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Coal as an Option for Power Generation in U.S. Territories of the Pacific

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Lawrence Livermore National Laboratory

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LAWRENCE LIVERMORE LABORATORY
University of California • Livermore, California • 94550

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Abstract

A survey of general considerations relating to the use of coal in U.S. territories and trust territories of the Pacific suggests that coal is a viable option for power generation. Future coal supplies, principally from Australia and the west coast of America, promise to be more than adequate, but the large bulk carriers (100,000–200,000 dwt) expected to serve Far Eastern markets will probably not be able to land coal directly in the territories because of inadequate port facilities. Hence, smaller than Panamax-class vessels (60,000 dwt) or some arrangement utilizing self-loading barges or lighters would have to be used. Except for Guam, with peak power requirements on the order of 175 MW_e, most territories have current, albeit inadequate, installations of 1 to 25 MW_e. Turnkey, conventional-coal-fired, electrical-power generating systems are available in that size range. Fluidized bed combustion is another option just now being commercialized. It has clear environmental advantages and can use a variety of fuels (e.g., coal, heavy oils, biomass, etc.) with no interruption of power generation. U.S. environmental laws, such as the Clean Air Act, are now applicable to Guam and American Samoa; the trust territories are exempt. When United Nations trusteeship terminates, the current unclear position of the Commonwealth of the Northern Marianas will cease and the laws will probably apply. Nonetheless, the small power requirements of many small islands will qualify for exemption from the New Source Performance Standards called for in the Clean Air Act.

The principal problems with coal use in the territories, apart from the shallow draft of most harbors, are the limited amount of land available and the high capital costs associated with conversion. Ocean dumping of ash and sludge can be permitted under existing Environmental Protection Agency regulations, and barge-mounted power installations are not out of the question. The feasibility of converting from oil-fired to coal-fired electrical-power generating systems must be determined with site-specific information.

Introduction

In 1981 a team of technical representatives from the Department of Energy (DOE) surveyed the territories and trust territories of the Pacific in response to directives of the Omnibus Territories Act of 1980 (PL 96-597). The ultimate objectives of the Act include preparation of a comprehensive energy plan for these "entities," with emphasis on indigenous renewable sources of energy. The Act also calls for assessment of the mix of energy sources (including fossil fuels) and identification of the technologies needed to meet the projected demand for energy.

The first phase in implementing the Congressional mandate resulted in a series of team recommendations[1] designed to provide information that would further the objectives of the Omnibus Territories Act. The recommendations were drawn up in concert with officials of the individual territories and, to a large measure, reflect their perceived needs in light of the energy future they envision as desirable in their particular territories. Thus, many chose to explore solar and wind options while others, as appropriate, believed in the potential of geothermal or biomass options. Land

availability in the Pacific territories is generally a critical factor in the choice of future energy sources. Hence, OTEC (ocean thermal energy conversion) was generally viewed as a highly desirable option. When perfected, it can provide base-load electrical power and, in this respect, is almost unique with respect to many of the renewable energy forms available to Pacific islanders.

There are indications that OTEC, even when it becomes available commercially, will be a capital-intensive option. More important than OTEC's expected high initial cost, however, is the fact that the energy problems, particularly those centered on fuels for electrical power generation, are acute *now* and need near-term solutions that OTEC cannot as yet provide. Costs for diesel and residual oils used for power generation are increasing rapidly and outstripping the ability of the various governments to pay for them.

Except for Guam and American Samoa, no territory (or trust territory) wished to consider coal as an alternate fuel and, with the exceptions noted, no concerted effort was made to appraise the coal option. Two reasons why coal was not favored were that, like oil and gas, it is an imported fuel with associated vulnerabilities and that new land requirements for plant sites, storage, loading, and ash disposal are implicit in its use for power generation.

Nonetheless, in view of the expected increase in international steam-coal trade, it seems worthwhile to review some issues related to the possible use of coal in the Pacific territories. How large will the coal trade become in Pacific Rim countries? Where will it come from? What will it cost relative to conventional liquid fuels? Could it become available in other territories? Are they are the main trade routes? These and many other questions can be broached in a general way to determine whether there is any possibility of converting to coal as an interim fuel for power generation—i.e., until base-load power capacity is developed from renewable energy sources.

The feasibility of coal use in any one entity must ultimately rest on site-specific considerations that, in turn, influence the cost of the installations. For this reason, no attempt is made here to estimate accurately the total cost of the possible systems that might be adopted to land coal, burn it to raise steam, and run turbines to generate electricity. Rather, the emphasis is on nonsite-specific issues.

Status of Territories

Guam and American Samoa have been U.S. territories since the end of the nineteenth century. By contrast, the U.S. Trust Territories of the Pacific Islands (TTPI, Fig. 1), under the aegis of the United Nations, came under U.S. administrative control after World War II. These Western Pacific islands include the Marshall Islands, Ponape (Ascension Island), Palau, the Marianas Islands, Yap, Truk, and Kosrae. The trusteeship is now in the process of termination, and new agreements are being established between the TTPI entities and the U.S. government. These agreements, which have varying natures, will probably be concluded during 1981–1982. Northern Marianas proposes to become a commonwealth of the U.S., while Palau, the Marshall Islands, and the Federated States of Micronesia—Ponape, Yap, Truk, and Kosrae—plan to be a party to "compacts of free association." When these agreements are concluded, there will be an interim period of perhaps 10 years; during this time, the U.S. government will, to some degree, continue to support the operation of the local governments.

The applicability of many U.S. laws and regulations now and in the future is, under the new agreements, not clear in all cases. The current and likely future applicability of U.S. laws is treated on a territory-by-territory basis in later sections dealing with environmental considerations. Uncertainties, as in the case of the CNMI (Commonwealth of Northern Marianas Islands), may persist until the laws are clarified.

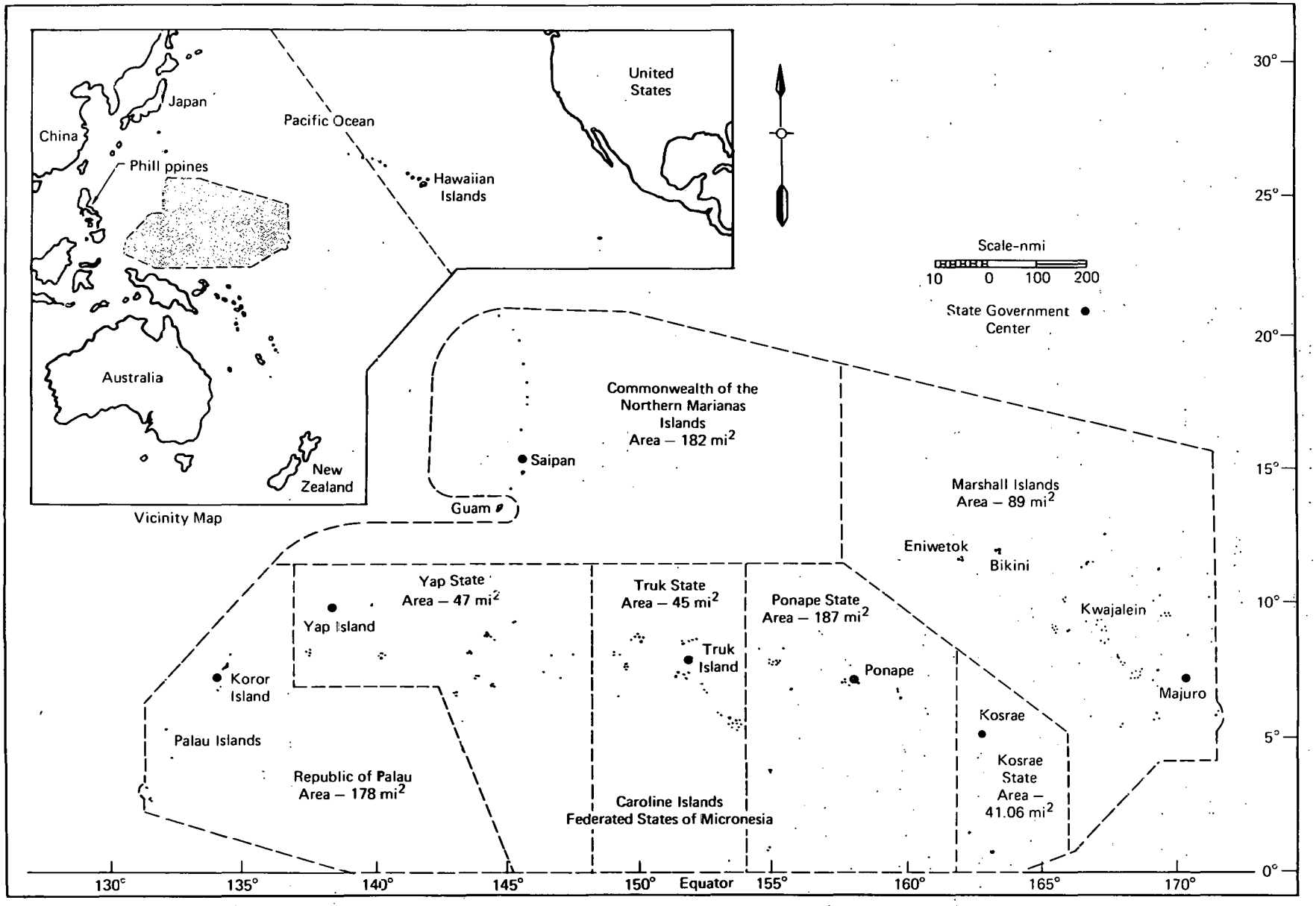

Figure 1. Trust Territories of the Pacific Islands.

Opportunities for Coal Use in Territories

The generation of electricity is the largest single end use for conventional hydrocarbons on most of the Pacific islands. The demand for fuel for resident fishing fleets is high on American Samoa and Palau, and military use for transportation is substantial on Guam. Table 1 shows the electrical generating capacity on the islands. The low operating capacity per person in some territories attests to the inadequacy of existing systems to meet minimal electrification standards; the dispersed nature of the population in some island groups such as Truk and Yap also accounts for the low figures. Thus, use of the operating capacity data on a per-capita basis must be used with reservation in attempting to gauge market size, future demand, or the likely size of future power plants.

Only Guam's demand is in the 100–200-MW_e range. All other territories have requirements on the order of 1–25 MW_e. Thus, the coal-fired boilers and turbines used as replacements for existing systems would be small. Depending on the system chosen, the annual coal requirements for a 25-MW_e unit are in the 105,000–122,000-ton range. These requirements correspond to two or three large dry-bulk-carrier deliveries per year, assuming storage space is available. In places like American Samoa, the large, indigenous fish industry could conceivably utilize waste heat from power production for canning processes. The cogeneration option might be pursued if a plant site convenient to the fisheries on Pago Pago Bay could be found. There are few new plant sites on the shores of the already crowded bay.

Table 1. Electrical generating capacity of territories and trust territories of the Pacific (1981).

Territory	Base load (MW)	Peak load (MW)	Operating capacity (MW)	Population	Operating capacity[a] (kW/person)
Guam	120	155	173	105,800	1.64
American Samoa[b]	12.6	13.3	13.3	32,395	0.41
CNMI[c]	10.5	14.5	21.6	16,862	1.28
Marshall Islands[d]	3.1	4.3	4.9	31,045	0.16
Palau	2.2	3.1	4.0	12,173	0.33
FSM[e]—Truk	1.1	3.1	6.0	37,383	0.16
—Ponape	1.8	2.3	2.5	22,367	0.11
—Yap	1.0	1.2	3.3	8,173	0.40
—Kosrae	0.2	0.3	0.52	5,522	0.094

[a] Typical figures for California (March 1981) are on the order of one kilowatt per person.[2]

[b] Includes Tutuila, Ofa, and Tau.

[c] Saipan only; Tinian, Rota, and others are less than one megawatt.

[d] Majuro, Ebeye, and Jaluit.

[e] Federated States of Micronesia.

World Demand for Steam Coal

Projected growth in international coal trade is impressive[3] (Fig. 2), with the largest share of the increase being in steam coals. Table 2 is a breakdown of steam-coal trade forecasts. Western Europe and the Far East will be the principal markets; the principal buyers, in almost equal amounts, will be the U.S., Australia, and South Africa.

Some indication of the breakdown in steam-coal demand in the Far East can be found in Table 3. The small differences between totals in Tables 2 and 3 reflect the differing opinions of the forecasters. The demand for steam coal in the Far East is dominated by industrial Japan. By 1980 Australia will have 40% of the Far Eastern steam-coal market, and the U.S. share will have increased to 20%. Canadian exports from Pacific Northwest ports are certain to increase, perhaps to a level of 25 million tons per year.[5] Exports to date have been comprised mainly of metallurgical coals and may continue to be so. Recently negotiated contracts with Japan call for 8 million tons of coking coal per year for a period of 20 years beginning in 1983. To what extent steam coals will make up Canada's future exports from Pacific ports is uncertain.

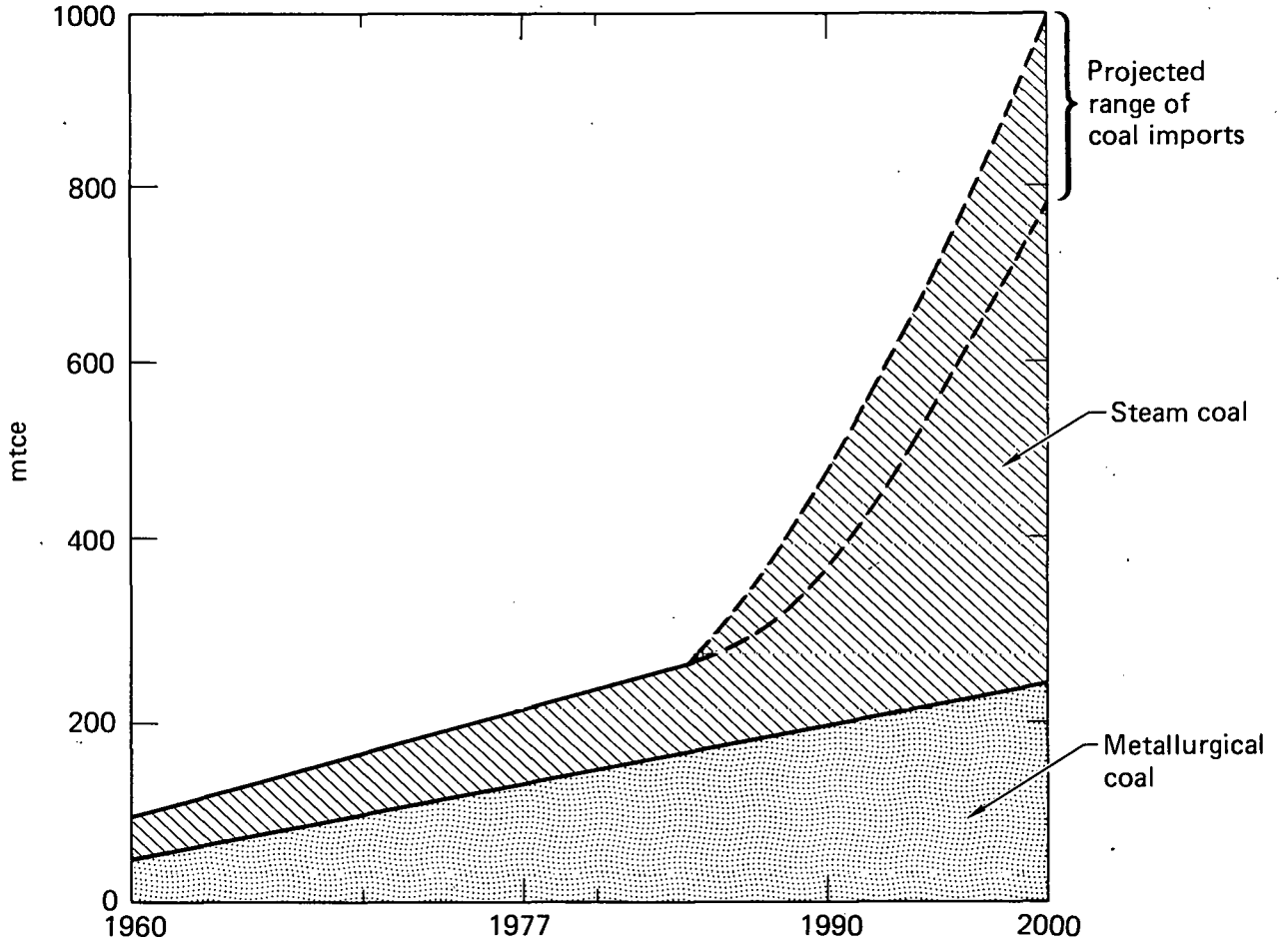

Figure 2. World coal imports (from Ref. 3).

Table 2. Steam-coal trade forecasts[4] (MST[a]).

Market	U.S.	Australia	South Africa	Other[b]	Total
Western Europe					
1985	28	17	38	19	102
1990	48	28	61	39	176
1995	63	63	80	51	257
Japan and Pacific Rim					
1985	8	28	4	18	58
1990	23	46	12	36	117
1995	48	77	22	53	200
Canada (Eastern)					
1985	12	—	—	—	12
1990	12	—	—	—	12
1995	12				12
Others					
1985	2	3	2	—	7
1990	5	6	2	—	13
1995	5	7	8	—	20
Total[c]					
1985	50	48	44	37	179
1990	88	80	75	75	318
1995	128	147	110	104	489

[a] Millions of "standard" short tons (24×10^{12} Btu).

[b] Western Canada, Colombia, China, USSR, and Poland.

[c] Excludes Eastern Europe.

Table 3. Demand for imported steam coal—Far East[6] (MMT[a]).

Country	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Japan	9.4	15.5	18.3	23.4	27.5	34.6	37.0	50.2	57.4	62.7
Taiwan	—	0.6	1.9	2.7	3.5	6.0	10.0	12.2	13.8	15.8
Korea	0.5	2.7	5.6	7.6	8.7	10.0	12.0	13.2	14.3	15.8
Hong Kong	—	1.3	2.8	3.9	4.7	5.2	6.4	8.2	8.2	8.2
Singapore	—	—	—	—	—	—	—	—	1.6	1.6
Others[b]	—	—	—	—	—	—	—	2.0	2.0	2.0
Total	9.9	20.1	28.6	37.6	44.4	55.8	65.4	85.8	97.3	106.1

[a] Million metric tons.

[b] Others, like the Philippines.

In the long term, the reliability of a foreign coal supply depends on the size of the resource. The data in Table 4 put the sources available to the Far East into perspective. Although additional sources could conceivably become available (e.g., from Europe or the U.S.S.R.), the countries listed remain the Far East's most likely sources to the turn of the century.

South Africa's port at Richards Bay, probably the most modern coal export center in the world today, is being upgraded to accommodate 200,000-dwt vessels. The price advantage South Africa currently has in international coal trade may persist for a decade or until the use of large ocean-going vessels between the U.S., Australia, and Canada allows economics in transportation costs that compensate for the low mining and domestic transportation costs in South Africa.

China supplies some coal to Japan now and may wish to cultivate a greater trade in the Pacific in the future. Coal promises to remain China's main source of fossil fuel.

Colombia is also hoping to supply coal to foreign markets and is discussing contracts with Brazilian, European, and Japanese buyers[8]; however, the country's reserve base is small. As described elsewhere in this report, expanding coal traffic from Canadian ports is certain. Indications are that Canada will continue to supply metallurgical rather than steam coal. Thus, the U.S. and Australia will likely share steam-coal trade in the Pacific Rim countries. Issues like price and dependability, as well as the ability to deliver needed quantities, will dictate market shares.

Table 4. Proved, recoverable coal reserves (billions of metric tons, coal equivalent) in selected countries[a,b] (Ref. 7).

Country	Bituminous/ anthracite	Subbituminous/ lignite
South Africa	25	—
Canada	1.6	2.8
U.S.	107	84
Colombia	1	Small
China	99	—
Australia	25	11

[a] The tonnages of subbituminous coals and lignites have been reduced by 0.78 and 0.3 to be on a par with bituminous coals/anthracites.

[b] Substantial "additional resources" are potentially available in all countries; they exist at depths below 450–1800 m depending on the reporting country.

The vast deposits of subbituminous coals in the western states of Montana and Wyoming may not find buyers despite their low sulfur content (Table 5). The high ash and water content of the coals lower the average Btu content per unit burned and raise transportation costs on a Btu basis to prohibitive levels. Beneficiation of the coal, although a solution, raises the price. The Japanese, Koreans, and Taiwanese have sought to conclude contracts with Utah and Colorado companies to ensure themselves of high-Btu steam coals.

Table 5. Quality of coals available for export to Pacific Rim countries.

Coal source	Sulfur content (%)	Btu/lb
Illinois Basin	2–5	11,000
Eastern North Appalachian coal	1.5–4(?)	13,000
Powder River, Wyoming	< 1	8,000–9,000
Utah	1–2	11,000–13,000
Colorado	< 1	11,000–14,000
Beluga, Alaska	< 1	7,000–8,000
Alberta, Canada	< 1	11,000–14,000
Australia—Blair Athol, Queensland	< 1	11,000
—Newcastle, New South Wales	< 1	12,000

Steam coals comprise between 67 and 86% of the total U.S. supply of bituminous coals depending on whether only premium coals are used for coking or a wider spectra of available coals are considered to be of metallurgical grade.[9]

Australia's annual production of raw black coal from colleries in New South Wales is in excess of 90 million tonnes. The Australians export about 43 million tons of coal, of which 80% is coking coal. More than two-thirds of the coal exported is destined for Japan. The large change in the character of worldwide demand that is taking place will alter the emphasis in Australia to steam-coal exports as it similarly promises to affect U.S. coal trade.

Australia has two main coal-producing areas (Fig. 3): the Sydney Basin in New South Wales and the Bowen Basin in Queensland[10] (Figs. 4 and 5). The rail distances between ports and the coal-producing areas indicated on the maps are on the order of 100–300 km. Deposits in the Sydney Basin are generally underground. The three main coal producers in the Sydney Basin are Broken Hill Properties Company, Ltd., which uses the coking coal it produces, the NSW Electricity Commission, which uses coal for power production, and Clutha Development, 50% of which is owned by British Petroleum Ltd., whose entire production is exported. Most coal in Queensland is mined by open-pit methods, and most of the production in the

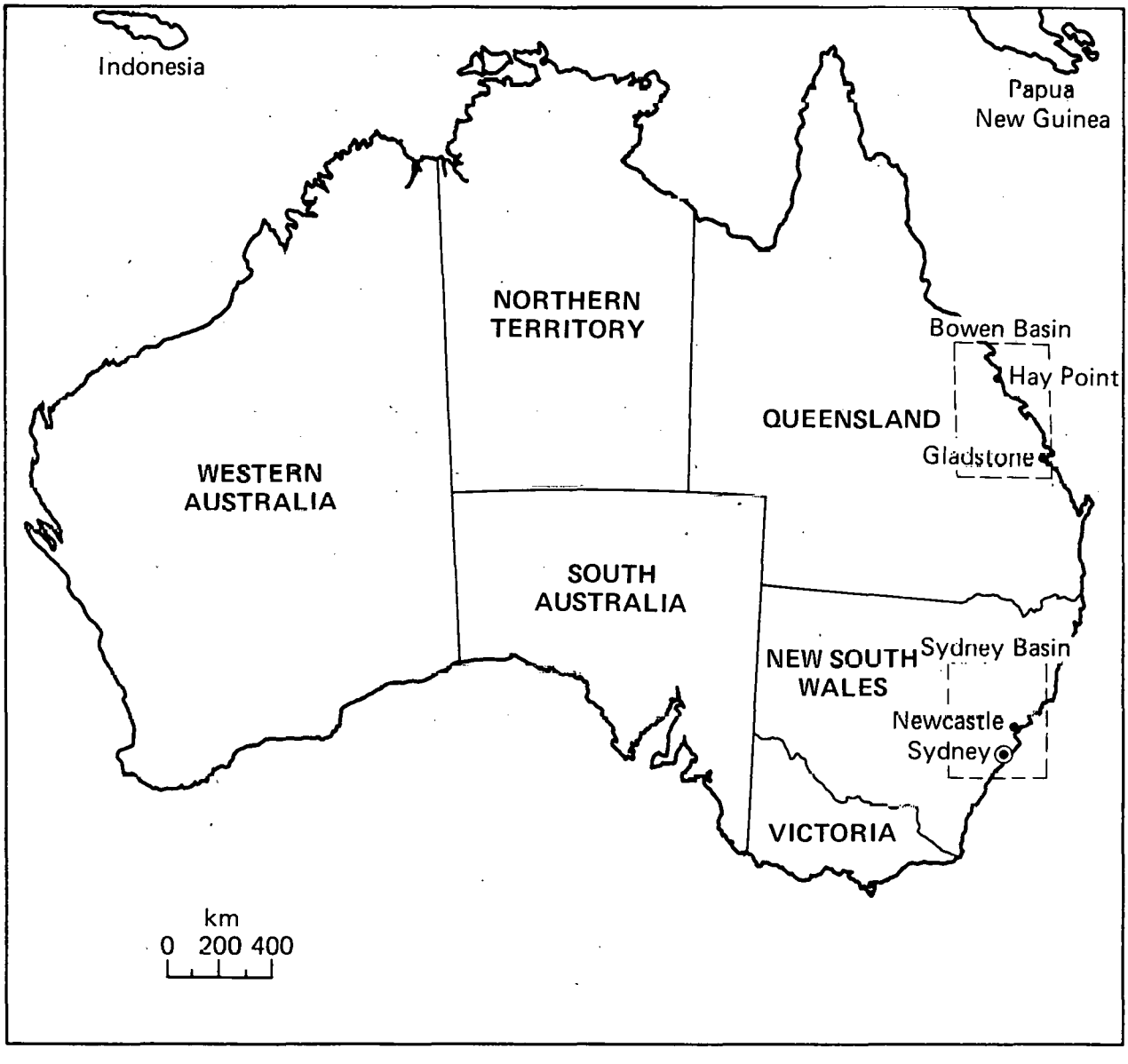

Figure 3. Principal coal-production areas in Australia.

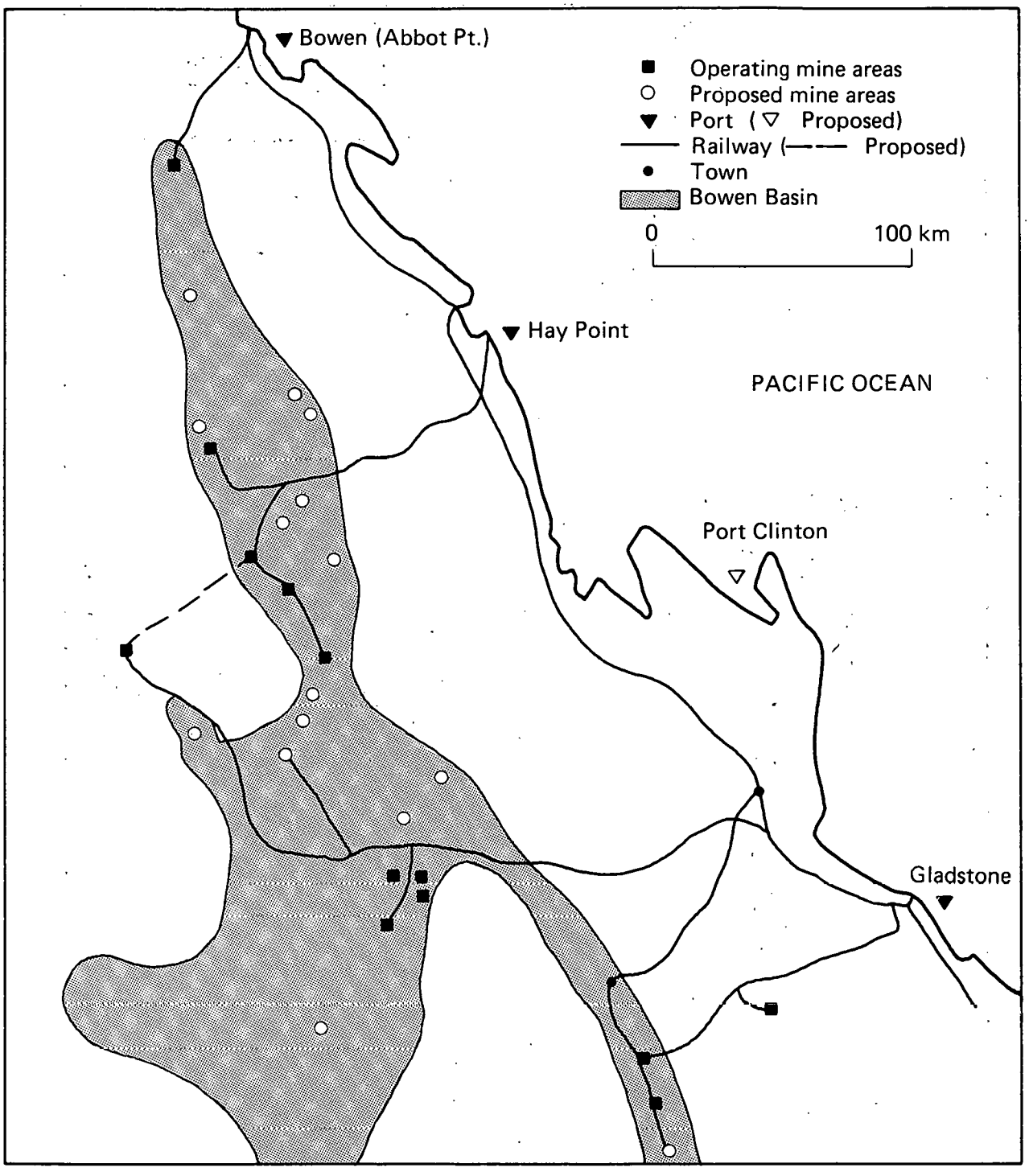

Figure 4. Bowen coal basin, Queensland, Australia. Source: Australian Coal Association.

Bowen Basin is by Utah International, a General Electric subsidiary. There are other foreign interests in Queensland, as well as a few small, domestically-owned mines.

Australia's ability to deliver coal to the export market is tied to labor relations in a nation where strikes are endemic. However, the size of the export facilities can mitigate problems associated with

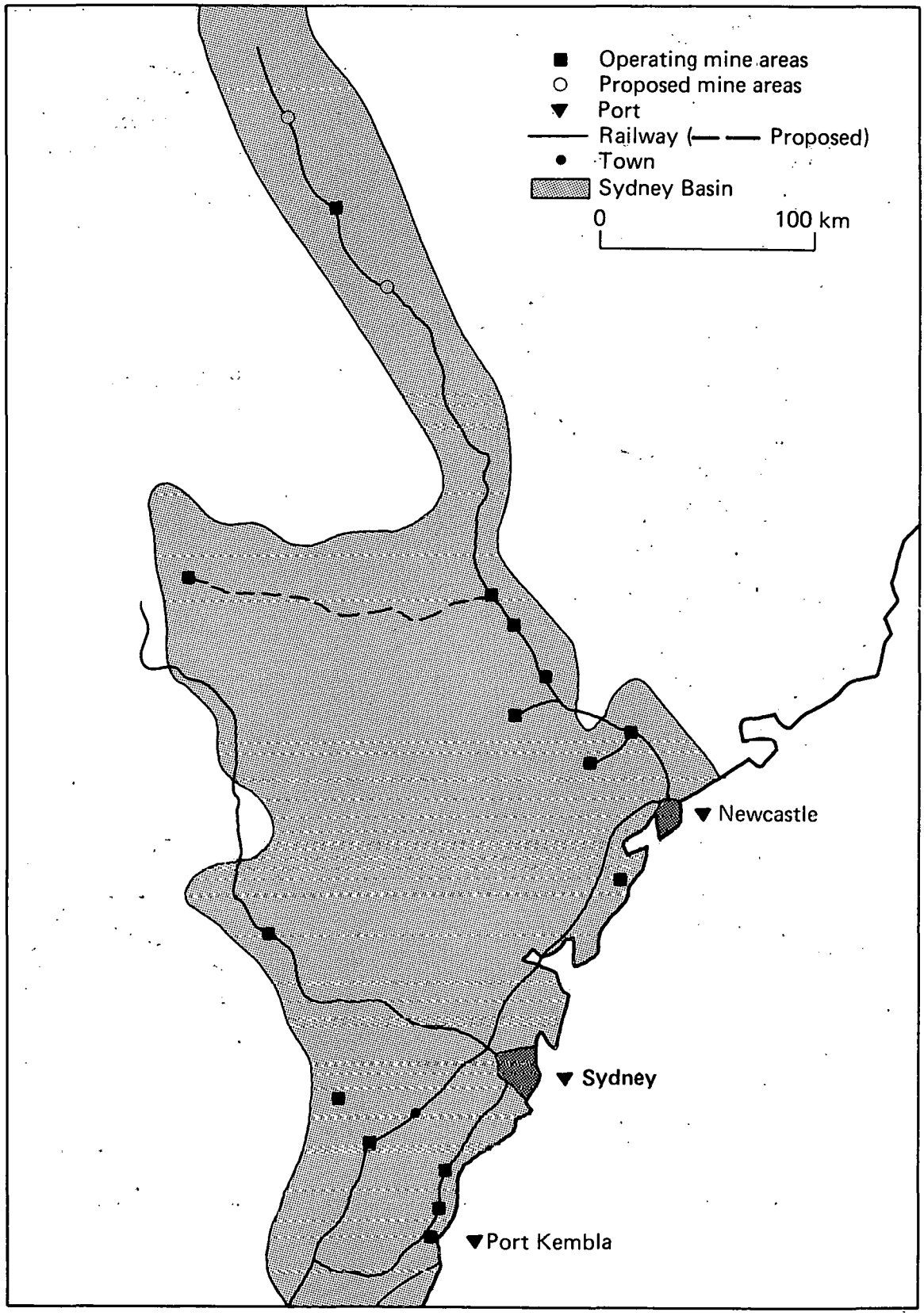

Figure 5. Sydney coal basin, New South Wales, Australia. Source: Australian Coal Association.

strikes as it did during the recent three-month strike at Utah International's Queensland mines, where large stockpiles at the Hay Point loader allowed the exporter to meet contractual agreements. Continued agitation is expected from the major maritime trade unions even though some progress was made in 1981 through the first agreements to export coal from Australia in Australian-owned and -crewed ships.[11] The added cost will be defrayed in part by using the vessels to import phosphate from Christmas and Naru Islands on return trips. In the long term, the coal trade will outstrip the phosphate trade and costs will have to be borne solely by coal users. Maintaining the edge in cost-competitiveness that Australia now has in Japanese markets may not be easy. Dismay over new, threatened Australian strikes has led the Japanese to seek other coal suppliers.[12]

In the long term, Australia's ability to meet anticipated great demand for steam coal (Table 2) is also dependent on development of requisite infrastructure. Adequate rail facilities are critical to an expanded industry; without them resulting port and rail congestion could drive markets elsewhere.

U.S. Coal Exports

International demand for U.S. coal increased markedly in 1980 because of numerous factors, only one of which was the switch from oil to coal (Table 6) for electrical power generation. Other factors were a mine workers' strike in Australia, a rise in ocean freight rates that made U.S. imports to Europe and Japan more attractive relative to those from South Africa and Australia, and the political unrest in Poland. The bulk of U.S. imports (exclusive of imports to Canada) is metallurgical-grade coal used primarily in steelmaking; in 1980 the ratio of metallurgical to steam coal was on the order of 5 to 1, while that in 1979 was 17 to 1 (Ref. 13). Thus, the market has begun to turn around. Metallurgical or coking coals are high-grade bituminous coals that, as mined or after cleaning, contain less than 8% ash and less than 1.25% sulfur. Steam coals vary substantially in heat, ash, and sulfur content. Because these coals are used as boiler fuels, heat content and rank have a strong influence on their price; however, environmental considerations relating to sulfur content increasingly require that tradeoffs be made. Future U.S. coal exports are expected to consist of a larger proportion of steam coals. Estimates as to the size of the total export market are given in Table 7.

Table 6. **Recent U.S. steam-coal exports (millions of short tons).**[4]

Importer	1977	1978	1979	1980
Western Europe	1.1	0.1	7.3	14.1
Japan and Pacific	—	—	0.1	1.7
Canada	10.6	9.2	11.6	10.8
Other	0.1	0.1	0.4	0.8
Total steam-coal exports	11.8	9.4	19.4	27.4
Total coal exports	53.7	39.8	64.8	89.9

During the first seven months of 1981, the European Economic Community (Belgium, France, West Germany, Italy, the Netherlands, the United Kingdom, Ireland, and Denmark) and Japan, respectively, bought 37% and 31% of exported coking coals and 51% and 10% of exported steam coals.[14] In the first quarter of 1981 the principal ports used for the export for bituminous coals, which comprise almost 100% of combined coking and steam coals, were Hampton Roads in Newport News and Norfolk, Virginia (62%), Baltimore, Maryland (11%), New Orleans, Louisiana (9%), and Los Angeles/Long Beach, California (5%).[15]

As indicated elsewhere in this report, U.S. coal prices are higher than those from some other sources; however, the dependability of supply from the U.S. may more than compensate for the higher costs. Even during the 110-day U.S. coal strike of 1977–1978, the exports of coal were not embargoed. A national commitment of dependability may keep U.S. coal prominent in international markets.

The Jones Act, which requires ships operating between U.S. ports to be owned, registered, and crewed by the U.S., is not applicable in the U.S. Trust Territories of the Pacific Islands. It does apply in Guam and American Samoa, however, and may become law when the trust territory status of the CNMI ceases and it becomes a commonwealth of the U.S.

Table 7. Long-range forecasts of net U.S. coal exports (overseas and Canada).

Source	Actual 1980 exports (million tons[16])	Forecasted exports (millions of short tons) 1985	1990	1995	2000
World Coal Study[3]					
High	90	88	132	—	221
Low	90	77	94	—	138
Sensitivity	90	—	—	—	386
U.S. Department of Energy[17]	90	85	108	143	—
Includes metallurgical coal	63	59	70	86	—
Includes steam coal	27	25	37	57	—
ICF, Incorporated[18]	27	65	80	—	—
Data Resources, Incorporated[19]	27	85	102	122	144
National Coal Association[20]	27	74	89	—	—
First Boston Corporation[21]	27	92–102	117–142	—	—
Dean Witter Reynolds[22]	27	100	120	—	—
Corps of Engineers et al.[23]	27	75	110	—	—

Prices

Costs for contracts yet to be negotiated are elusive, but some comparisons have been made for supplies going to Japanese markets. Table 8 shows the cost-competitiveness to Japan of various bituminous coal sources.[4,10] Costs, as opposed to rates or prices, are quoted in 1981 dollars. Coal from new mines would cost more. These estimates are useful only for comparison since costs and prices have escalated in all markets during 1981. Australia's Sydney Basin steam coal ex Newcastle was $54.40 FOBT (free on-board terminal) by May 1981.[24] Price trends for 1980 and 1981 are given in Fig. 6.

Figure 7 puts these costs into further perspective by adding pollution-abatement equipment and maintenance costs and comparing them to the amount of oil needed to provide equivalent heat. Japan has the most stringent pollution laws in the world. By mid-1980, however, coal costs were only half those of conventional boiler fuels such as oil. Excluded from this analysis were capital costs associated with the conversion to coal for electrical power generation. It is also worthwhile pointing out that the cost/price estimates in Table 8 and Fig. 6 reflect the economy of scale available to a large industrial nation like Japan. In other words, fuel costs could be significantly higher for both coal and oil if deliveries were smaller or more frequent or if storage and unloading facilities were inadequate. From a strict fuel point of view, however, conventional steam coal has a clear cost advantage over diesel or residual oils used for power generation.

Table 8. Cost-competitiveness to Japan of bituminous steam coals ($/short ton).

Source	Mine cost[a]	Transportation cost Domestic[b]	Ocean[c]	Total cost
U.S.				
Utah Central	$24	$18	$12	$54
South Africa	20	8	15	43
Australia[b]				
New South Wales	22	7	15	44
Queensland	24	9–11	13	46–48
Western Canada	30	12	10	52

[a] Includes taxes.

[b] Assumes unit trains.

[c] Includes loading/unloading and assumes 100,000–150,000-dwt vessels.

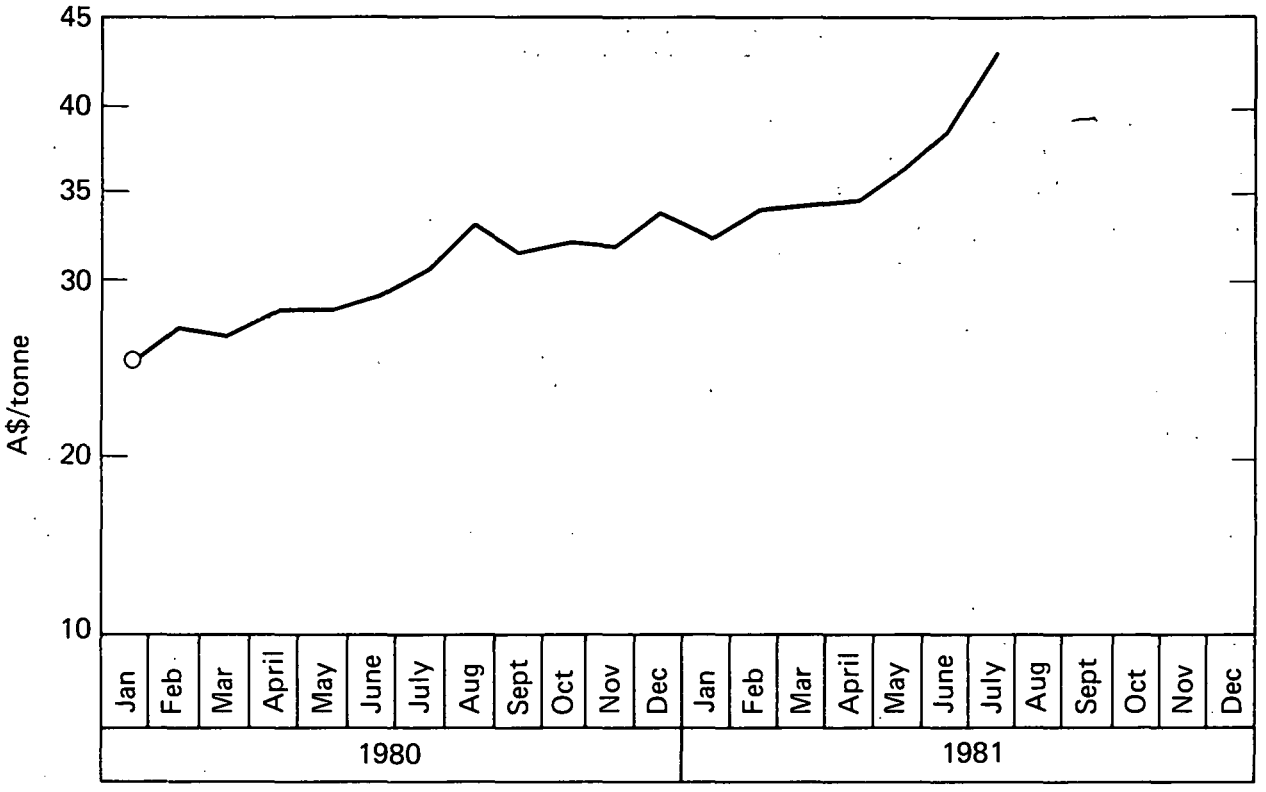

Figure 6. Price of Australian steam coal to Asia, FOBT ($1.15 U.S. to $1.00 A).

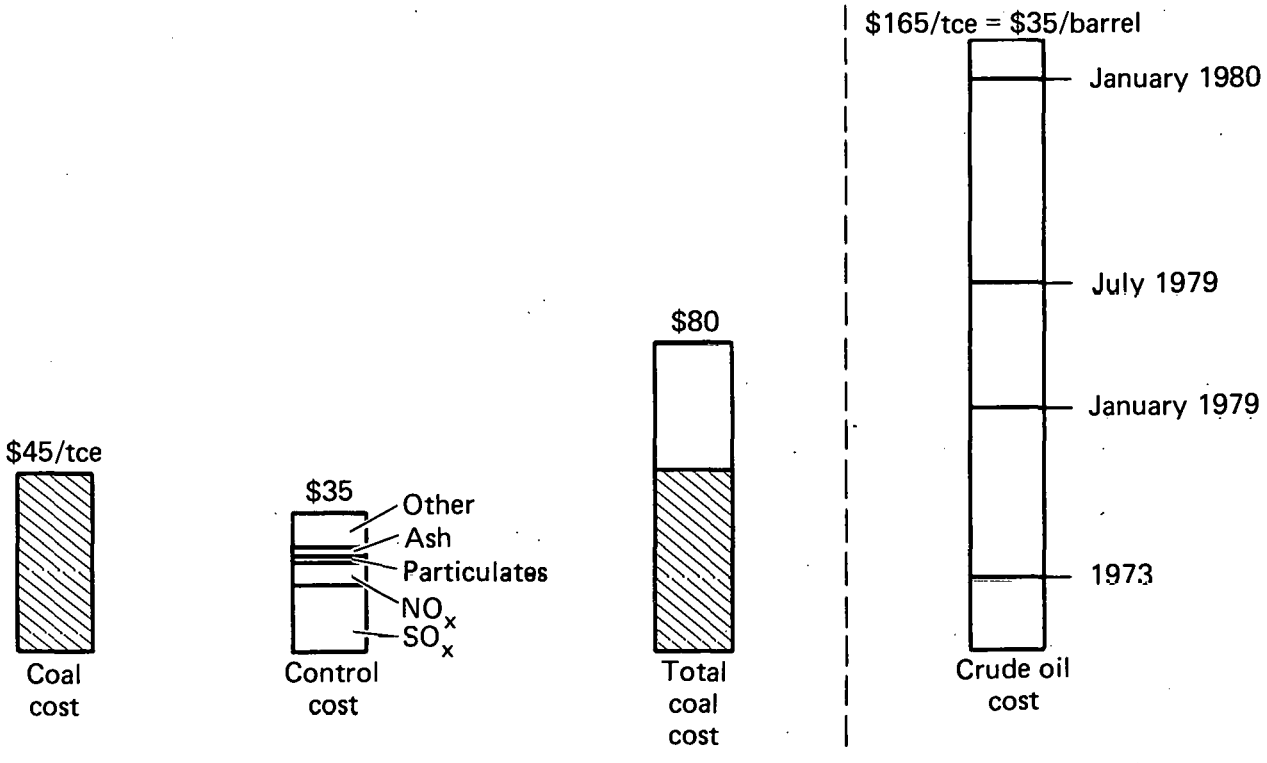

Figure 7. Environmental costs of coal in Japan (from Ref. 3).

U.S. Export Facilities

The anticipated increase in coal exports from U.S. ports will require the upgrading and enlargement of ports, transportation, and terminal facilities. The transportation system includes domestic railroads, barges, and possibly slurry pipes, in addition to deep-sea bulk carriers. Critical terminal facilities include land for storage, equipment to load/unload rail cars or barges and to convey, sample, and mix and, in the case of slurried coal, dewatering plants.

Ports

U.S. ports and harbors (Table 9) are currently inadequate to handle large increases in steam-coal exports economically. The problems relate to their inability to accommodate deep-draft, dry-bulk carriers in the 100,000–200,000-dwt category (Table 10). Significant cost savings can be realized by utilizing large vessels when the distances traveled are measured in thousands of miles. Only two coal-loading ports in the U.S. (Los Angeles/Long Beach and Norfolk) are able to handle larger than 100,000-dwt vessels.[25] On the other hand, Japan has 13 ports that can handle carriers with drafts greater than 45 ft, while Canada has two and Australia has one. Dredging and upgrading are going on at six Australian coal-exporting centers, at two Canadian ports, and at least three Japanese ports. Many U.S. ports have considered increasing their capability to handle large ships, but the method of financing the improvements has not been settled. Historically, the U.S. Corps of Engineers has had the task and the costs have been borne by the Federal government. In an effort to limit Federal spending, the Reagan Administration has been reluctant to back proposals such as the National Port and Navigation Improvement Act introduced in 1981 that would involve a 60% contribution by the government. Rather, the Administration proposes 100% non-federal funding of all costs, suggesting that the ports themselves contribute to construction costs and that user fees be levied to pay for the operation and maintenance of new facilities. Discussion in the U.S. House and Senate continues, but the issue has not been resolved.[26]

Some 83% of the world's dry-bulk carrier fleet weighs less than 50,000 dwt.[27] From all indications,[28,29] however, 30% of ocean-borne coal traffic will be in vessels in excess of 100,000 dwt (45-ft draft) by 1985. By the year 2000, the common carrier will weigh 150,000 dwt (53-ft draft).

Table 9. Eastern and Gulf Coast coal-exporting facilities.

City	Dock	Railroad	Theoretical annual capacity (million tons)
Philadelphia, Pennsylvania	Pier 124	Conrail	3
Baltimore, Maryland	Curtis Bay	B&O	14
Newport News, Virginia } Hampton	Piers 14/15	C&O	19
Norfolk, Virginia } Roads	Piers 5/6	N&W	34
New Orleans, Louisiana	Electro-coal	M.P.	10
	International Marine Terminal	B.N.	11.5
Mobile, Alabama	McDuffie Terminal	Miss Rv B.N. S.L.S.F.	8-10
Toledo, Ohio East Chicago, Illinois Sandusky, Ohio Astabula, Ohio Connaut, Ohio	Lake Michigan and Lake Erie	Many	Large

Table 10. Dimensions of dry-bulk freighters.

Vessel (dwt)	Fully-loaded draft (ft)	Length (ft)
20,000	30.2	558
25,000	31.8	591
32,000	34.1	623
40,000	36.7	689
50,000	39.4	755
60,000	41.7	787
80,000	43.3	820
100,000	45.9	853
125,000	48.2	914
160,000	54.1	984
200,000	65.3	984

To pass through the Panama canal, ships must be in the 60,000–70,000-dwt or Panamax class. Presumably, future coal destined for the Far East from either eastern or Gulf ports would be of that size, although coal destined for Japan has been shipped in large boats (170,000 dwt) from ports on the St. Lawrence Seaway.[30] With the availability of larger ships on all routes, the selection of route will be influenced increasingly by considerations of distance. Hence, West Coast exports to the Far East will become more important.

West Coast ports with coal-handling facilities are grouped in Table 11. Ports in the Los Angeles harbor ship Utah and Colorado steam coal, while Vancouver handles Alberta coking coal shipped to the Far East. Roberts Bank, British Columbia, is the largest port on the West Coast in terms of the capacity and size of vessel it can accommodate. Taking the expansion plans of all ports into account, Roberts Bank is likely to remain the largest coal-exporting facility well into the 1990s. Also listed in Table 11 are proposed, new, or enlarged facilities. Many have only reached the proposal stage since funding and guaranteed coal supplies for shipment are not assured. If all proposed U.S. facilities were built, they would more than exceed the demand for U.S. coal exports and it seems unlikely that all will be built.[32] Of the proposals listed in Table 11, only those at Astoria, Oregon, and Prince Rupert, British Columbia, Canada, could handle carriers larger than 100,000 dwt.

Railroads

Adequate rail facilities are requisite to U.S. coal exports. Unit trains consisting of 98–110 cars are used increasingly to transport coal between mine and user or marine terminal. "Bottom dump" or swivel coupling allows dumping without decoupling. A 110-car train with 11,500 tons of coal can be unloaded in four hours or less.[33] Some of the railroads serving coal-exporting ports, i.e., Burlington Northern (B.N.) are in excellent shape and are already geared up to handle increased traffic. Others are not so well prepared because they lack cars, loop track for turnaround, adequate road beds, or proper grades and curves.

The decision to develop the port at Prince Rupert rather than Kitimat in British Columbia was influenced strongly by costs associated with upgrading the Kitimat rail route.[34] In the West, Union Pacific (U.P.) is involved in enlarging its coal-carrying capacity this year by adding 400 cars to the 8,300 in operation. In the first seven months of 1981, Union Pacific handled three million tons of coal destined for Pacific Rim countries. Southern Pacific (S.P.) runs three mine-to-power-plant unit trains but has not served export markets to date even though the potential is there. Western Pacific (W.P.) delivered a unit train of Utah coal to Nevada (its first) and expects to handle export business in the future.

Terminals

Regardless of how it is delivered, coal arrives more or less continuously but leaves in 20,000–100,000-ton amounts depending on ship size. On-site storage is needed in either railroad cars or piles. In the case of metallurgical or coking coal, the coal is kept in cars to facilitate accurate mixing with other suppliers' coal to meet buyer specifications. The complexity of the mixing process associated with coking coal will probably not extend to steam coal, but buyer specifications on sulfur, water, ash, and Btu content will require some segregation. As a rule, storage is needed for about 10% of the annual throughput—i.e., for an annual throughput of 15 million tons of exports, 1.5 million tons of storage would be needed. This storage space amounts to about 100 acres or roughly the area enclosed by a railroad loop

Table 11. West Coast coal-exporting facilities.

Port	Channel depth (ft)			Capacity (million tons)			Railroad
Existing facilities							
U.S.	Existing plan (year)			Existing plan (year)			
Long Beach, California	51	60	(1985)	3	10–15	(1985)	U.P./A.&S.F./ S.P.
Los Angeles, California	51	65	(1985)	2	10	(1987)	Same
					15	(1990)	
Stockton, California	32	37	(1986)	0.05	1	(1982)	W.P./S.P./
					5	(1990)	Utah Pac.
Anchorage, Alaska[31]				0.10			
Canada							
Vancouver							
Roberts Bank	>58	>61	(1983)	11	25	(1983)	B.N.
Neptune Terminal	>50			3.5			B.N.
Proposed new or enlarged facilities							
U.S.[a]	Proposed plan (year)			Proposed plan (year)			
Sacramento, California	30	35		3			S.P./
				8–13			W.P.
Redwood City, California		36		2		(1983)	S.P.
		40		10–15		(1996)	
Richmond, California	38	41		2		(1983)	
Astoria, Oregon	40	55		12			B.N.
Portland, Oregon	40			3–5		(1984)	U.P./
				10–12		(1989)	B.N.
Vancouver, Washington	40			3–5		(1984)	U.P./
				6		(1992)	B.N.
Canada							
Prince Rupert, British Columbia		>61	(1983)	7.7		(1984)	C.N.
				15		(1990)	

[a] Other proposed new or enlarged facilities include Selby, California, Coos Bay, Oregon, and Gray's Harbor, Bellingham, Tacoma, Kalama, and Anacortes, Washington.

track.[27] Thus, a large coal-loading facility has a substantial land requirement.

Loading from storage to shipside can be accomplished in a number of ways. Traveling shiploaders can load at the rate of 5,000 tons per hour. Other devices, such as various sorts of conveyors, are also possible.

Australian Port Facilities

To increase coal exports substantially, Australia has started an extensive program of port expansion. Exports of 78–95 million tons (1985) are expected to reach 100–130 million tons by 1990.[35] Currently, only the Hay Point coal facility in Queensland can handle vessels larger than 100,000 dwt; the remaining ports cater to the Panamax-size (60,000 dwt) vessel. By 1984, almost all ports will be able to accommodate ships in the 120,000–150,000-dwt class (Table 12). Both ports and railroads are owned by the Australian states. If port-improvement plans go ahead as planned, rail

Table 12. Australian coal-loading facilities.

	1980 annual loading capacity[10] (million tons)	1984 annual loading capacity[10] (million tons)	1984 maximum draft (ft)	Vessel size (dwt)
New South Wales				
Newcastle (2 berths)	17.0	25.0	49–54	125,000–175,000
Sydney (2 berths)	4.5	4.5	42	60,000
Pt. Kembla	7.5	14.0	53	150,000
Total New South Wales	29.0	43.5		
Queensland				
Hay Point	20.0	35.0	61	200,000
Gladstone (3 berths)	17.0	23.0	49–53	120,000–150,000
Abbot Point (near Bowen)	–	4.0	53	120,000–150,000
Other	1.0	1.0		
Total Queensland	38.0	63.0		
Total Australia	67.0	106.5		

links to mines, infrastructure at railheads, new rail cars, and upgraded road beds will have to be forthcoming to meet the anticipated increase in exports.

Sea Routes to the Far East

The shortest routes from the west coast of North America to Yokahama, Japan, are great circular routes that pass south of the Aleutian Islands (Fig. 8). The Vancouver/Yokahama route is approximately 4,250 nautical miles; the Los Angeles/Long Beach route is 4,840 miles. During the winter months (November–March) southern sea routes cross the Pacific 200–500 miles north of the Midway Islands. By these longer routes, Yokahama to Vancouver and Los Angeles are, respectively, 4,900 and 5,300 nautical miles. No conventional sea lane to Japan, Taiwan, South Korea, Hong Kong, or Singapore passes near the islands of Micronesia or the territories.

Trade moving between the west coast of Australia and the Far East has the choice of many routes. Bowen, Queensland, to Yokahama is on the order of 3,000 nautical miles. Points in between or near shipping lanes such as the Northern Marianas, Guam, Truk, Yap, and Palau are less than 2,000 nautical miles from Queensland ports.

Ponape, Kosrae, the Marshall Islands, and American Samoa are also between 1,800 and 2,000 nautical miles from the east coast of Australia; however, they are not convenient to sea lanes to the Far East. American Samoa, in fact, is almost due east of Australia.

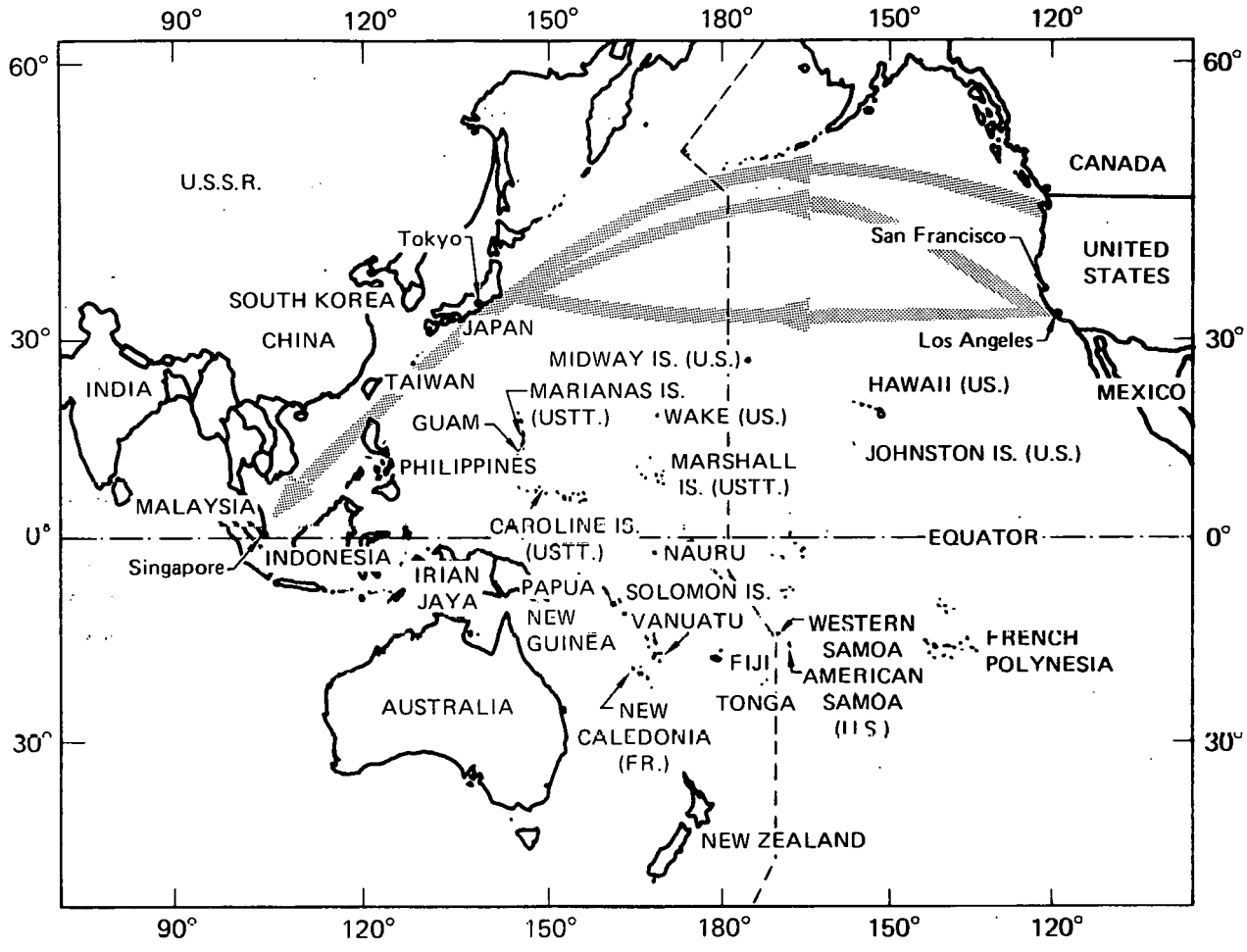

Figure 8. Sea routes to the Far East from the West Coast of America.

Territorial Harbors

The use of coal for electrical power generation in the Pacific islands is tied to the suitability of docks, harbors, and channels for use by the dry-bulk carriers that ply the oceans. Diesel and residual oils—the most common fossil fuels currently being used by most islands—can, by contrast, be delivered by pipeline from moorings some distance from the actual docks. Hence, dockside depths are not necessarily critical to the use of liquid fuels. In the case of coal, pipeline delivery is possible but not likely. Slurried coal is expensive to transport long distances by boat, and adding water once in harbor to transport the coal by pipeline has few if any precedents.

Coral development near the shores of many Pacific islands restricts the access of large vessels in all but a few locations. Table 13 lists the major and potential ports in the U.S. territories and trust territories. In general, existing facilities can rarely accommodate vessels whose drafts are greater than 40 ft (50,000 dwt). The common Panamax-size (60,000 dwt) dry-bulk carrier can only be brought dockside in a few places like Guam or Kwajalein in the Marshall Islands. However, several undeveloped harbors could be developed, such as those in American Samoa. In addition, dredging is planned for several existing ports or has been completed since the charts referred to in Table 13 were

Table 13. Harbor and channel depths in U.S. territories and trust territories.

Territory	Maximum depth near shore (ft)	Minimum channel depth (ft)	Defense Mapping Agency chart No.	Chart date
Guam			81054	11/22/80
Apra Harbor				
Cabras (commercial port)	32–36	100		
Dry Dock Point (wharf E&D)	38–42	100		
Inner Harbor	30	35		
American Samoa			83484	03/26/77
Pago Pago	36	210		
Fagasa Bay	30	78		
Fagatele Bay	108	168		
Larsen Bay	108	156		
Other sites on southeast side	96	Large		
Northern Marianas–Saipan				
Puetton Tanapag			81076	09/10/77
Pier C	29	29–30		
Pier A (if rebuilt)	30	29		
Bahia Laulau (if filled)	60	Large	81071	04/05/80
Northern Marianas-Tinian	28	30	81071	04/05/80
Palau			81151	09/27/75
Koror				
Malakal Harbor	32	66		
Koror Harbor				
Pipiroi Inlet	20	77		
Ebaduls Pier	39	77		
Federated States of Micronesia				
Truk			81329	04/01/78
Eten Island	21	90		
Dublon (Pore)	30	48		
Dublon	30	60		
Moen	32	147	81327	05/09/81
Yap			91193	05/06/78
Tomil Harbor	18–24	90		
Ponape			81453	05/20/78
Not Point	27	96		
Takatik	28–32	96		
Kosrae			81488	04/25/81
Lele Harbor (Yepan Point)	36	138		
Lele Harbor (Lele Island)	27	138		
Coquille Harbor	66	210		
Marshall Islands				
Majuro (Uliga)	34	120	81782	09/10/77
Kwajalein	60	72	81711	02/16/80
Ebeye (Entiwetok Passage)	6	72	81711	02/16/80

updated. The suitability of these docks and harbors for coal transfers must be determined on a case-by-case basis since potential storage areas and possibly power-plant sites must also be considered. Nonetheless, except for a few isolated cases, it seems unlikely that the large coal carriers (100,000–200,000 dwt) envisaged to form the backbone of Far East coal trade in the 1990s and beyond will ever service the islands directly. Other alternatives can be imagined, such as using large but stationary floating coal vessels in deep waters to offload the coal as needed to smaller ships or barges for transport to shore. Cost and environmental factors will influence the viability of such proposals. Suffice it to say that the ability of the territories to land coal will be an important determinant in decisions regarding its use.

Coal and Storage Requirements

The amount of fuel needed to fire boilers for steam production depends on the heat content of the available fuel and the exact system used. In general, coal-fired boilers for a 25-MW_e power station need 12 to 14 tons per hour of 10,000-Btu/lb coal.[6,36,37] Lesser amounts are required for smaller systems, or if a higher-Btu coal is used.

In the U.S., it is customary to store a 60- to 90-day supply of fuel in case of shortfalls from suppliers, i.e., 16–25% of annual throughput. For 25 MW_e, this equates to a storage requirement of 17,000–20,000 tons for a 60-day supply and to 26,000–30,000 for a 90-day supply. Dead storage of this sort would occupy one to two acres of land, assuming the coal is built up to 25 feet compacted and is preferably enclosed or sodded and seeded.[38] Additional ("live") storage is also needed to accommodate surges in coal delivery brought about by high-tonnage, intermittent ship deliveries. This storage area could consist of barges—e.g., with an 8,000-ton capacity—that are equipped with a tripper or stacker designed to unload 4,000 tons per hour, which is the unloading rate of self-unloading ships.[38] Alternatively, clamshell bucket unloaders could be used with slower digging and transfer rates. Overland conveyors would be suitable for transfer between the plant and the "live" and "dead" storage areas.

Ash disposal and transport is another area of concern. Four to seven percent ash content by weight is typical of the ash content of bituminous coals. Ocean dumping is feasible but must be approved by the Environmental Protection Agency if done by a territory or commonwealth of the U.S. Dumping permits are from point of origin, so the territorial limit, whether 12 or 200 miles, is immaterial.[39]

Coal-Burning Technologies for Power Production

Currently, conventional combustion of coal usually refers to direct combustion of pulverized coal in high-pressure boilers. Another so-called "conventional" combustion mode is moving-grate-fired coal boilers. The product of both is steam. For a 25-MW_e unit, approximately 250,000 pounds of steam per hour must be raised to 950°F and, depending on the system, up to 1300 psig. *Unabated* emissions consist of 0.83 lb SO_2, 0.50 lb NO_x, and 4.18 lb particulates per 10^6 Btu.[38] Scrubbers can remove more than 76% of the SO_2, and electrostatic precipitators can reduce particulates to very low levels. Ultimate waste consists of bottom and fly ash and scrubber sludge, which is produced at rates of about 1,000 lb (ash) and 1,100 lb (sludge with 50% moisture) per hour, again depending on the system and on the character of the coal. Costs in the continental U.S. are on the order of $1,000–$1,500 (1981 dollars) per installed kilowatt.

A promising coal-conversion technology uses fluidized bed boilers (FBB). Its advantages over other conventional systems are its ability to burn a variety of fuels (e.g., low-grade coals, coal-oil mixtures, wood, biomass, and heavy oils) and cost advantages associated with environmental and pollution controls. Ground limestone ($CaCO_3$) is fed into the FBB with coal, and limestone scrubs up to 90% of the SO_2 from effluent gases. The $CaSO_4$ formed

is removed with the ash. In the island environment, reef limestone is ubiquitous and is quarried for use as road metal. The low firing temperatures (815–870°C) in the FBB lead to a reduction in NO_x production over conventional systems, and furnace slagging is eliminated.[40] Numerous conventional systems are in operation primarily as industrial heat sources. The first large, commercial, coal-fired FB steam generator in the world is being installed by Foster Wheeler Boiler Corporation at the Shell Nederland Raffinaderiji BV complex at Europort. This generator will furnish 110,000 lb of steam per hour at 923°F and 1,190 psi to a turbine. Its capacity to generate electricity will be in the 12–13-MW_e range. The plant at Europort is 100 by 200 ft and 120 ft in height. Such plants can be barge-mounted, and the number and shape of the boilers can be modified to suit specific site requirements. Numerous manufacturers are entering the marketplace (Babock and Wilcox, Steinmuller, Combustion Engineering, and Stone–Platt Fluidfire Ltd. to name but a few), and packaged minipowerhouses will be available in the near future. Costs for Stone–Platt Fluidfire Ltd. are estimated at $1,344–$1,456 per kilowatt installed (1981 dollars) for a 5–10-MW_e installation.[36] These estimates include the cost of the building, coal hoppers, cooling-tower circuit, switchgear, stacks, and installation. The main-package (boiler, turbogenerator, condensors, and feed system) cost estimates are approximately $700 per installed kilowatt. The 10-MW_e system is housed in a building that is 54 by 150 ft and approximately 41 ft in height. Installation time is estimated at 13 weeks.

Despite the fact that numerous engineering firms are proposing to build FBB, these systems are still emerging from the experimental stage. The reliability of the systems still has to be assessed, as does their economics under operating conditions. The costs quoted here are the minimal costs for island applications and installations. Further, the added complexity of the units (over conventional systems) may, as far as operation and maintenance are concerned, tax technical resources at the installation sites. Operators for all types of coal-conversion technologies will probably have to be trained in equivalent U.S. facilities.

Applicability of U.S. Environmental Laws to Pacific Territories

The provisions of the Clean Air Act and its 1970 and 1977 amendments apply to Guam, American Samoa, and the Commonwealths according to Section 302d of the Act. (According to this section of the Act, the term "state" means a state, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, Guam, and American Samoa and includes the Commonwealth of the Northern Marianas Islands.) The U.S. trust territories are exempt. This is contested by CNMI since it is a commonwealth bound by the 1976 covenant with the U.S., with an elected, constitutional, Independent government, and yet still covered by the U.N. trusteeship that is due to be terminated in the near future. CNMI has objected to being subject to the law and, in contrast to Guam and American Samoa, has never filed a "state implementation plan" with the Environmental Protection Agency (EPA).[26]

Implementation of the Clean Air Act and its amendments by EPA requires that the following standards be taken into account when new power plants are sited:

- Standards of Performance for New Stationary Sources (40 Code of Federal Regulation 60, December 23, 1971; revised 1977).
- Prevention of Significant Deterioration (Part C, Clean Air Act, as amended by PL 95-95, August 7, 1977, and by PL 95-190, November 16, 1977).
- New Source Review (40 Code of Federal Regulation 51, November 25, 1971; revised 1976 and 1977).

The Stationary Source standards are applicable to new or modified fossil fuel plants of more than 73 MW_t (2.5×10^8 Btu/hour heat input) or approximately 20 MW_e of 27% efficiency.[38] Because most electrical-power generating facilities needed in the Pacific territories are smaller than 28 MW_e, the emission standards associated with the EPA regulations probably would not have to be met.

However, Guam power stations, which have a collective current peak load of 155 MW, would, if replaced or modified, almost certainly qualify. In fact, when Guam was building the Cabras power plant (132 MW) in 1973–1975, a Delayed Compliance Order[41] was issued to investigate an innovative technique to remove SO_2 from the high-sulfur (3–14%) residual oils being burned. The seawater scrubbers that were installed have allowed relief from New Source Performance Standards, but the test will end in 1982; at this time the Guam Power Authority will have to demonstrate the adequacy of the experimental scrubbers, install conventional abatement equipment, or go to lower sulfur fuels.

Notwithstanding attainment and maintenance of U.S. national air quality standards, the Clean Air Act also requires "states" to protect the air from degradation. A precondition for construction or modification of any major stationary source is that a plan be formalized to ensure continuing maintenance of air quality or, in the case of nonattainment, of the standards.

The New Source provisions of the Clean Air Act prohibit the construction of any pollution source that would interfere with the attainment of air quality standards. Implementation of this directive has varied with state and district. Exemptions of many sorts have been granted in the U.S., e.g., because of the use of innovative abatement technology, which results in lower emissions than do standard technologies. In California, exemptions have been granted when there were benefits to be gained through emission reductions or by "tradeoffs" at existing sources.

Prevailing trade winds and high rainfall greatly minimize pollution problems in all the Pacific Island territories. Meeting EPA ambient air quality standards is not difficult in most places; however, emission limitations set by the New Source Performance Standards could prove troublesome in new installations larger than about 20 MW_e. Fortunately, except for Guam, new installations are likely to be substantially larger (Table 1).

Other U.S. environmental laws potentially pertinent to the use of coal in the islands could be cited, including the Clean Water Act of 1977, which has jurisdiction in Guam, American Samoa, and the Trust Territories of the Pacific Islands (Section 502) and governs water discharge from power plants, and the Marine Protection, Research, and Sanctuaries Act of 1972 (PL 92-532) and its amendments, whose implementation by the EPA regulates dumping in ocean waters and would determine the conditions under which coal could be dumped. All territories and trust territories are covered by this act and by the Resource Conservation and Recovery Act of 1976 (PL 94-580), which authorizes EPA and the states to regulate the monitoring and disposal of solid waste. As of this writing, the latter act has jurisdiction in Guam, American Samoa, and the CNMI.

Thus, of the four environmental laws considered, only the Clean Water Act has jurisdiction in the Trust Territories of the Pacific Islands. This jurisdiction will presumably cease upon termination of the U.N. trusteeship for all but the CNMI. Unless Congress passes special exemptions, all four laws will be applicable (if they are not already) in Guam, American Samoa, and the CNMI.

Conclusions

The coal option in the U.S. territories and Trust Territories of the Pacific Islands has been examined in a general way to determine if it is viable as a near-term solution to pressing problems associated with electrical power production in almost all entities. It is clear that world traffic of steam coal will at least triple by 1990; Far East imports, principally to Japan, Taiwan, and Korea may increase by a factor of 10 in the same time frame. Hence, the availability of fuel to the Pacific Rim countries and to the Pacific is not in question. By most accounts, Australia will continue to dominate Far Eastern markets and perhaps the world market as well until the turn of the century. The U.S.,

although not far behind as a major world exporter, will face competition from Western Canada, Colombia, South Africa, and China, as well as Australia, for the Far Eastern market. The principal western ports of embarcation will be the Los Angeles/Long Beach harbors and Vancouver, British Columbia. Many western states are thinking about enlarging their export facilities to accommodate the anticipated increase in steam-coal exports (e.g., Astoria, Oregon, and Stockton, Richmond, and Sacramento, California); however, financing of the ambitious programs has not been forthcoming.

The trend to very large dry-bulk carriers for coal (100,000–200,000 dwt) poses a problem for both exporting ports and importing countries. Major U.S. coal ports will be upgraded by 1984. The size and draft of the large vessels anticipated to carry 30% of world coal traffic by 1985 and most of the coal traffic by the year 2000 limit the number of existing facilities that will be able to land coal by conventional techniques. Very few existing harbors in the territories can handle vessels of that size now. Some ports, such as Apra Harbor in Guam, plan to increase dockside depths in the near future, but most harbors will still be unable to handle very large coal-carrying vessels. Any carrier would have to be of the Panamax size or smaller—comprising 83% of the world's dry-bulk carriers—to unload coal at dockside at most territory and trust territory facilities. Alternative sea deliveries can be imagined. For example, seagoing barges with self-loading/unloading capabilities could be used as lighters for large vessels moored offshore.

One reason Australia will dominate Far East markets is the shorter distances between principal coal ports in Queensland and New South Wales and the ports of other exporting nations. The shortest routes from the west coast of the U.S. to Japan, Korea, Taiwan, etc., tend to be several thousand miles longer than from Australia. By and large, the islands of Micronesia discussed here are not near these great circular routes. The cost saving associated with transportation from Australia, however, is balanced to a degree by Australian state royalties, export duties, and excise taxes. In addition, continuing labor problems in Australian colleries and ports have caused many coal-importing countries on the Pacific Rim to diversify their sources of supply irrespective of the cost penalty. There is also the additional question of whether smaller countries lying far off conventional trade routes would be served by vessels engaged in international trade.

There are several options for the use of coal in power production; the most common conversion technology is in high-pressure boilers using pulverized, bituminous coal. The total installed cost at conventional U.S. sites is in the range $1,000–$1,500 per installed kilowatt (1981 dollars). Presumably, the cost would be higher in island locations in the Pacific. Turnkey electrical-power generating facilities are available from a number of engineering firms. Another in-use combustion technology is the fluidized bed boiler, which is clearly advantageous because it is able to utilize a wide range of feedstocks (coal, heavy oil, biomass, etc.) and requires a minimum of pollution-abatement equipment. Its disadvantages include slightly higher capital costs, system complexity, and the relatively untried nature of the technology in commercial electrical-power generating sectors. All the coal-combustion technologies that might be envisaged as appropriate to island installations would require that personnel be trained in the U.S. at sites of operating units.

When compared on a Btu basis, the price of coal is substantially lower than the price of crude oil. By mid-1980, for example, coal at $45 per ton on a common Btu basis can be equated to oil at $165 per ton coal equivalent, i.e., to oil at $35 per barrel. Added pollution costs for coal might bring the cost up to $80 per ton of coal equivalent—still less than half the cost of crude oil. The cost of refined oil products, such as distillates and residual oils, would increase the disparity in fuel costs even further. Nonetheless, the high capital costs associated with the installation of coal-burning power plants must be balanced against the fuel saving over the lifetime of the plant.

Guam, American Samoa, and the Commonwealths are subject to EPA regulations relating to power-plant construction that stem from the Clean Air Act and its amendments. The TTPI is exempt but, because the U.N. trusteeship remains to be terminated, the double status of the CNMI has led to disputes as to whether EPA regulations are applicable. Compliance with the Jones Act, which requires that transport between U.S. ports be in vessels registered, crewed, and owned by the U.S., is also in dispute in the case of the CNMI. Although the Act holds for Guam and American

Samoa, the TTPI is not subject to the Act now and will probably be excluded from its provisions in the future.

Because the power-plant requirements of most territories are below the limit stipulated in the New Source Performance Standards (about 20 MW_e), the purchase of pollution-abatement equipment could possibly be avoided in many territories. Other pollution laws relating to water discharge and ocean dumping must be met, however. Under certain circumstances, the ocean dumping of ash and sludge is clearly permitted. The future applicability of U.S. laws and regulations to the trust territories will, once the U.N. trusteeship is terminated, be determined by the compacts of free association now being negotiated.

This review indicates that coal combustion could be an energy source for electrical power generation in the territories and trust territories of the Pacific. Although there do not appear to be any insurmountable obstacles of a general sort, land and capital requirements for construction of new power plants are important considerations. Evaluations and recommendations must be made with detailed site-specific information that has not been included here.

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