first slowly, and then nearly doubled between 1969 and 1971 to 8,007,765 tons. This tonnage equaled 1.4% of the national production for that year. Wyoming's 1972 tonnage was close to the 10-million-ton mark which would be a new state record. The existing record is 9,836,788 tons in 1945.

Recorded Wyoming coal production between 1865 and Jan. 1, 1972 is over 451 million tons of which 383 million (85%) came from underground operations and 68 million (15%) from surface mining. Mining losses account for another 397 million tons and bring the total production and mining losses to almost 848 million tons. Ninety-nine and four-tenths per cent of Wyoming's original explored coal resource remains unmined after more than a century of mining.

Future roles in production

Wyoming jumped from the eleventh to the ninth largest coal producing state in 1972. In this decade, Wyoming's coal production is expected to increase 2 to 7 million tpy. This is an average annual increase of 4.2 million tons. At this rate, annual tonnage will be about 38.8 million tons or almost four times 1972's production by 1980. These predicted increases only satisfy the electric power market and do not include requirements of a synthetic-fuels industry.

In a state-sponsored development study made in 1969, Cameron Engineers made longer-range predictions. Their projections for annual increases for steam-electric power plants were in excess of 20 million new tons per decade. Already, their estimate for this decade is low. Cameron's predictions for the synthetic-fuels industry begin at 10 million tons in 1980 and increase 40 to 50 million tons per decade. Small increases for the coking industry, railroads and other users are also forecast. If Cameron's predictions materialize, Wyoming's annual production will top 150 million tons by the end of this century. Naturally, these long-range forecasts must be viewed with caution, but they surely demonstrate the potential of Wyoming's coal industry.

Historical problems

Historically, Wyoming's coal industry has faced the following problems:

1. A geographic location remote from metropolitan and industrial centers.
2. High transportation costs.
3. Competition from oil, gas and hydropower.
4. Few in-state markets.
5. Coal with low-heat values.
6. Coal without coking qualities.
7. Coal-storage and handling problems.

Although these problems still remain, each is now tempered to varying degree.

First, today's enormous energy demands help reduce the traditional handicap of remoteness. Second, unit-train concepts also offset the problem of distance by lowering transportation costs. Third, inadequate supplies of oil, gas and new hydroelectric sites, reduce the competition from these energy sources. Fourth, the lack of in-state markets is already partially alleviated by the growing electric power industry of the state. The synthetic-fuel industry looms as an even larger market. Hopefully, Wyoming coal's near-fatal dependence on a single market like the steam locomotive will not be repeated as more diversified uses are sought and developed. Fifth, the stigma of low-heat value is currently offset by the thickness and low sulfur and ash content of cheaply and easily mined seams. Sixth, advanced technology has permitted synthetic coking of Wyoming's otherwise noncoking coals. Finally, proper storage and transportation procedures reduce the dangers of spontaneous combustion and other handling problems.

Coal reserves

In the words of the Hon. Fenimore Chatterton, Wyoming's secretary of state in 1902:

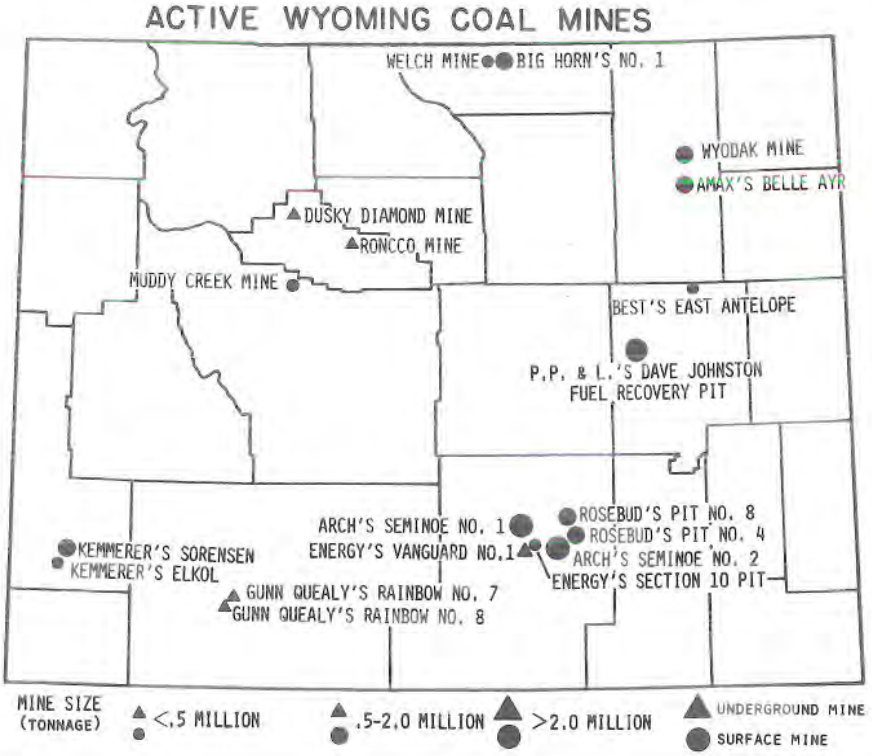
"Coal? Wyoming has enough with which to run the forges of Vulcan, weld every tie that binds, drive every wheel, change the North Pole into a tropical region or smelt all hell."

Quantified, Wyoming has 545 billion tons of coal between 0 and 6,000 ft of cover. This is 17% of the national total and ranks Wyoming first among the states in total coal resources.

Of this resource, only 25% or 136 billion tons is in a mapped and explored category within 3,000 ft of the land surface. Of that amount, approximately 2% is lignite, 10% bituminous and 88% subbituminous. One-half or 68 billion tons of the mapped resources are considered recov-

erable. Seventeen percent or 23.7 billion tons of the explored resources are classified as strippable. This strippable resource is greater than that of any other state and represents nearly 20% of the nation's known strippable coals. Of those 23.7 billion tons, 19 billion are termed recoverable and 14 billion of that are classed as reserves by today's standards. For the latter figure, strippable reserves are defined by the US Bureau of Mines as coal deposits with 1) a minimum seam thickness of 5 ft, 2) an overburden ranging between a maximum of 60 to 200 ft, and 3) a stripping ratio between 1.5:1 and 10:1.

While almost 90% of Wyoming's strippable coals underlie the Powder River basin, the Hams Fork and Green River regions each contain over 4%. The remaining 1.2% of the resources lie in the Hanna field and Bighorn basin areas.



Coal seams

The rank of Wyoming coal ranges from lignite to high-volatile "A" bituminous. Lignite occupies a very small region in the northeastern part of the Powder River basin. Bituminous coal is restricted to the Black Hills region and portions of the Hanna field, Green River region, Hams Fork region and Bighorn basin. High-volatile "B" and "A" bituminous coal is reported only in the Hams Fork region. Subbituminous coals are found in all the major coal regions except the Black Hills region, and account for most of the state's resources and current production.

Typical Wyoming coal analyses exhibit the following ranges and averages:

As-received	Range	Average
Moisture, %	1.7–32.8	14.2
Volatile matter, %	32.0–46.0	39.0
Fixed carbon, %	– –	41.0
Ash, %	1.4–17.5	5.2
Sulfur, %	0.2–5.0	0.7
Heat value, Btu/lb.	7,500–13,500	10,850

In terms of quality, coals with the lowest heat values, as well as the highest moisture and volatile contents, are found in the Powder River basin. The higher heat values are more prevalent in the western and southern portions of the state. Ash varies widely, with small isolated pockets of high-ash content (15-18%, dry basis) in the Powder River basin, Bighorn basin and Hams Fork region. Sulfur contents are relatively low and variable. The southern and eastern parts of the Green River region contain some of the highest sulfur values. Overall, more than 99% of Wyoming's coal contains less than 1% sulfur and about one-half of that is less than 0.7% (as-received basis). Ninety-six percent of the strippable coals contain less than 1% sulfur, 3.5% is between 1 to 2%, and 0.5% is greater than 2% sulfur (as-received).

There are 25 coal seams currently being mined in Wyoming. They range from a low of 3.7 ft to a high of 118 ft thick. Seams mined underground range from 3.7-20 ft, averaging 8.5 ft. Surface-mined seams are between 6 and 118 ft, but average 32 ft. The thickest mined seams occur in the Hams Fork region and Powder River basin. The latter basin also contains the nation's, and perhaps the world's, thickest seam. That 220-ft-thick seam, which occurs near Buffalo, is not currently being mined.

Descriptions and analyses of the seams currently mined in Wyoming are tabulated below:

Bighorn Coal basin

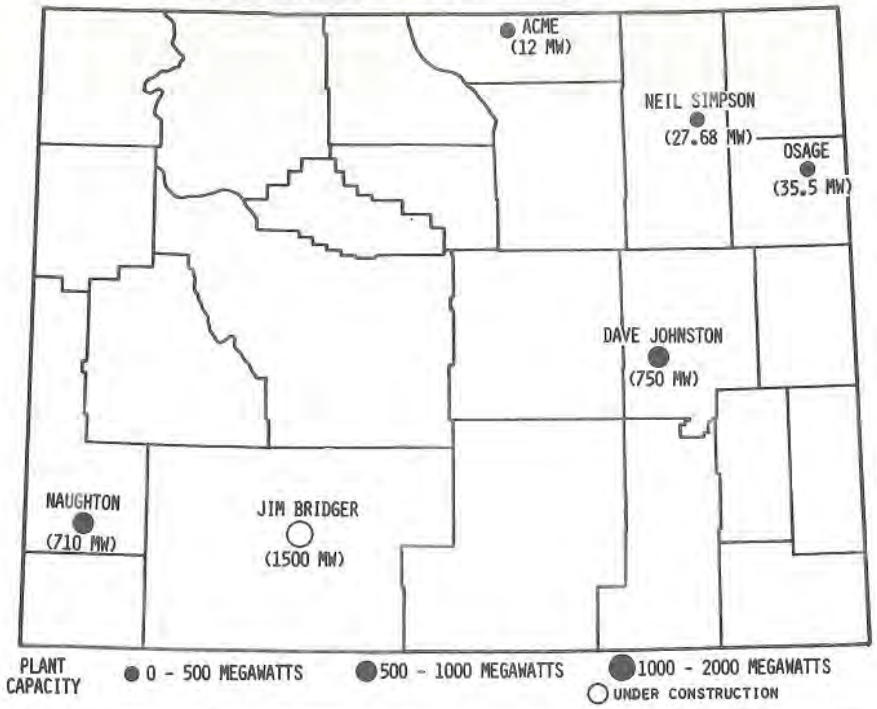
Unnamed seam

Age: Cretaceous
Formation: Mesaverde
Field: Gebo
County: Hot Springs

Average seam thickness by mining method and coal region

Coal-bearing region	Underground, ft	Surface ft
Bighorn basin	6.5-20	0
Green River	4.0-4.5	0
Hams Fork	0	16-84
Hanna field	7	11-30
Powder River	0	12-71
Statewide	8.5	32

WYOMING COAL-FIRED POWER PLANTS



Rank: Subbituminous
Thickness range: 6 to 9 ft
Average thickness: 6.5 ft
Producer and mine type:
Roncco Coal Co., Inc.: slope

Analysis: Tipple range

Moisture (as-rec'd.), %	11.2 - 15.3
Volatile matter (dry), %	40.1 - 44.7
Fixed carbon (dry), %	51.1 - 56.7
Ash (dry), %	2.8 - 7.4
Sulfur (dry), %	0.5 - 1.1
Heat value (as-rec'd.) Btu/lb	10,850 - 11,650

Unnamed seam

Age: Paleocene
Formation: Ft. Union
Field: Grass Creek
County: Hot Springs
Rank: Subbituminous
Thickness range: 20-40 ft
Average thickness: 20 ft (mined)
Producer and mine type:
Dusky Diamond Coal Co.; drift

Analysis: Tipple range

Moisture (as-rec'd.), %	9.5 - 13.1
Volatile matter (dry), %	37.9 - 42.4
Fixed carbon (dry), %	48.0 - 51.6
Ash (dry), %	8.4 - 12.0
Sulfur (dry), %	0.4 - 0.6
Heat value (as-rec'd.), Btu/lb	10,370 - 11,310

Green River coal region

Rocky Springs No. 7

Age: Cretaceous
Formation: Rock Springs
Field: Rock Springs
County: Sweetwater
Rank: Bituminous
Thickness range: 4-5 ft
Average thickness: 4.5 ft
Producer and mine type:
Gunn-Quealy Coal Co.: Rainbow No. 8; drift

Analysis: Typical (as-rec'd.)

Moisture, %	8.60
Volatile matter, %	38.55
Fixed carbon, %	49.50
Ash, %	3.59
Sulfur, %	0.70
Heat value, Btu/lb	12,452

Hams Fork coal region

Adaville seams
(nine mined coals)
Age: Cretaceous
Formation: Adaville
Field: Kemmerer
County: Lincoln
Rank: Subbituminous
Thickness range: 6-118 ft
Average thickness: 16-84 ft
Producer and mine type:
Kemmerer Coal Co.; Sorensen, Elkol; surface mines

Analysis: Average (as-rec'd.)

Moisture, %	21.24
Ash, %	3.57
Sulfur, %	0.59
Heat value, Btu/lb	9,671

Hanna coal field

Bed No. 25
Age: Paleocene
Formation: Ferris
Field: Hanna
County: Carbon
Rank: Subbituminous
Average thickness: 22 ft
Producer and mine type:
Arch Mineral Corp.; Seminoe No. 1; strip mine

Analysis: Average (as-rec'd.)

Moisture, %	13.96
Ash, %	6.68
Sulfur, %	0.37
Heat value, Btu/lb	10,000

Bed No. 65

Age: Paleocene
Formation: Ferris
Field: Hanna
County: Carbon
Rank: Subbituminous
Thickness range: 6-8 ft
Average thickness: 7 ft
Producer and mine type:
Energy Development Co.; Vanguard No. 1; drift

Analysis: Typical (as-rec'd.)

Moisture, %	11.6
Ash, %	7.1
Sulfur, %	0.7
Heat value, Btu/lb	11,020

Bed No. 80

Age: Paleocene
Formation: Hanna
Field: Hanna
County: Carbon
Rank: Subbituminous
Thickness range: 15.5-24 ft
Average thickness: 18 ft

Producer and mine type:
Rosebud Coal Sales Co.; surface mine

Analysis: Average (as-rec'd.)

Moisture, %.....14.50
Ash, %.....6.94
Sulfur, %.....0.78
Heat value, Btu/lb.....10,523

Brooks seam

Age: Paleocene
Formation: Hanna
Field: Hanna
County: Carbon
Rank: Subbituminous
Thickness range: 8-15 ft
Average thickness: 11 ft
Producer and mine type:
Energy Development Co.; surface mine

Analysis: Typical (as-rec'd.)

Moisture, %.....13.66
Ash, %.....6.50
Sulfur, %.....0.45
Heat value, Btu/lb.....10,806

Hanna No. 2 coal

Age: Paleocene
Formation: Hanna
Field: Hanna
County: Carbon
Rank: Subbituminous
Thickness range: 30-35 ft
Average thickness: 30 ft
Producer and mine type:
Arch Mineral Corp.; Seminoe No. 2; strip mine

Analysis: Range (as-rec'd.)

Moisture, %.....7.5 - 12.7
Ash, %.....3.9 - 6.6
Sulfur, %.....0.2 - 0.6
Heat value, Btu/lb.10,650 - 11,660
Fusion, deg.F.....2,200 - 2,450

Powder River Coal basin

Armstrong seam

Age: Paleocene
Formation: Ft. Union
Field: Sheridan
County: Sheridan
Rank: Subbituminous
Average Thickness: 12 ft
Producer and mine type:
Big Horn Coal Co.; Big Horn No. 1; surface mine

Badger seam

Age: Paleocene
Formation: Ft. Union
Field: Glenrock
County: Converse
Rank: Subbituminous
Thickness range: 17-20 ft
Producer and mine type:
Pacific Power & Light Co.; Dave Johnston Fuel Recovery Pit; strip

Analysis: Typical (as-rec'd.)

Moisture, %.....25.7
Volatile-matter, %.....34.5
Fixed-carbon, %.....32.6
Ash, %.....7.2
Sulfur, %.....0.6
Heat value, Btu/lb.....8,250

"D" seam

Age: Paleocene
Formation: Ft. Union
Field: Gillette
County: Converse
Rank: Subbituminous
Thickness range: 8-65 ft
Average thickness: 20 ft
Producer and mine type:
Best Coal Co.; East Antelope; surface mine

Analysis: Tipple average (as-rec'd.)

Moisture, %.....25.7
Volatile matter, %.....44.0
Fixed carbon, %.....49.4
Ash, %.....6.6
Sulfur, %.....0.5
Heat value, Btu/lb.....9,060
Fusion, deg.F.....2,370

Monarch seam

Age: Paleocene
Formation: Ft. Union
Field: Sheridan
County: Sheridan
Rank: Subbituminous
Thickness range: 16-57 ft
Average thickness: 44 ft
Producer and mine type:
Big Horn Coal Co.; Big Horn No. 1; surface mine
Welch Coal Co.; surface mine

Analysis: Typical Big Horn (as-rec'd.)

Moisture, %.....23.85
Volatile matter, %.....32.36
Fixed carbon, %.....38.49
Ash, %.....5.30
Sulfur, %.....0.61
Heat value, Btu/lb.....9,300
Fusion, deg.F.....2,200

School seam

Age: Paleocene
Formation: Ft. Union
Field: Glenrock
County: Converse
Rank: Subbituminous
Thickness range: 22-38 ft
Average thickness: 35 ft
Producer and mine type:
Pacific Power & Light Co.; Dave Johnston Fuel Recovery Pit; strip

Analysis: Average or range (as-rec'd.)

Moisture, %.....26.0
Volatile matter, %.....33.0
Fixed carbon, %.....32.0
Ash, %.....9.0 - 14.0
Sulfur, %.....0.5
Heat value, Btu/lb.....7,500 - 8,000

Wyodak/Roland-Smith seam

Age: Paleocene
Formation: Ft. Union
Field: Powder River
County: Campbell
Rank: Subbituminous
Thickness range: 55-106 ft
Average thickness: 71 ft
Producer and mine type:
Amax Coal Co.; Belle Ayr; surface mine
Wyodak Resources Development Corp.; surface mine

Analysis: Range Wyodak (as-rec'd.)

Moisture, %.....22.3 - 32.8
Ash, %.....6.6 - 15.2
Sulfur, %.....0.4 - 1.4
Heat value, Btu/lb.....7,640 - 8,640
Fusion deg.F.....2,110 - 2,460

Wind River coal basin

Unnamed seam

Age: Cretaceous
Formation: Meeteetse
Field: Muddy Creek
County: Fremont
Rank: Subbituminous
Thickness range: 9.4-17.4 ft
Average thickness: 17 ft
Producer and mine type:
Muddy Creek Mines Corp.; surface

Analysis: From vicinity of this mine (as-rec'd.)

Ash, %.....8.1

Sulfur, %	0.4
Heat value, Btu/lb	9,920

Basic mining methods to date

Wyoming coal mining methods include underground, surface and auger. Augers have been used less than a year in the state. Underground mines, however, have produced nearly 85% of Wyoming's total production since 1865. The recent dominance of surface mining is rapidly reducing that percentage. Within two decades surface mines should produce as much coal as was mined by a century of deep mining.

Room-and-pillar systems of deep mining have predominated in Wyoming, but panel systems also have been used. Although longwall machines were briefly tried as early as 1910, no longwall production has been reported. Mechanization of the state's drift, slope and shaft mines began with compressed air-driven cutting and drilling machines in 1882. By 1930, electric machines like excavating shovels, undercutting machines, drilling machines, loaders, scraper loaders and shaking conveyors had gradually replaced pick-and-shovel mining and hand-loading methods of the past. With mechanization and modern pillar robbing techniques, extraction efficiencies, which had been about 40% in the past, are now occasionally as high as 70%. Today's larger deep mines are fully automated and even the smaller mines report no hand-mined coal. Of the four active underground mines in Wyoming, three use conventional cut-and-drill techniques while the largest one uses continuous miners. The largest underground mine, Vanguard No. 1, produced almost 75% of the estimated 1972 underground tonnage of 400,000 tons.

Not until 1954 did surface-mined tonnage exceed that of the underground mines. Since then strip-mine production has more than quintupled to 7,866,706 tons in 1971. In contrast, deep mining slumped to one-tenth of its 1954 level, or 140,000 tons in 1971. Wyodak Coal Co. opened Wyoming's first surface mine in 1925, and it is still active. No additional surface mines were opened before 1942, some 18 years later.

Although open-pit and contour types of surface mining are about equally represented today, open pits are likely to dominate future mining. Active surface mines have highwalls between 0 and 150 ft with the average between 40 and 60. As for the future, an open pit with total terraced-relief of up to 900 ft has been considered in the Kemmerer area. While open-pit mining generally utilizes scrapers and shovels for overburden removal, contour stripping most frequently uses draglines with 12- to 62-cu yd buckets. Front-end loaders, dozers, overburden and coal drills, and 50- to 100-ton trucks or truck-trailer combinations comprise the other common equipment. In one instance a belt loader is used to load trailers with overburden.

A single-bit augering machine was used to follow up surface mining near Reliance in 1971 and 1972. In a few months the auger mined 12,000 tons. It used a 42-in. bit for seams ranging between 4 and 10 ft thick. Two rows, one above the other, were bored into the thicker seams and penetrated up to 120 ft horizontally into the highwalls. The augering was discontinued only because the mine closed in mid-1972. The success of the equipment makes future augering operations probable.

Percentages mined by surface and underground

Forty-four underground mines produced 99%, or 8.8 million tons, of Wyoming's record 1945 tonnage. In contrast, a mere 10 surface mines produced more than 9 million tons in 1972. Since 1945, the importance of the two basic mining methods has almost completely reversed, with more than 98% of Wyoming coal now being surface mined. Surface mining should remain dominant well into the next century. Current indications are that deep mines will continue to account for less than 2% of the state's annual production for the next 25 to 30 years. Strict new regulations banning or seriously limiting surface mining could materially alter this outlook. Because most of Wyoming's strippable deposits are too thick and under too little cover to be effectively deep mined, such regulations would exclude 17% of the state's resources from production and would also raise the cost of winning coal in more lives, more dollars, and reduced extraction efficiency.

Manpower

Overall, Wyoming coal industry's manpower requirements plummetted from approximately 3,500 employees in 1945 to 727 in 1971. In this same 27 years, however, employment in surface mines more than quadrupled from 170 to 638. The major reduction, therefore, was in underground mining, which decreased more than 97%, or by 3,241 men. Furthermore, of the 89 men employed by deep mining companies in 1971, only 48 were officially reported as working underground since 41 performed surface support functions. An employment ratio of seven or more surface to one underground employee is expected to continue as long as surface mining maintains its prominence.

Manpower requirements in Wyoming already exceed the availability of trained miners and equipment operators, so that semi-skilled or unskilled applicants must frequently be hired and then trained on the job. This trend is also evidenced at the supervisory, engineering and exploration levels.

Frequent seesawing of trained personnel between the state's coal, uranium and trona industries, as well as between different coal companies, is not uncommon. Coal companies, realizing that it takes more than wages to keep an employee these days, are working with local communities to improve living conditions. An example of this can be seen at Hanna in southeastern Wyoming. Through the encouragement of Energy Development Co., a new housing development is under construction. Even as the first 30 homes were finished, a new shopping mall was opened and a motel

Manpower breakdown by mine type and size in 1971

Mine type	Mine size, annual tonnage	Number of mines	Number of employees Range	Average
Surface	less than 100,000	2	1-2	2
	100,000-500,000	3	12-43	25
	500,000-1,000,000	1	–	32
	1,000,000-2,000,000	4	44-196	123
	Statewide total	**10**	**1-196**	**60**
Underground	less than 5,000	2	–	4
	5,000-50,000	1	–	34
	50,000-100,000	1	–	48
	Statewide total	4	4-48	23

completed. Similar activities will have to continue if the growing coal industry is to attract and retain the work force it will need.

The current work force is about equally divided between unionized and nonunionized companies. A definite trend, one way or the other, is not presently recognizable.

The water problem

Wyoming's industrial water problem is a multiple one. First, the state is not endowed with an overabundance of water. Second, there is little of the state's water that is not already held under a valid water right. These handicaps, coupled with interstate compacts guaranteeing certain amounts of stream flow to neighboring states, seriously limit the water resources available for new development in the state.

Wyoming water law is based on the theory of "prior appropriation." This means all water rights in the state are regulated by priority, with the earliest rights entitled to water during periods of limited supply and those with later rights being denied water during those times. Wyoming's water law further defines preferred uses of water which include, among others, steam power plants and industrial purposes. All other uses are defined as non-preferred uses. However, the priority of a water right, preferred or non-preferred, determines who is entitled to water. Only by condemnation through court action or by purchase can a preferred right take water from a non-preferred prior right.

Although coal mines themselves require little water, the industries they fuel or propose to support are very dependent on relatively large volumes of water. For instance, a conventional, 1,000 Mwe steam electric plant requires 10,000 to 15,000 acre-feet of water per year. If a plant is air-cooled, however, this water requirement is reduced to around 1,500 acre-feet. Proposed 250-Mcfd synthetic gas plants will need 15,000 to 25,000 acre-feet annually. Liquefaction plants (100,000 bbl per day) will consume anywhere from 10,000 to 62,500 acre-feet per year.

For comparison, industrial water consumption for Wyoming's coal mines and coal-fired power plants in 1972 was less than 20,000 acre-feet. The US Bureau of Mines projects that annual water requirements for a synthetic-fuels industry in the Powder River basin of Wyoming and Montana alone could be as high as 2.2 million acre-feet by 1990. Without new or enlarged reservoirs and imported Green River water, they estimate that the industrial water reserves that could presently be diverted to the Powder River basin total only 832,000 acre-feet per year. While such reserves may be adequate to prove the feasibility of coal conversion processes, additional water must be acquired before the remaining requirements can be met.

The limited availability of water resources will be one of the greatest limiting factors to new power plants and coal conversion plants in Wyoming. Obviously, construction of both these types of facilities will hinge on a company's water rights priority.

Reclamation

Under Wyoming's Open Cut Reclamation Act, coal companies reclaimed nearly one-half the surface acreage they affected between 1969 and 1971. In 1971, they reclaimed a record 728 acres or eight times the acreage reclaimed in 1970. Approximately 29% of 3,936 surface acres affected by coal mining through 1971 have been reclaimed.

Admittedly, revegetation of some of this acreage will require years to be fully established, but it is a matter of time rather than an impossibility. The remaining 2,793 acres are abandoned or still actively mined. About 68% of this unreclaimed land predates Wyoming's reclamation act, which has no retroactive clause. Many of these older unreclaimed mines are now naturally revegetated by pioneer native plants. About 75% of the open cuts are used as community landfill sites or are at least periodically used as water holes by livestock and game. Although none of these unreclaimed areas present a documented pollution problem, many limit vehicular access through areas, slightly lower productivity of the land for grazing purposes, and evoke strong aesthetic criticism by contrasting with natural surrounding landforms.

Before mining, most of these affected areas had low land values anywhere from $3-50 per acre. By contrast, reclamation costs for leveling, grading, minimal seed-bed preparation and planting would average at least $200 per acre, and probably more, since there is now no mining equipment nearby with which to accomplish the task.

Because Wyoming coals underlie Indian and public domain lands, as well as state and private lands, reclamation requirements fall under three authorities: Indian, Federal and state. Since there are currently no surface or underground coal mines on Indian lands, it will suffice to say that pertinent regulations can be found in Title 25—Indians: Interior, Chapter 1, Subchapter P, Part 177, Federal Register (effective date Jan. 18, 1969). Regulations pertaining to public lands are set forth in Title 43—Public lands: Interior, Subtitle

Land disturbed by surface coal mining

	Acres
Land disturbed in 1971	1,016
Land reclaimed in 1971	728
Total land disturbed through 1971	3,936
Total land reclaimed through 1971	1,143
Remaining unreclaimed land through 1971	2,793

Wyoming acreage underlain by potentially strippable deposits

	Square miles	Acres
Powder River Basin[1]	110.25	70,560
Green River region[1]	92.09	58,935
Hams Fork region[1]	20.00	12,800
Hanna field[2]	13.13	8,400
Bighorn basin[2]	.07	42
Total	235.54	150,737

1. USBM. 2. Wyoming Geological Survey.

A, Part 23, Federal Register (effective date Jan. 18, 1969, unless new legislation predates publication of this article).

Under these regulations exploration and mining plans for a proposed mine must be approved by a mining supervisor of the USGS and the district manager of the Bureau of Land Management. A minimum bond of $2,000 is required. Reclamation must be as stated and approved in the mining plan. Annual operations reports are required, as well as grading, backfilling, and planting reports.

Because state and Federal requirements are mutually acceptable, Wyoming regulates the reclamation of all affected public coal lands in the state with one exception. That exception is a strip mine exempted by the state because 1) it is totally on public land and 2) it is only a temporary mining method for the company. The USGS inspects that mine and also periodically checks all other operations that affect public lands.

The State's Open Cut Land Reclamation Act became effective May 23, 1969. It regulates the surface mining of all mineral resources in Wyoming, excepting those on Indian lands or others it specifically rules to exempt. Administration and enforcement of the act is delegated to the commissioner of public lands in Cheyenne. The act gives the commissioner authority to adopt and promulgate reasonable rules and regulations for administering the act. Briefly, the act of 1969, or its rules pertinent to coal require:

1. Mining permits ($50).
2. Sufficiency of surety bonds equal to reclamation costs.
3. Minimum guidelines for grading.
4. Reseeding whenever practicable.
5. An annual report that indicates all measures taken to effect land reclamation to include a map.
6. Reclamation timing left to the commissioner's discretion.

Because changes in the Wyoming Open-Cut Land Reclamation Act are imminent this year and will probably occur even before this article is published, some of the more commonly proposed changes are itemized below:

1. Extension of the act's jurisdiction to deep mining.
2. Repeal of the present act and insertion of new statutes into a proposed Environmental Quality Act. Administration would then be under a nine-man board.
3. Require land to be reclaimed to a use of equal or greater value than its prior use.
4. Require an operator's license with provisions for permit denial in the act.
5. Require a reclamation plan prior to issuance of a permit with strict guidelines for the plan. In essence this merely puts current rules and regulations into the act itself, thereby reducing the administrator's authority to make rules.
6. Increase permit fees and add renewal fees and amendment fees.
7. Raise bond minimums to $5,000.
8. Require advertisement of permit applications and public hearings.
9. Require mandatory separation and replacement of topsoil, contour backfilling and revegetation.
10. Rigid time schedule for reclamation.

The requirement dealing with reclamation timing could be particularly detrimental to the state's coal industry since mining methods and plans progress at different rates throughout the state. For example, the Wyodak open-pit mine has operated since the mid-20s. Portions of the pit have been reclaimed in that time, but other portions have remained active. Similarly, other open-pit mines cannot be fully reclaimed until mining terminates.

Contour strip mines on the other hand reclaim a goodly portion of their operation simultaneously with mining. Pacific Power & Light's Dave Johnston Fuel Recovery Pit and Arch Mineral's Seminoe No. 1 mines are two excellent examples of mines that are reclaimed, as much as possible, even while coal extraction continues. To apply to both types of surface mining, timing must be flexible.

Besides these possible changes at the state level, one cannot rule out new Federal requirements. New Federal legislation, however, is not expected before July.

Although the present acreages disturbed by surface coal mining are minimal compared to the state's total land area, the projected expansion of the coal industry will significantly increase the number of affected acres. Known strippable coal resources underlie approximately 150,755 acres or 235.6 sq mi of the state. Based on past records, surface mines have affected two to two and one-half times this pit acreage while mining that resource. Careful mining and reclamation could minimize this disparity between affected acreage and pit acreage. With industry cooperation, sensible reclamation laws and adequate enforcement, there is no reason why forecast coal expansion should cause significant environmental degradation.

Financial climate for mine development

Until recently, an optimistic climate for financing Wyoming coal mines of 2- to 3-million-tpy capability was self-evidenced by the announcement or the opening of five new mines between 1970 and

1972. Now this financial optimism is tempering as the moratorium on Federal leasing and permitting lengthens. Since exploration and acquisition of new reserves are seriously hampered, financial capital is shrinking. Under these conditions, the financing of additional mines could soon be limited to a small group of companies with yet uncommitted reserves. Newcomers would be virtually eliminated and expansion of many existing companies stymied. The Interior Department's recent announcement of a limited short-term leasing policy, designed to keep active operations going, is the first sign of any thawing.

As for the future, financing of synthetic-fuel facilities will have to include the financing of a 5- to 6-million-tpy mine for each new conversion plant. Capital expenditures for such a facility are currently estimated in the neighborhood of $300 to 400 million with estimates of $14 to 20 million of that related to the mine. A recent symposium on Financing Synthetic Fuels, held in Cheyenne, revealed that the financing of the synthetic fuels industry does not have the backing of commercial lenders. Their reluctance to invest in a conversion plant falls squarely on the fact that conversion processes are not sufficiently proven to warrant the investment risk. They pointed out that conversion technology would not be satisfactorily proven until a full-scale plant was on line. The lenders recommended that companies form joint ventures and finance a prototype plant themselves or seek government help if necessary. Since that meeting, several joint ventures have been announced and companies with holdings in Wyoming are participating.

In addition to the question of the technological reliability of conversion processes, environmental, transportation, marketing and pricing questions must also be resolved before an optimistic financial climate will prevail. Again the Federal leasing moratorium could seriously affect this coal use and certainly limits the potential Wyoming participants in such ventures to those already possessing adequate resources.

Wyoming revenues from coal leases, royalties and mineral taxes

	1970	1971	1972
State share of federal lease and bonus bid collections (37.5%)	$145,000	$2,745,000	---
State share of federal royalty collections (37.5%)	114,000	181,000	---
State lease collections	164,407	196,995	---
State royalty collections	1,730	3,970	---
Gross production tax	347,831	731,847	874,263
Severance tax	66,074	128,236	152,305
Total	$839,042	$3,987,048	

Coal mining's multiplier effect

"The decade of conservation, as the 1970s are being called, is having a big economic impact on Wyoming. Far from closing down mines, mills and factories, it is bringing new industry to the energy state."—**Casper Star-Tribune**, Editorial, 1972.

Both industrial and domestic construction, employment, new supportive businesses and railroads are climbing an economic bean stalk just below "King Coal." Tipples, warehouses, silos, offices, maintenance shops, and conveyor belt lines are continually built as mines expand or new mines open to fuel coal-fired power plants in as many as eight states besides Wyoming. Even while the construction of one multimillion dollar power plant in the state nears completion, plans for another plant have been announced. In conjunction with each of these new plants is the additional construction of transmission lines and in the first case, a 42-mi-long water pipeline. In the last 12 years, 14 separate joint state and county industrial roads were built at a cost of nearly $2 million. Many of these roads were to coal mines and power plants.

Between 1967 and 1971 coal mining employment alone has more than doubled from 324 to 727. It is estimated that these 403 new employees create another 320 jobs for direct and indirect support of the industry and to provide it with goods and services it will need. In line with this, at least two new mining service and supply companies established offices in Wyoming in the last six years.

Besides an increase in coal miners, new power plants also create additional jobs. As a recent example, the Jim Bridger plant near Rock Springs employs more than 900 workers in the construction phase and, after its completion, will retain some 200 permanent employees for the plant and mine. A 1969 Cameron Engineer's forecast estimated upwards of 2,300 people will be employed by coal mining or related industries by 1980 and as many as 7,200 by the end of the century. This poses a tenfold increase in less than 25 years. Mining or utility towns like Hanna, Glenrock, Superior and Rock Springs have already witnessed considerable growth, and its related problems as well.

Estimated annual payrolls for coal-related labor forces in the years 1980 and 2000 are $20 million and $60 million, respectively. Capital investments for new mines, power plants and conversion facilities that would employ these people could exceed $5 billion in that same time span.

Just to meet the current influx of permanent and temporary laborers discussed previously, the real estate, home building, and particularly the trailer business, are booming. In fact the demand for housing more frequently exceeds supply and often forces commuting.

Rocky Mountain railroads are experiencing perhaps their greatest rejuvenation in 40 years. In addition to approximately 30 mi of new spur lines already laid in the last four years, another 15 mi of track are already under construction. In late 1972, Burlington