The Outlook for Thermal Coal

Boum-Jong Choe

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ABSTRACT

This paper uses an econometric simulation model of world energy markets to project the competitive supply, demand, and prices for thermal coal as a part of overall energy balance projections. Under the assumptions of moderate economic growth in the market-economy countries and a pricing path for OPEC oil that remains relatively stable for the rest of the 1980s but increases steadily in the 1990s, the market economies' demand for thermal coal is projected to increase from 1,247 mtce in 1982 to 1,505 mtce in 1990 and 2,020 mtce in the year 2000. The share of coal in total primary energy consumption is expected to remain approximately constant for the 1982-90 period but increase slightly in the 1990s.

Recent setback suffered by the coal industry resulted primarily from economic recession. Latest data show that substitution of thermal coal for hydrocarbon fuels in thermal electricity generation took place steadily in the industrial countries, despite the softening of petroleum prices. It is the continuation of this substitution process that will provide one of the main sources of demand growth for thermal coal in the medium term. Sensitivity results with the model, however, show that petroleum prices will have a major medium- to long-term impact on the degree of substitution and hence on the demand for thermal coal. Uncertainties of economic growth, nuclear power supplies, and price elasticities of fuel demand are also shown to be the key elements that can substantially change the future of thermal coal.

World coal resources are more than adequate to meet the increasing demand for thermal coal to the year 2000 and beyond. In view of the basically competitive structure of the world coal industry, it is reasonable to expect that, in the long term, the international coal prices will not increase beyond its long-term costs of supply. Based on the available estimates of the long-term supply curve for the important coal exporters, the international export price of thermal coal is projected to increase at 1.3% p.a. between 1985 and the year 2000.
Cette étude utilise un modèle de simulation économétrique des marchés mondiaux de l'énergie pour projeter la situation de l'offre, de la demande et des prix du charbon de chaufferie dans le cadre de projections globales du bilan énergétique. Si l'on suppose que les pays à économie de marché auront une croissance économique modérée et que les prix du pétrole de l'OPEP resteront relativement stables vers la fin des années 80 mais qu'ils augmenteront régulièrement dans les années 90, la demande de charbon de chaufferie dans les économies de marché devrait passer de 1,247 millions de tonnes d'équivalent charbon à 1,505 en 1990 et 2,020 en l'an 2000. La part du charbon dans la consommation totale d'énergie primaire devrait rester à peu près constante de 1982 à 1990 mais on s'attend à ce qu'elle soit légèrement en hausse dans les années 90.

La crise récente de l'industrie charbonnière tient principalement à la récession économique. Les dernières données montrent que le remplacement des hydrocarbures par du charbon de chaufferie pour la production d'électricité thermique s'est de plus en plus imposé dans les pays industrialisés malgré le fléchissement des prix du pétrole. La poursuite de cette tendance sera l'une des principales causes de la croissance de la demande de charbon de chaufferie à moyen terme. Les résultats de l'analyse de sensibilité montrent pourtant que les prix du pétrole auront une forte influence à moyen et à long terme sur l'intensité
du remplacement et par là même sur la demande de charbon de chaufferie. Les incertitudes de la croissance économique, l'approvisionnement en énergie nucléaire et l'élasticité-prix de la demande de combustible sont également considérés comme des éléments clés susceptibles de modifier sensiblement l'avenir du charbon de chaufferie.

Les ressources mondiales de charbon suffisent amplement à faire face à la demande croissante de charbon de chaufferie jusqu'en l'an 2000 et au-delà. Vu la structure généralement compétitive de l'industrie mondiale du charbon, il est raisonnable de penser que, à long terme, les prix internationaux du charbon ne dépasseront pas les coûts à long terme de l'offre. Selon les estimations disponibles de la courbe de l'offre à long terme chez les principaux exportateurs de charbon, le prix international du charbon de chaufferie à l'exportation devrait augmenter de 1,3 % par an entre 1985 et l'an 2000.
En este documento se utiliza un modelo de simulación econométrica de los mercados mundiales de energía a fin de proyectar la oferta, la demanda y los precios competitivos del carbón térmico como parte de las proyecciones globales de balance de energía. Según los supuestos de crecimiento económico moderado en los países con economía de mercado y la trayectoria de precios para el petróleo de la OPEP que seguirá relativamente estable durante el resto del decenio de 1980, pero se elevará paulatinamente en los años noventa, se prevé que la demanda de las economías de mercado con respecto al carbón térmico aumentará de 1.247 Mtec (millones de toneladas de equivalente en carbón) en 1982 a 1.505 Mtec en 1990 y a 2.020 Mtec en el año 2000. La proporción de carbón en el consumo total de energía primaria deberá permanecer constante en el período de 1982-90, pero aumentar ligeramente en el decenio de 1990.

Los recientes reveses experimentados por la industria del carbón fueron básicamente el resultado de la recesión económica. Los últimos datos muestran que la sustitución de combustibles de hidrocarburo por carbón térmico en la generación de electricidad tuvo lugar regularmente en los países industriales, no obstante la disminución de los precios del petróleo. Es la continuación de este proceso de sustitución lo que proporcionará una de las principales fuentes de aumento de la demanda de carbón térmico a plazo mediano. Sin embargo, los resultados de la prueba de sensibilidad con el modelo indican que los precios del petróleo tendrán un
importante efecto a mediano y largo plazo sobre el grado de sustitución y, por lo tanto, sobre la demanda de carbón térmico. También muestran que las incertidumbres en cuanto al crecimiento económico, los suministros de energía nuclear y las elasticidades en función de los precios del combustible serán los elementos críticos que pueden cambiar considerablemente el futuro del carbón térmico.

Las reservas mundiales de carbón son más que suficientes para atender la creciente demanda de carbón térmico hasta el año 2000 y después. En vista de la estructura básicamente competitiva de la industria mundial del carbón, es razonable prever que, a largo plazo, los precios internacionales no aumentarán más allá de sus costos de suministro a largo plazo. Con base en las estimaciones disponibles de la curva de suministro a largo plazo de los exportadores importantes de carbón, se prevé que el precio internacional de exportación del carbón térmico aumentará a razón de 1,3% anual entre 1985 y el año 2000.
ACRONYMS AND ABBREVIATIONS

GDP - Gross Domestic Product
p.a. - Per annum
lb - Pound
ton - Metric ton
b/d - Barrels per day
mbd - Million barrels per day
boe - Barrels of oil equivalent
mboe - Million barrels of oil equivalent
bdoe - Barrels per day of oil equivalent
toe - Tons of oil equivalent
mtoe - Million tons of oil equivalent
mbdoe - Million barrels per day of oil equivalent
tce - Tons of hard coal equivalent
mtce - Million tons of hard coal equivalent
BTU(s) - British thermal unit(s)
KWh - Kilowatt hour
GWh - Gigawatt hour
FOB - Free on board
EEC - European Economic Community
IEA - International Energy Agency
OECD - The Organization for Economic Co-operation and Development
OPEC - The Organization of Oil-Exporting Countries
UN - The United Nations
NOAM - Industrial North America
WEUR - Industrial Western Europe
JANZ - Japan, Australia, New Zealand
CSEX - Capital-Surplus Oil-Exporting Countries
CDOP - Capital-Deficit OPEC countries
NOEX - Non-OPEC Net Oil-Exporting Developing Countries
OIDC - Net Oil-Importing Developing Countries

CONVERSION FACTORS

1 toe = 7.3 boe = 1.47 tce = 40.8 million BTUs
1 mtoe = 0.02 bdoe
1,000 cubic meters of natural gas = 0.926 toe
1 million KWh = 3,412 million BTUs = 123 tce = 83.5 toe = 610 boe
## COUNTRY GROUPS

<table>
<thead>
<tr>
<th>Group Number</th>
<th>Group Symbol</th>
<th>Countries Included in the Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NOAM</td>
<td>United States, Canada.</td>
</tr>
<tr>
<td>2</td>
<td>WEUR</td>
<td>European members of OECD except Spain, Greece, Portugal and Turkey.</td>
</tr>
<tr>
<td>3</td>
<td>JANZ</td>
<td>Japan, Australia, New Zealand.</td>
</tr>
<tr>
<td>4</td>
<td>CSEX</td>
<td>Iran, Iraq, Libya, Kuwait, Oman, Qatar, Saudi Arabia, UAR.</td>
</tr>
<tr>
<td>5</td>
<td>CDOP</td>
<td>Algeria, Ecuador, Gabon, Indonesia, Nigeria, Venezuela.</td>
</tr>
<tr>
<td>6</td>
<td>NOEX</td>
<td>Angola, Bahrain, Bolivia, Brunei, Congo, Egypt, Malaysia, Mexico, Syria, Trinidad and Tobago, Tunisia, Zaire.</td>
</tr>
<tr>
<td>7</td>
<td>OIDC</td>
<td>All countries in the world excluding the groups 1-6 above and the centrally planned economies.</td>
</tr>
</tbody>
</table>

Centrally Planned Economies

Albania, Bulgaria, Czechoslovakia, Germany, D.R., Hungary, Poland, Romania, USSR, Cuba, Dem. Kampuchea, Laos, Vietnam, Korea, D.P.R., Mongolia, China, P.R.
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1. INTRODUCTION AND SUMMARY

The state of high expectations for thermal coal prices in the wake of the second oil-price increases in 1979-80 has been followed by a sharp downturn in the coal market since late-1982, with severely depressed export prices, low demand, and excessive production capacities and stocks. However, recent market conditions do not suggest a fundamental reversal of the trend towards substitution of thermal coal for petroleum that was set in motion after the 1973-74 oil-price increases. The setback can be explained for the most part by such transitory developments as economic recession, excessive capacity expansion and stock accumulation, and exchange rate adjustments. The share of coal in thermal electric power generation, the largest market for thermal coal, steadily increased until the most recent period for which data are available, indicating that competitiveness of coal vis-a-vis other fuels largely remained intact.

This paper uses a seven-region econometric simulation model of world energy markets—known as the World Energy and Petroleum Model (WEPM)—to project the competitive supply, demand and prices for thermal coal as a part of overall energy balance projections. Under a set of base-case assumptions about economic growth and OPEC oil pricing, world demand for thermal coal 1/ is projected to increase from 1,247 mtce in 1982 to 1,520 mtce in 1990 and 2,105 mtce in the year 2000. The demand growth rate is projected to accelerate from 2.5% p.a. between 1982 and 1990 to 3.3% p.a. in the 1990s.

1/ World is defined as the totality of the market-economy countries. Thermal coal demand is defined as the demand for coal by all economic sectors except the iron and steel industry.
The projected growth rate of thermal coal demand for the 1982-2000 period is approximately equal to that of total primary energy demand and slightly falls short of that of electricity demand. Rapid increases in nuclear and hydro electricity supplies projected for this period substantially reduce the scope for expansion of thermal electricity generation, restricting its average annual growth rate to about one percentage point below that of total electricity demand. However, the share of thermal coal in thermal electricity generation is projected to increase steadily through continued substitution of coal for petroleum and natural gas in existing and new power plants. This is expected to raise the growth rate of thermal coal demand to a level only slightly below that of total electricity demand. Substitution of coal for petroleum and natural gas in thermal electricity generation is expected to be almost completed by the year 2000, when the share of coal is projected to reach 85% of the market.

It is important to keep in mind that projections of thermal coal demand will be subject to wide variations, depending upon the particular assumptions made; these include, among others, assumptions about economic growth, the price of OPEC oil, demand adjustments to fuel prices, and nuclear power supplies. Simulations with WEPM suggest that the demand for thermal coal changes more than proportionately in response to changes in GDP, because of the relatively high income elasticity of the demand for electricity and the assumed non-responsiveness of primary electricity supply projections to changes in GDP. If the primary energy and electricity demands are projected to increase faster than the base case (because of higher GDP growth or lower price elasticities of final energy demand), the demand for thermal coal will be higher than the base case by a greater percentage than that of primary energy.
The simulation results suggest that the prospects for thermal coal critically depend on the ease with which coal can be substituted for other fuels. Environmental constraints as well as technological and economic factors will determine the degree of substitution. The tacit assumption adopted in this paper is that even under stringent environmental standards, and given enough time, coal will be capable of replacing the bulk of petroleum and natural gas-fired power plants in base-load thermal power generation at today's relative fuel prices. In the industrial sector market, however, technological and economic factors do not favor coal as much as in thermal power generation, considerably restricting coal's penetration into that market.

If OPEC follows a pricing path somewhat lower than that of the base case, the long-term demand for thermal coal could suffer appreciably. Under the current market conditions, the cost advantage of thermal coal vis-a-vis other fuels is not an overwhelming one for a large segment of the market; for example, power generation using imported coal and the industrial boiler market. Substitution to coal cannot be sustained in these markets if the price of oil falls below the current level.

An OPEC oil price path somewhat higher than that of the base case can stimulate the growth in the demand for thermal coal, but the elasticity of thermal coal demand with respect to crude oil prices is substantially less than unity and steadily declines over time along with increases in crude oil prices. This results from the exhaustion of substitution possibilities in the long run while higher oil prices dampen the demand growth rates of primary energy and electricity.
A lower growth of nuclear power supplies than assumed in the base case is translated mostly into additional demand for thermal coal, approximately in proportion to the market share of coal in thermal power generation. For instance, if half of the nuclear power supplies projected for the year 2000 do not materialize, world thermal coal demand would be 24% higher than in the base case.

World coal resources are more than adequate to meet the increasing demand for thermal coal to the year 2000 and beyond. Currently, reserves and production are heavily concentrated in several countries (United States, Canada, Australia, South Africa, India, Poland, USSR, and China), but the potential exists for several developing countries to become important producers and exporters.

As in the past, the international coal market is expected to maintain its basically competitive structure. In the short term, the international export price of thermal coal is not likely to recover substantially from its currently depressed level because of relatively slow demand growth and excessively large capacity and stocks at hand. In the long term, the price of thermal coal will be determined at the level of the long-term marginal cost of supplying the equilibrium level of demand. Based on the available estimates of the long-run supply curve for the important coal exporters, the international export price of thermal coal is projected to increase at 1.3% p.a. between 1985 and the year 2000. This assumes constant real costs of transporting coal from mines to ports and 2% p.a. increases in the cost of mining.
II. RECENT DEVELOPMENTS OF THE THERMAL COAL MARKET

After a period of expectations of high prices for thermal coal in the wake of the second oil price increases, the international thermal coal market has been beset by a progressively worsening supply/demand balance and lower prices. After increasing from $39.6/ton in 1978 to $56.5/ton in 1981 (in current US dollars), the international export price of thermal coal 1/ declined to $43.5 in early 1984. Table 2.1 shows recent movements in export prices of thermal coal for the major exporting countries. The severity of the market downturn is better revealed by the fact that in 1983 US thermal coal exports suffered a 34% decline below its level in 1982. In addition to the general market weakness, US exports suffered because of their higher export prices during this period; South African thermal coal of comparable quality was available in 1983 for $37.3/ton and Australian thermal coal for $39.1/ton while US coal was priced at $44.5/ton.

What do these developments portend for the future of thermal coal? To answer this question, we need an analysis of the factors that led to the market downturn. The following is a descriptive account of the developments in the thermal coal market in the 1970s and early 1980s.

1/ Spot export price of thermal coal (12,000 BTU/lb, <1.0% sulfur, 12% ash), FOB piers, Hampton Roads/Norfolk, United States.
Table 2.1: SPOT EXPORT PRICES OF THERMAL COAL (US$/Ton)

<table>
<thead>
<tr>
<th>Year</th>
<th>United States /a 1983</th>
<th>South Africa /b 1983</th>
<th>Australia /c 1983</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Current $</td>
<td>Constant $</td>
<td>Current $</td>
</tr>
<tr>
<td>1977</td>
<td>33.4</td>
<td>43.2</td>
<td>19.6</td>
</tr>
<tr>
<td>1978</td>
<td>39.6</td>
<td>43.6</td>
<td>20.1</td>
</tr>
<tr>
<td>1979</td>
<td>35.4</td>
<td>35.0</td>
<td>21.2</td>
</tr>
<tr>
<td>1980</td>
<td>43.1</td>
<td>39.4</td>
<td>30.5</td>
</tr>
<tr>
<td>1981</td>
<td>56.5</td>
<td>53.9</td>
<td>40.9</td>
</tr>
<tr>
<td>1982</td>
<td>52.2</td>
<td>50.6</td>
<td>42.7</td>
</tr>
<tr>
<td>1983</td>
<td>44.5</td>
<td>44.5</td>
<td>31.6</td>
</tr>
<tr>
<td>1984 Jan-Sept.</td>
<td>47.9</td>
<td>31.3</td>
<td>35.7</td>
</tr>
</tbody>
</table>

US Quality Equivalent Prices

<table>
<thead>
<tr>
<th>Year</th>
<th>1983</th>
<th>1984 Jan-Sept.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current $</td>
<td>44.5</td>
<td>47.9</td>
</tr>
<tr>
<td>Constant $</td>
<td>44.5</td>
<td>37.0</td>
</tr>
</tbody>
</table>

/a 12,000 BTU/lb, <1.0% sulfur, 12% ash, FOB piers, Hampton Roads/Norfolk, United States.

/b 11,300 BTU/lb, <1.0% sulfur, 15% ash, FOB piers, Richards Bay, South Africa.

/c 12,000 BTU/lb, <1.0% sulfur, 14% ash, FOB piers, Newcastle/Port Kembla, Australia.

/d Deflated by the index of the unit value of manufactured exports of industrial countries.

/e May-December, 1977.

Sources: Coal Week and Coal Week International, various issues.
Table 2.2 shows for the period 1970-82 data on world consumption of thermal coal—defined as solid fuels used for non-coking purposes. 1/ After decades of stagnation, world thermal coal consumption 2/ registered a strong 3.5% p.a. growth between 1975 and 1982. The share of thermal coal in world coal consumption increased from 77% in 1975 to 83% in 1982 as a result of strong growth of thermal coal demand at a time when metallurgical coal demand remained weak. The consumption increases were more pronounced in the market-economy countries than in the centrally planned economies. In the industrial countries, thermal coal consumption started to reverse its long-term declining trend (an exception is North America) only a few years after the first oil price increases; significant increases in consumption took place during the 1976-80 economic expansion, giving rise to a substantial increase in international trade in thermal coal. Increases in thermal coal consumption slowed down in 1981 and 1982 as economic recession in the industrial countries began to take its toll. Increases in thermal coal demand in developing countries took place somewhat later than in industrial countries, but continued through 1982.

1/ Published data rarely show consumption of thermal coal as a separate item. Two different definitions of thermal coal consumption are used in this paper. The first one used for descriptive purposes in this section defines thermal coal consumption as total solid fuels consumption minus coal used by coke plants. This definition could produce underestimation of thermal coal consumption because coke plants use a certain blend of metallurgical and thermal coals. The second definition used in the next section for analytical and projection purposes measures thermal coal consumption by subtracting from total solid fuels consumption the portion used by the iron and steel industry. This definition will result in over-estimation of thermal coal consumption because some metallurgical coal is consumed by other sectors.

2/ World including the centrally planned economies.
### Table 2.2: WORLD COAL CONSUMPTION 1970-82 /a (mtce)

<table>
<thead>
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</thead>
<tbody>
<tr>
<td><strong>Industrial Countries</strong></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Thermal Coal</td>
<td>965</td>
<td>867</td>
<td>1,028</td>
<td>1,043</td>
<td>1,040</td>
</tr>
<tr>
<td>Metallurgical Coal</td>
<td>674</td>
<td>595</td>
<td>789</td>
<td>813</td>
<td>835</td>
</tr>
<tr>
<td><strong>Developing Countries</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal Coal</td>
<td>173</td>
<td>210</td>
<td>270</td>
<td>292</td>
<td>307</td>
</tr>
<tr>
<td>Metallurgical Coal</td>
<td>139</td>
<td>170</td>
<td>222</td>
<td>245</td>
<td>259</td>
</tr>
<tr>
<td><strong>Centrally Planned Economies /b</strong></td>
<td>1,021</td>
<td>1,183</td>
<td>1,326</td>
<td>1,306</td>
<td>1,346</td>
</tr>
<tr>
<td>Thermal Coal</td>
<td>850</td>
<td>985</td>
<td>1,110</td>
<td>1,095</td>
<td>1,134</td>
</tr>
<tr>
<td>Metallurgical Coal</td>
<td>171</td>
<td>198</td>
<td>216</td>
<td>211</td>
<td>212</td>
</tr>
<tr>
<td><strong>World Total</strong></td>
<td>2,159</td>
<td>2,260</td>
<td>2,624</td>
<td>2,641</td>
<td>2,693</td>
</tr>
<tr>
<td>Thermal Coal</td>
<td>1,663</td>
<td>1,750</td>
<td>2,121</td>
<td>2,153</td>
<td>2,228</td>
</tr>
<tr>
<td>Metallurgical Coal</td>
<td>496</td>
<td>510</td>
<td>503</td>
<td>488</td>
<td>465</td>
</tr>
</tbody>
</table>

Note: Figures may not add due to independent rounding.

/a Thermal coal consumption is estimated by subtracting 1.35 times coke-oven coke production from total solid fuels consumption. Coke yield of metallurgical coal varies depending on its volatility and other qualities. The factor of 1.35 is the average of the OECD countries in 1979-81.

/b Includes centrally planned Asia and Cuba.


The data on electric utility consumption of thermal coal (Table 2.3) reveal the underlying changes that took place in this market, by far the largest market for thermal coal. Although thermal coal offtake by the US electric utilities stagnated in 1982, it is clear that the stagnation can be attributed to economic recession in that year and the consequent fall in the
demand for electricity. The share of coal in thermal electric power generation achieved spectacular gains throughout the 1975-83 period, at the expense of petroleum and natural gas. This clearly shows that substitution of coal for hydrocarbon fuels in electricity generation has proceeded without interruption in recent years. When the rest of the OECD countries are considered, the picture up to 1982 is not much different from that of the United States. Substitution took place largely from petroleum to thermal coal; although the share of thermal coal is still substantially lower than that of the United States, its percentage increase between 1975 and 1982 was slightly higher.

Table 2.3: ELECTRIC UTILITY CONSUMPTION OF THERMAL COAL: UNITED STATES AND OECD

<table>
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</thead>
<tbody>
<tr>
<td><strong>United States</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consumption (mtce)</td>
<td>323.8</td>
<td>335.8</td>
<td>462.5</td>
<td>484.4</td>
<td>484.4</td>
<td>509.5</td>
</tr>
<tr>
<td><strong>Fuel Shares (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal Coal</td>
<td>56.4</td>
<td>59.2</td>
<td>66.2</td>
<td>68.5</td>
<td>71.9</td>
<td>74.4</td>
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<td>20.9</td>
<td>20.1</td>
<td>14.0</td>
<td>11.8</td>
<td>9.0</td>
<td>8.7</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>22.7</td>
<td>20.8</td>
<td>19.7</td>
<td>19.7</td>
<td>19.1</td>
<td>16.9</td>
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<td><strong>Other OECD Countries</strong></td>
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<td></td>
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<tr>
<td>Consumption (mtce)</td>
<td>236.7</td>
<td>237.4</td>
<td>320.2</td>
<td>321.9</td>
<td>330.3</td>
<td></td>
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<tr>
<td><strong>Fuel Shares (%)</strong></td>
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<td></td>
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<tr>
<td>Thermal Coal</td>
<td>46.1</td>
<td>44.9</td>
<td>54.2</td>
<td>56.9</td>
<td>59.2</td>
<td></td>
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<tr>
<td>Petroleum</td>
<td>45.0</td>
<td>43.4</td>
<td>34.5</td>
<td>32.2</td>
<td>29.2</td>
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<tr>
<td>Natural Gas</td>
<td>8.9</td>
<td>11.7</td>
<td>11.3</td>
<td>10.9</td>
<td>11.6</td>
<td></td>
</tr>
</tbody>
</table>

The recent slowdown in the demand for thermal coal, therefore, can be attributed for the most part to economic recession rather than to a deterioration in economic competitiveness of thermal coal vis-a-vis other fuels. Demand for thermal electricity fluctuates more than that for total electricity because operating costs of thermal electricity production are higher than those of hydro and nuclear power generation, resulting in lower capacity utilization rates at times of lower demand. Total electricity production in the OECD countries declined by 0.2% in 1982 from its 1981 level, but that of thermal electricity was down by 2.8%. In the United States, total electricity generation fell by 2.3% in 1982 and increased by 3.1% in 1983 over the preceding years. Thermal electricity production, however, declined by 6.3% in 1982 and increased by only 2.1% in 1983.

World production of solid fuels (including metallurgical coal) increased steadily from 2.15 billion tce in 1970 to 2.71 billion tce in 1982. Of the world incremental production between 1970 and 1982, about 51% was accounted for by the People's Rep. of China, U.S.S.R. and Poland, and 45% by United States, Canada, South Africa and Australia. Solid fuels production in OECD Europe, where a substantial increase in the demand for thermal coal was partially offset by a decline in the demand for metallurgical coal, experienced an 18% decline between 1970 and 1978 but there was a 9.7% increase between 1978 and 1982. Among developing countries other than South

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1/ Published data do not show the thermal coal component of this total. One can safely assume, however, that world total production of thermal coal would approximately be the same as world thermal coal consumption shown in Table 2.2.

2/ The People's Republic of China alone accounted for 37% of the world incremental production during the period.
Africa, India had the most impressive increase in production, from 54 mtce in 1970 to 94 mtce in 1982. Moderate increases were recorded in several Latin American countries (Colombia, Brazil and Mexico), Republic of Korea, Turkey, and Yugoslavia.

Between 1975 and 1982 when world thermal coal demand sharply increased, world coal imports and exports increased at 5.2% p.a. and 4.7% p.a., respectively. Three countries—the United States, Australia and South Africa—virtually monopolized the increment of world exports during this period as well as the declines in exports from other countries. The incremental exports were shared almost equally between the three countries. In 1983, however, Australia and South Africa were able to capture a larger share of the export market at the expense of the United States, by virtue of their lower export prices than those of the United States. The appreciation of the US dollar vis-a-vis the currencies of these countries partly contributed to this shift. Sharp increases in production in the centrally planned economies, particularly in the People's Republic of China, were mostly for domestic consumption, implying little changes in the net trade of this group. Production increases in developing countries other than South Africa were also used primarily for domestic consumption.

On the import side, increases were most pronounced in OECD Europe, Japan and a few developing countries such as Turkey, Republic of Korea, and Brazil. Net imports of coal in OECD Europe and Japan increased from 123.8 mtce in 1975 to 165.2 mtce in 1980, to 170.2 mtce in 1981, and to 173.2 mtce in 1982. Of the 1981 net imports, 67 mtce were net imports of thermal coal,
or 39.4% of total net imports of coal. 1/ In 1982, OECD Europe and Japan accounted for 69% of world gross imports of coal. Between 1978 and 1982, net imports plus production in OECD Europe and Japan increased by 20% while consumption increased by 14%. This meant an accumulation of stocks, particularly in OECD Europe where net additions to stocks amounted to 57 mtce in the three year period, 1980-82. The lack of significant increases in production or imports in the majority of developing countries is indicative of the poor state of progress in substituting coal for hydrocarbon fuels.

The behavior of imports and stocks in the wake of the 1979-80 oil price shock explains a good part of the fluctuation of thermal coal export prices shown in Table 2.1. The second round of petroleum price increases provided a strong incentive to substitute coal for petroleum in power generation and industrial sector consumption. This led to a rush on the part of the importers to secure enough supplies for short-term needs that have suddenly increased and to line up long-term sources of supplies for substantially expanded future thermal power programs. This rush is understandable because the cost of failing to obtain sufficient and secure sources of coal supply is high. The result was a large increase in imports and in accumulations of stocks. The subsequent economic recession, which dragged on longer than anticipated, worsened the situation. This behavior probably resulted in increases in thermal coal export prices during 1979-81 beyond normal supply/demand equilibrium, and sustained prices at the high level until the latter part of 1982. Conversely, the 1983 crash in thermal coal prices would have been less severe had the stock levels not been so high.

In brief, the recent developments of the thermal coal market can be explained for the most part in terms of short-term overshooting phenomenon which is typical of markets characterized by low, short-term price elasticities of demand and supply.
III. DEMAND FOR THERMAL COAL

Until the first oil price shock of 1973/74 the coal industry was a declining industry, largely because of the availability of cheap petroleum. The petroleum price increases in the 1970s, however, brought on a reversal of this trend. The extent to which this new trend will continue will depend for the most part on the price of coal relative to that of petroleum and other fuels. Apart from the economic competitiveness of coal, its future will also be affected by economic growth, environmental regulations, and government policies affecting nuclear/hydro electric power supplies and synthetic fuels from coal.

In this section we will look at the demand prospects for thermal coal, primarily on the basis of the economic competitiveness of coal burning in relation to the use of other fuels. This analysis is carried out by means of the World Energy and Petroleum Model (WEPM) that features three final energy consumption sectors and one energy transformation sector (thermal electricity generation). Since the details of the model are described elsewhere, discussion here will be limited to those features of the model that have an important bearing upon the prospects for thermal coal. Implications of the uncertainties surrounding future economic growth, nuclear/hydro supplies and petroleum prices for the demand for thermal coal will be investigated through sensitivity analysis. The section ends with a discussion of environmental issues associated with coal burning.

Relative Fuel Prices and Interfuel Substitution

Economic growth, the price of OPEC crude oil, population growth, non-OPEC supplies of hydrocarbon fuels and supplies of nuclear/hydro electricity and synthetic fuels are exogenous to WEPM. On the basis of these assumptions, the model generates energy balance projections for the seven world regions. The market shares of the various fuels are determined by a translog cost share model of interfuel substitution, under the assumption of competitive cost minimization in the industrial, residential/commercial and thermal power sectors; for rail/barge transportation, fixed fuel shares of the recent past are used.

An important assumption for interfuel substitution between petroleum and coal in the model is the way petroleum product prices, particularly the price of heavy fuel oil, are determined. The model assumes that the ex-refinery price differentials between petroleum products will remain constant at their 1976-78 average levels for each region. This assumption may result in an overestimation of the demand for thermal coal if the price of heavy fuel oil fails to increase as fast as those of other petroleum products because of its direct competition with low-cost thermal coal.

Past experience, however, shows that the assumption of fixed petroleum product price differentials may not be an unrealistic one. Figure 3.1 plots the ratios of the prices of regular motor gasoline, jet kerosine and light fuel oil to the price of low-sulfur heavy fuel oil at the Rotterdam international product market. No clear long-term trend can be detected in any of these ratios over the 1970-82 period. It can be seen that the prices of gasoline, jet fuel and light fuel oil increased more than that of heavy fuel oil during the periods of severe market disruption (1973-74 and 1979-80) but the price ratios were eventually restored to the long-term average levels.
Figure 3.1
Trends of Relative Petroleum Product Prices at Rotterdam Market

Legend:
- Gasoline Price/Heavy Fuel Oil Price Ratio
- Jet Kerosine Price/Heavy Fuel Oil Price Ratio
- Light Fuel Oil Price/Heavy Fuel Oil Price Ratio

It was the flexibility of petroleum refinery technology that prevented a slide in the relative price of heavy fuel oil in relation to other petroleum products. Table 3.1 shows the percentage share of heavy fuel oil in total petroleum product production. These figures show clearly how the United States, the forerunner in refinery technology, achieved a share of residual fuel oil yield which is only one-third the level of the rest of the world. Since the late 1970s, softening of the gasoline market and relatively strong heavy fuel oil prices in the United States led to an increase in the refinery yield of residual fuel oil and a preference for heavy crude oil because of a higher netback. For the world as a whole, the share of residual fuel oil has been steadily declining in response to changes in market structure. In view of what has already been achieved in the United States at today's relative product prices, it is reasonable to expect that refinery technology in the rest of the world will be capable of adapting to a substantially reduced demand for residual fuel oil instead of resulting in steady deterioration of its price vis-a-vis other petroleum products. Therefore, the assumption of

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</thead>
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<tr>
<td>United States</td>
<td>6.7</td>
<td>8.1</td>
<td>10.4</td>
<td>12.0</td>
<td>12.3</td>
<td>13.2</td>
<td>10.8</td>
</tr>
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<td>World /a</td>
<td>35.5</td>
<td>35.3</td>
<td>33.8</td>
<td>32.4</td>
<td>32.2</td>
<td>31.7</td>
<td>30.5</td>
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</table>

/a World including centrally planned economies.

fixed price differentials between petroleum products is not considered an
unrealistic one.

Interfuel substitution responses also depend on the choice of own-
and cross-price elasticities as well as on changes in relative fuel prices.
In the translog cost share model of interfuel substitution, however, the
substitution elasticities are determined largely by the fuel shares rather
than by the coefficients of the relative fuel price variables. For this
reason, the choice of the coefficients has a relatively minor impact on the
results. The coefficients in WEPM, chosen on the basis of recent studies of
industrial countries, are assumed to be the same for all seven regions of the
model. This may appear to ignore the interregional differences in substitution
characteristics, but a large part of the differences has to do with the
differences in fuel shares, which are reflected in the form of interregional
differences in interfuel substitution elasticities.

Base-Case Projections

To serve as a reference point, let us start with the base-case
projections for thermal coal demand, which were made under the set of
assumptions summarized in Table 3.2. The demand for thermal coal here is
defined as solid fuels consumption by sectors other than the iron and steel
industry. Although this will overstate the demand for thermal coal, it
greatly simplifies demand analysis and projection. The base case assumes
moderate economic growth rates for the industrial and developing countries and
a price path for OPEC oil that remains at relatively low levels for the
rest of the 1980s, but increases at about 4% p.a. in the 1990s (Table 3.2).
The end-user prices of various fuels to the industrial and thermal power
sectors underlying the base-case projections are shown in Figure 3.2.
Table 3.2: BASE-CASE ASSUMPTIONS

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<td>3.3</td>
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<td>4.1</td>
<td>4.9</td>
<td>5.1</td>
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<tr>
<td></td>
<td>29.1</td>
<td>25.9</td>
<td>29.5</td>
<td>36.1</td>
<td>44.2</td>
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<table>
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<tr>
<th>Nuclear Power Supplies (mbdoe)</th>
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<td>Industrial Countries</td>
<td>1.13</td>
<td>1.21</td>
<td>2.16</td>
<td>2.95</td>
<td>4.08</td>
</tr>
<tr>
<td>Developing Countries</td>
<td>0.06</td>
<td>0.09</td>
<td>0.32</td>
<td>0.59</td>
<td>1.06</td>
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</tbody>
</table>

Source: Economic Analysis and Projections Department, World Bank

Table 3.3 presents the base-case projections of thermal coal demand by regions. The demand projections for metallurgical coal by the iron and steel industry are also shown as the difference between total coal demand and thermal coal demand.

The world demand for thermal coal is projected to increase at an average annual rate of only 2.4% between 1982 and 1990, but at 3% in the 1990s. This pattern of growth reflects the following underlying forces. The demand for primary energy and the demand for electricity are expected to grow at substantially lower rates in the 1980s than in the 1970s, primarily as a result of the projected slowdown of economic growth and the petroleum and energy price increases that took place in the 1970s and the early 1980s.
Figure 3.2
BASE-CASE PROJECTION OF END-USER FUEL PRICES TO INDUSTRY AND THERMAL POWER SECTORS

Legend:
- Coal
- Oil
- Natural Gas
- Electricity

NORTH AMERICA

WESTERN EUROPE

JAPAN, AUSTRALIA, NEW ZEALAND

OIL-IMPORTING DEVELOPING COUNTRIES


YEAR

($/MMBtu)


YEAR

$/MMBtu

$/MMBtu

$/MMBtu

$/MMBtu
Table 3.3: BASE-CASE PROJECTIONS FOR TOTAL COAL AND THERMAL COAL DEMAND, BY REGIONS

(mtce)

<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>NOAM</td>
<td>644.7</td>
<td>663.1</td>
<td>637.4</td>
<td>695.0</td>
<td>780.0</td>
<td>880.0</td>
<td>1,000.0</td>
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<tr>
<td>Thermal Coal</td>
<td>594.9</td>
<td>620.7</td>
<td>607.9</td>
<td>655.0</td>
<td>730.0</td>
<td>830.0</td>
<td>950.0</td>
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<tr>
<td>WEUR</td>
<td>357.9</td>
<td>348.6</td>
<td>339.2</td>
<td>360.0</td>
<td>380.0</td>
<td>440.0</td>
<td>530.0</td>
</tr>
<tr>
<td>Thermal Coal</td>
<td>306.1</td>
<td>295.5</td>
<td>293.1</td>
<td>310.0</td>
<td>330.0</td>
<td>385.0</td>
<td>470.0</td>
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<tr>
<td>JANZ</td>
<td>132.2</td>
<td>139.0</td>
<td>140.1</td>
<td>154.0</td>
<td>185.0</td>
<td>230.0</td>
<td>290.0</td>
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<tr>
<td>Thermal Coal</td>
<td>83.0</td>
<td>91.4</td>
<td>92.3</td>
<td>104.0</td>
<td>133.0</td>
<td>175.0</td>
<td>230.0</td>
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<tr>
<td>OPEC</td>
<td>2.3</td>
<td>2.5</td>
<td>2.6</td>
<td>4.4</td>
<td>8.8</td>
<td>13.0</td>
<td>18.0</td>
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<tr>
<td>Thermal Coal/a</td>
<td>1.1</td>
<td>1.6</td>
<td>1.9</td>
<td>2.2</td>
<td>3.0</td>
<td>4.0</td>
<td>6.0</td>
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<tr>
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<td>8.1</td>
<td>10.8</td>
<td>16.2</td>
<td>23.0</td>
<td>35.0</td>
</tr>
<tr>
<td>Thermal Coal/a</td>
<td>3.7</td>
<td>4.7</td>
<td>4.8</td>
<td>6.4</td>
<td>8.8</td>
<td>12.0</td>
<td>19.0</td>
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<tr>
<td>OIDC</td>
<td>261.2</td>
<td>282.0</td>
<td>296.2</td>
<td>325.0</td>
<td>380.0</td>
<td>440.0</td>
<td>530.0</td>
</tr>
<tr>
<td>Thermal Coal/a</td>
<td>214.9</td>
<td>234.1</td>
<td>246.6</td>
<td>270.0</td>
<td>315.0</td>
<td>360.0</td>
<td>430.0</td>
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<tr>
<td>World Total</td>
<td>1,405.3</td>
<td>1,443.1</td>
<td>1,423.6</td>
<td>1,549.2</td>
<td>1,750.0</td>
<td>2,026.0</td>
<td>2,403.0</td>
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<tr>
<td>Thermal Coal/a</td>
<td>1,203.7</td>
<td>1,247.3</td>
<td>1,246.6</td>
<td>1,347.6</td>
<td>1,519.8</td>
<td>1,766.0</td>
<td>2,105.0</td>
</tr>
</tbody>
</table>

/a Actuals for the 1980-82 period are estimated, using the average consumption share of iron and steel industry in total coal consumption for the developing countries included in Energy Balances of Developing Countries, 1971/82 and Energy Balances of OECD Countries, 1971/82, IEA/OECD, Paris, 1984.

Source: Economic Analysis and Projections Department, the World Bank.
World consumption of primary energy is projected to increase at 2.5% p.a. between 1982 and 1990, and total electricity consumption at 2.8% p.a.. However, given the projected increase at 4.6% p.a. in primary electricity supplies (mostly nuclear power) over the same period, there is little room left for expansion of thermal electric power generation (projected to increase only at 1.5% p.a. for the period). Despite the setback suffered by the nuclear power industry, the nuclear power plants already under construction will substantially increase the medium-term supply capacity of nuclear power.

For the period up to 1990, therefore, the main source of the base-case projected increases in the demand for thermal coal is the substitution of coal for petroleum and natural gas in industry and thermal power generation. Table 3.4 shows that the share of coal is projected to increase steadily throughout the projection period. Recall that the share had reached 68% in 1982 in OECD as a whole and 74% in the United States in 1983; the rate of increase in this share is projected to decelerate during 1985-90 partly because of the weakness of petroleum prices assumed for this period.

The 1990s present a somewhat different picture. The world demand for thermal coal is projected to increase at a faster rate than in the 1980s, on account of the projected increases in world primary energy demand (2.9% p.a.) and world electricity demand (3.2% p.a.). The impact on energy demand of the dramatic petroleum price increases of the past should by and large have dissipated by 1990 and the moderate increases of petroleum prices assumed for the 1990s are expected to only mildly dampen the growth rate of energy demand. Steady growth in the world economy projected for the 1990s are expected to result in growth rates of the demand for primary energy and electricity that
Table 3.4: SHARES OF THERMAL COAL IN INDUSTRY AND THERMAL POWER SECTORS

(Percent)

<table>
<thead>
<tr>
<th></th>
<th>Actual</th>
<th></th>
<th>Projected</th>
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</thead>
<tbody>
<tr>
<td><strong>Industrial Sector</strong>/a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industrial Countries</td>
<td>7.7</td>
<td>9.5</td>
<td>10.6</td>
</tr>
<tr>
<td>Oil-Importing Developing Countries</td>
<td>14.5</td>
<td></td>
<td>19.5</td>
</tr>
<tr>
<td><strong>Thermal Power Sector</strong></td>
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<td></td>
</tr>
<tr>
<td>Industrial Countries</td>
<td>56.5</td>
<td>65.2</td>
<td>75.3</td>
</tr>
<tr>
<td>Oil-Importing Developing Countries</td>
<td>49.7</td>
<td></td>
<td>69.8</td>
</tr>
</tbody>
</table>

/a Excluding metallurgical coal consumption by the iron and steel industry.

Source: Economic Analysis and Projections Department, the World Bank.

are substantially higher than those in the 1980s (recall that the 1982-90 economic and energy demand growth rates substantially exceed those for the 1980-90 period because of recession in 1982).

The projected average annual increases in primary electricity supplies of 3.8% during the 1990s implies that the demand for thermal electric power will increase only at 2.5% p.a. The demand for thermal coal for electricity generation, however, is projected to increase at a faster rate, at 3.0% p.a., because of continued increases of its share in the thermal power market. The share of coal in the thermal electricity market is expected to reach 85% by the year 2000 in the industrial and oil-importing developing
countries. This share is probably close to the maximum in view of the requirement for peak-load power generation. In other words, under the relative fuel prices assumed for the base case, substitution to coal in the thermal power sector is expected to be completed for the most part by the year 2000.

The world industrial sector (excluding the iron and steel industry) demand for thermal coal is expected to increase at 3.2% p.a. between 1982 and the year 2000, while the world industrial sector final energy demand is projected to increase at 2.3% p.a. This implies a substantial increase in the share of thermal coal in world industrial energy consumption—approximately doubling between 1978 and the year 2000 (Table 3.4). Although this is a significant increase, the level of coal's projected share indicates that it is not likely to play a prominent role even in the long run in meeting industrial energy needs.

The ease of substitutability between coal and other fuels varies widely between industries. The cement and brick-making industries have been recognized as ones in which there is a high degree of substitutability. A substantial part of the potential conversions to coal in these industries have already been realized and the remainder are expected to follow in the near future. The total potential demand for thermal coal by these industries, however, is relatively small; the total in OECD countries is estimated at only about 50 mtce by the year 2000.

In OECD countries in 1977, about 80% of the industrial consumption of thermal coal was used as a boiler fuel by a variety of industries and the
remaining 20% as a non-boiler fuel by the cement and other industries. 1/
Since the bulk of industrial boilers still rely on hydrocarbon fuels, it would
seem that this sector presents a great potential market for thermal coal. How-
ever, the economic advantages of thermal coal as an industrial boiler fuel are
not as great as in the case of coal-fired thermal power generation because of:
(a) the relatively small size of industrial boilers, (b) the low capacity
utilization rate or load factor (20-35%), (c) industrial location, which is
mostly dictated by factors other than the availability of coal, and (d) large
infrastructure investments for conversions to coal.

The base-case projections here assume that thermal coal will capture
about 30% of the industrial boiler fuel market by the year 2000 in the
industrial countries, up from the current market share of 15%. One study has
suggested that this share could be in the range of 40–75% by the year
2000. 2/ The low end of this range corresponds to the case where conversion
to coal is carried out by the private sector on the basis of market prices,
while the high end postulates heavy government intervention and subsidization.
Since our base-case projections do not assume any government intervention in
this regard, the proper comparison would be with the low end of this range.
However, Ezra does not appear to have taken full account of the costs
mentioned above, particularly the costs of infrastructure.

2/ Derek Ezra, "The Use of Coal in Industrial Boilers," in The Use of Coal in
Sensitivity to Alternative Assumptions

In this section, we investigate the sensitivity of the demand for thermal coal to the following variations to the base-case assumptions:

(1) **Low Economic Growth Scenario (LEG):** Economies of the industrial and developing countries are assumed to grow at rates that are 25% lower than the base-case growth rates.

(2) **High Economic Growth Scenario (HEG):** Economic growth rates are assumed to be 25% higher than the base-case growth rates.

(3) **Low Energy Demand Adjustment Scenario (LDA):** Price elasticities of final energy demand are assumed to be 20% lower than those of the base case.

(4) **Low Oil Price Scenario (LOP):** The price of OPEC oil is assumed to follow a path lower than that of the base case, as shown in Figure 3.3.

(5) **High Oil Price Scenario (HOP):** A higher price path for OPEC oil than the base case is postulated, as shown in Figure 3.3.

(6) **Low Nuclear Power Supply Scenario (LNS):** Nuclear power supplies in the year 2000 are reduced by 50% from the base case, with linear interpolation for the 1985-2000 period.

In addition to the above, implications of changing the own- and cross-price elasticities of interfuel substitution are investigated separately.

Table 3.5 presents the projections of thermal coal demand for the seven alternative scenarios, expressed in terms of percentage deviations from the base case. The changes made to the base-case assumptions generally result in only minor differences in the short- to medium-term demand projections, but lead to major differences in the long-term level of demand.
Figure 3.3
ALTERNATIVE SCENARIOS FOR OPEC PRICING

Legend:
- Base
- Low
- High

YEAR

1983S/BOE

World Bank – 26740
Table 3.5: PROJECTIONS OF THERMAL COAL DEMAND UNDER ALTERNATIVE SCENARIOS
(Percent difference from the base case)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LEG:</strong> World Total</td>
<td>-0.1</td>
<td>-6.6</td>
<td>-12.5</td>
<td>-18.9</td>
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<tr>
<td>Industrial Countries</td>
<td>-0.1</td>
<td>-5.5</td>
<td>-10.1</td>
<td>-14.3</td>
</tr>
<tr>
<td>Developing Countries</td>
<td>-1.7</td>
<td>-11.9</td>
<td>-22.3</td>
<td>-37.9</td>
</tr>
<tr>
<td><strong>HEG:</strong> World Total</td>
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<td>6.7</td>
<td>13.2</td>
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<td>10.5</td>
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<td>1.3</td>
<td>12.5</td>
<td>24.6</td>
<td>41.4</td>
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<tr>
<td><strong>LDA:</strong> World Total</td>
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<td>9.7</td>
<td>12.6</td>
<td>15.0</td>
</tr>
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<td>10.3</td>
<td>13.3</td>
<td>15.5</td>
</tr>
<tr>
<td>Developing Countries</td>
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<td>7.0</td>
<td>9.5</td>
<td>12.8</td>
</tr>
<tr>
<td><strong>LSP:</strong> World Total</td>
<td>-1.8</td>
<td>-5.2</td>
<td>-10.4</td>
<td>-14.7</td>
</tr>
<tr>
<td>Industrial Countries</td>
<td>-1.8</td>
<td>-5.2</td>
<td>-10.3</td>
<td>-14.0</td>
</tr>
<tr>
<td>Developing Countries</td>
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<td>-4.9</td>
<td>-10.6</td>
<td>-17.4</td>
</tr>
<tr>
<td><strong>LOP:</strong> World Total</td>
<td>3.3</td>
<td>3.4</td>
<td>5.7</td>
<td>7.3</td>
</tr>
<tr>
<td>Industrial Countries</td>
<td>3.3</td>
<td>3.5</td>
<td>5.6</td>
<td>6.9</td>
</tr>
<tr>
<td>Developing Countries</td>
<td>3.0</td>
<td>3.2</td>
<td>5.8</td>
<td>8.3</td>
</tr>
<tr>
<td><strong>LNS:</strong> World Total</td>
<td>0.0</td>
<td>6.3</td>
<td>13.4</td>
<td>23.8</td>
</tr>
<tr>
<td>Industrial Countries</td>
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<td>6.6</td>
<td>13.6</td>
<td>22.7</td>
</tr>
<tr>
<td>Developing Countries</td>
<td>0.0</td>
<td>5.2</td>
<td>12.6</td>
<td>28.3</td>
</tr>
</tbody>
</table>

Source: Economic Analysis and Projections Department, World Bank.

First, the demand for thermal coal changes more than proportionately to changes in GDP. In the high economic growth scenario, the level of world GDP in the year 2000 is 15.5% higher than the base case, but the demand for thermal coal is 20.7% higher. This would suggest an income elasticity of the demand for thermal coal of 1.33. The low economic growth scenario also implies the same income elasticity. The higher-than-unitary income elasticity.
of the demand for thermal coal is largely a reflection of the following two factors: (a) the income elasticity of the demand for electricity is higher than that for final energy; (b) the demand for thermal electricity is treated as a residual demand, after subtracting from total electricity demand the supplies of primary electricity which are projected exogenously.

The sensitivity of thermal coal demand to changes in economic growth is greater in developing countries than in industrial countries; the income elasticity implied by the simulation results is close to 2.0 for developing countries and 1.15 for industrial countries. This result is understandable because developing countries have higher income elasticity of demand for electricity and a higher share of primary electricity in total electricity supplies than industrial countries.

Higher economic growth results in faster increases in the cost of coal production; the international export price of thermal coal is projected at a level 4.9% higher for the year 2000 under the high economic growth scenario than under the base-case scenario. The share of thermal coal in thermal electricity generation and industrial sector consumption, therefore, is slightly lower under the high economic growth scenario than under the base case, but this negative impact is only minor compared with the positive effect of higher economic growth on total energy demand and hence the demand for thermal coal.

If the price elasticities of final energy demand were lower as assumed in the low demand adjustment scenario, the demand for thermal coal would be higher by a greater percentage (by 15.0% in the year 2000) than the demand for total primary energy (by 8.8% in the year 2000). The reason for this is the same as that mentioned above for the high economic growth
scenario. It is also of interest to note that the short- to medium-term impact of lower demand adjustments to prices could be quite substantial. This is because the prospects for energy demand over the next several years depend critically on how economies adjust to the energy price increases that took place in 1973-74 and 1979-80.

Variations in the price of OPEC oil are shown to have a substantial impact on the demand for thermal coal. It was, after all, the two rounds of OPEC oil price increases that led to the rejuvenation of thermal coal as a substitute fuel. The low oil price scenario assumes somewhat lower prices than the base case until 1990, but the gap between them drastically widens in the 1990s (Figure 3.3). The sensitivity results show that in the short- to medium-term the demand for thermal coal will not suffer greatly from a moderate softening of oil prices. Over the long term, however, the difference becomes substantial as the oil price diverges widely between the two scenarios. Under the low oil price scenario, the growth rate of the demand for thermal coal is projected at 2.0% p.a. between 1982 and the year 2000, down sharply from 2.9% p.a. growth in the base case.

More illustrative of the impact of lower oil prices is the share of thermal coal in thermal power generation. In industrial countries, for example, the share reaches 75% by 1990 under the low oil price scenario compared with 77% under the base-case oil prices, but only to 79% by the year 2000 compared with the base case share of 85%. Under the low oil price scenario, substitution of coal for petroleum continues to take place but at a substantially reduced rate.

The impact of higher oil prices is asymmetrical to that of lower oil prices. The elasticity of thermal coal demand with respect to the price of
OPEC oil is approximately the same in the short term for both oil price increases and oil price declines, but the long term elasticity for oil price increases is substantially lower than that for oil price declines. This makes sense because in the long term the potential for interfuel substitution will be exhausted even under the base-case oil price scenario, and further oil price increases will make only marginal differences.

With nuclear power supplies 50% below the base-case level for the year 2000, the demand for thermal coal will increase by 24% (or by 550 mtce) for the same year. About 85% of this reduction in nuclear power supplies is replaced by coal-fired electricity generation, in accordance with the base-case projected share of thermal coal in thermal power generation. It is, however, likely that all of the reduction in nuclear power supplies will be replaced by coal-fired electricity in oil-importing countries because nuclear power plants are base-load facilities and all future base-load thermal power capacities in these countries are likely to rely on thermal coal.

Sensitivity results of the WEPM translog cost share model of interfuel substitution suggest that the long-term projections of fuel shares can vary considerably depending on the assumptions about the substitution elasticities. Table 3.6 shows the effect on world demand for coal and petroleum of changing the own- and cross-price elasticities by a constant factor. A 20% increase in all the elasticities, for example, results in approximately 7.8% increase in world coal demand and 8.5% decrease in world petroleum demand by the year 2000. Instead of changing all the elasticities by the same proportion, the alternative set of own price elasticities postulate that the demand for petroleum and natural gas are much more price elastic than the base case, while the demand for coal is assumed to be
Table 3.6: SENSITIVITY TO CHANGES IN ELASTICITY OF SUBSTITUTION  
(percent difference from base case)

<table>
<thead>
<tr>
<th>Constant Elasticity Multiplies /a</th>
<th>Alternative Set /b</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.8</td>
<td>1.2</td>
</tr>
<tr>
<td>World Coal Demand</td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>-2.0</td>
</tr>
<tr>
<td>2000</td>
<td>-11.89</td>
</tr>
<tr>
<td>World Petroleum Demand</td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>-1.36</td>
</tr>
</tbody>
</table>

/a All base-case substitution elasticities are multiplied by a constant factor shown here. For the base-case elasticities, see Choe, op. cit., pp. 40-61.

/b With the following own-price elasticities: $e_{CC}=-1.5$, $e_{GG}=-2.3$, $e_{OO}=-1.7$, $\varepsilon_{EE}=-0.6$ for industrial sector; $e_{CC}=0.2$, $e_{GG}=-2.5$, $e_{OO}=-1.8$, $\varepsilon_{EE}=-0.9$ for residential sector; $e_{CC}=-1.1$, $e_{GG}=-2.0$, $e_{OO}=-1.4$ for thermal power sector.

slightly more price elastic than the base case. Because of this differentiation between fuels in terms of the degree of adjustments to prices, the demand for petroleum declines substantially below the base-case level. It is of interest to note, however, that the corresponding increase in the demand for coal is by no means small. This serves to illustrate the point that high own-price elasticities for petroleum and natural gas are possible only under the circumstances where the substitutes for these fuels (specifically, coal and electricity) are sufficiently price elastic. In the translog cost share model, changes in the coefficients of relative fuel price variables make relatively small impact on the long-term projected demand for fuels because
the substitution elasticities of the model are determined mostly by the cost shares rather than the coefficients.

In summary, world demand for thermal coal in the years ahead is subject to a wide range of uncertainty depending, among other things, on economic growth, petroleum prices, energy demand adjustments to prices and supplies of nuclear power. Changes in economic growth result in greater than proportional changes in the demand for thermal coal. The demand for thermal coal shows sizable but asymmetrical responses to high and low OPEC oil price scenarios; the short-term impact on thermal coal demand of higher OPEC oil prices is relatively larger than its long-term impact and vice versa. The likelihood of a significant shortfall in nuclear power supplies points to the possibility of a substantially higher demand for thermal coal. The future demand for thermal coal will be determined largely by what happens in the industrial countries, not only because they will account for the bulk (75-80%) of the market but also because they will play the pivotal role in determining the final outcome of the uncertainties considered here.

Comparison with Other Projections

It is of interest to compare the base-case projections with those made by other groups in this field. The projections chosen here for comparison are the projections of total coal demand made by other international and national organizations. No attempt has been made to reconcile the differences in the underlying assumptions.

The International Energy Agency (IEA) in its *World Energy Outlook 1982* foresees substantially higher long-term demand for coal than our base-case projections for most of the industrial-country regions (Table 3.7). The projections in World Energy Outlook were done immediately following the second
Table 3.7: A COMPARISON OF THE BASE CASE WITH OTHER PROJECTIONS  
(percent difference from the base case)

<table>
<thead>
<tr>
<th></th>
<th>1990</th>
<th>2000</th>
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<tbody>
<tr>
<td>World Energy Outlook /a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>North America</td>
<td>0.2 ~ 0.4</td>
<td>9.0 ~ 33.4</td>
</tr>
<tr>
<td>Western Europe</td>
<td>23.4 ~ 29.5</td>
<td>37.2 ~ 37.8</td>
</tr>
<tr>
<td>Japan/Australia/New Zealand</td>
<td>4.3 ~ 15.8</td>
<td>-22.1 ~ 15.7</td>
</tr>
<tr>
<td>Developing Countries</td>
<td>-21.8 ~ -12.0</td>
<td>-14.4 ~ -0.6</td>
</tr>
<tr>
<td>World Total</td>
<td>3.3 ~ 8.2</td>
<td>8.8 ~ 26.8</td>
</tr>
</tbody>
</table>

Coal Information Report /b

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
<td>1.1</td>
<td>8.1</td>
</tr>
<tr>
<td>Western Europe</td>
<td>-2.1</td>
<td>-18.7</td>
</tr>
<tr>
<td>Japan/Australia/New Zealand</td>
<td>-8.8</td>
<td>-13.4</td>
</tr>
<tr>
<td>Total, Industrial Countries</td>
<td>-1.1</td>
<td>-3.1</td>
</tr>
</tbody>
</table>

Annual Energy Outlook /c

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>-1.7</td>
</tr>
</tbody>
</table>


/b International Energy Agency, Coal Prospects and Policies in IEA Countries: 1983 Review, Paris, 1984. Comparison here uses IEA's projected level of solid fuels consumption minus consumption of non-commercial fuels which is assumed to remain constant at its 1982 level through the year 2000. Since some Western European countries are not a member of IEA, the comparison used IEA's projected rates of change for Western Europe.

oil price increases, at the height of optimism for thermal coal. The IEA's projections for the developing countries, however, are substantially lower than our base-case projections. Although the differences are within the ranges of sensitivity results shown in the preceding section, it is difficult to account for them in terms of differences in the underlying assumptions. IEA's high demand scenario assumes constant real prices for OPEC oil throughout the projection period and economic growth rates that are close to our base-case assumption. It would, therefore, be more appropriate to compare IEA's high demand scenario with our low oil price scenario, suggesting that the differences in perception are greater than the percentage differences shown in Table 3.7. A notable feature of IEA's projections is the insensitivity of the demand for thermal coal to OPEC oil prices.

Projections contained in IEA's Coal Prospects and Policies in IEA Countries are based on recent individual country submissions to IEA. Also shown is the latest projection of US coal demand done by the US Department of Energy. A notable feature of these recent projections is a sharp downward revision from the earlier ones, particularly for Western Europe and Japan. Recent projections by Data Resources Inc. (Europe) of net imports of coal into Western Europe show an increase from 69 mtce in 1982 to 123 mtce in 1990 and 243 mtce in the year 2000. The low demand scenario of IEA's World Energy Outlook puts coal net imports of Western Europe at 196 mtce in 1990 and 399 mtce in the year 2000. Our base-case projections imply net imports of 115 mtce in 1990 and 280 mtce the year 2000. This is an illustration of not only the degree of uncertainties involved but also of the severity of the change in the perception of analysts.
Environmental Pollution and Its Abatement

An array of environmental problems are associated with the coal fuel cycle, significantly distracting from its cost advantage. Remedial measures taken so far in the industrial countries have successfully alleviated most of the problems at costs that allow coal's cost advantage vis-a-vis hydrocarbon fuels to be maintained. Coal mining can cause land subsidence (in the case of underground mining) or disturbance of surface terrain and vegetation (in the case of surface mining); emissions of noise and dust affect surrounding areas, and pollution of surface and ground water by drainage occurs wherever coal is exposed to leaching. Conscientious efforts and careful planning made it possible to eliminate most of these problems at new and existing mines. While progress is continuing through wider application and improvement of pollution-control technology, environmental concern also keeps shifting its focus. Recently, attention has been centered on acid rain and the climatic implications of carbon dioxide, which transcend national boundaries and encompass all fossil fuels.

It is often difficult to separate environmental control costs from general mining costs; available estimates put the environmental costs of coal mining at $1.00-5.00 (1982 US dollars) per ton of coal produced. Coal preparation enhances the quality of coal by reducing the content of sulfur, ash and other impurities. For this reason, not all of the costs of preparation, estimated at $1.00-4.00 (1982 US dollars) depending upon the quality of the run-of-mine coal, can be considered environmental. Reduction of the sulfur content through a preparation process can substantially ease the problem of sulfur oxide emission at the combustion stage.
The costs of pollution control at mining and preparation stages are included as a part of the total cost of production. The long-run coal supply function in WEPM implicitly assumes that the environmental control costs will increase at the same rate as the total cost of production.

Combustion of coal produces such pollutants as sulfur oxides, carbon monoxide and dioxide, particulates, and organic compounds and trace metals. Among these, sulfur oxides pose the most serious and costly pollution problem. Methods of coping with sulfur oxide emissions have been primarily twofold: one is to burn low-sulfur coal and the other is to use one of the available flue gas desulfurization (FGD) technologies, or "scrubbers." Developments in FGD systems have overcome much of the inefficiency and unreliability problems encountered initially, and now are widely accepted. Typical systems can eliminate 95% of sulfur oxides from flue gas. With more stringent sulfur emission standards being imposed in industrial countries, application of FGD technologies is expected to expand rapidly, even to some of the facilities initially designed to use low-sulfur coal.

One important drawback of FGD is its high cost; the capital cost of an FGD system is typically $70-180 (1982 US dollars) per KW of capacity, depending on the sulfur content of coal it is designed to process. This is 11-20% of non-environmental capital costs of a large-scale coal-fired power plant, or 8-18% of the total cost of electricity generation. Technological progress in several directions (use of adipic acid or other organic acids in conjunction with wet limestone systems, limestone injection multistage burners, and fluidized bed combustion) promises to either reduce the capital cost or enhance the efficiency of sulfur oxide removal.
Control of nitrogen oxide emission has been a relatively neglected area, with no emission standards imposed in many industrial countries. The most common and inexpensive method of reducing nitrogen oxides from flue gas is to minimize the oxygen availability during the combustion process (called combustion modification), which generally removes up to 50% of the nitrogen oxides in the flue gas. Further reduction requires one of the flue gas denitrification processes. Currently, full-scale flue gas denitrification is practiced only in Japan. Capital costs for combustion modification range between $5-10/KW, while Japanese experience shows capital costs of flue gas denitrification in the range of $35-40/KW.

More than 99.5% of the particulates can be removed from the flue gas by either electrostatic processes or fabric filters (bag-houses), at investment costs of $10-40/KW and $25-50/KW, respectively. These well-established, highly efficient systems are used in almost all large-scale coal combustion facilities. Fabric filters are more efficient than electrostatic devices in removing very small particles. For this reason and because of the concern for trace metals and other pollutants contained in small particles, fabric filters are likely to increase their share in the years ahead.

Disposal of ash and FGD wastes could add $15-30/KW to the capital costs of a coal-fired power plant. These costs, however, can be recovered to some extent by economic use of the waste material. About 30-40% of pulverized fly ash is used for specialized road fills, in the manufacture of building blocks, and as a substitute for cement. Japan uses FGD sludge to produce gypsum.

In summary, the capital costs of pollution control in coal-fired power plants can amount to $100-300/KW (1982 US dollars), depending on the
degree of anti-pollution requirements. Would these costs discourage the choice of coal over oil? To answer this question, Table 3.8 shows estimates of the costs of electricity generation for hypothetical new power plants. The calculations show that coal-fired power generation will cost substantially less than oil-fired electricity at today's fuel prices, even under high

<table>
<thead>
<tr>
<th>Table 3.8: COSTS OF ELECTRICITY GENERATION OF HYPOTHETICAL NEW POWER PLANTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1982 mills/KWh; capacity factor = 65%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Low-Sulfur Coal</th>
<th>High-Sulfur Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Heavy Fuel Oil</td>
<td>Heavy Fuel Oil</td>
</tr>
<tr>
<td>Fuel Cost</td>
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<td>37</td>
</tr>
<tr>
<td>Fuel Price</td>
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<td>$24.6/bbl</td>
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<tr>
<td>Conversion Efficiency</td>
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<td>36%</td>
</tr>
<tr>
<td>Operating Cost</td>
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<tr>
<td>Capital Cost (10%)</td>
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<td>12.1-13.8</td>
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<tr>
<td>Cost (15%)</td>
<td>14.7-16.1</td>
<td>17.4-19.8</td>
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<tr>
<td>Power Plant ($/KW)</td>
<td>550-600</td>
<td>550-600</td>
</tr>
<tr>
<td>Pollution Control ($/KW)</td>
<td>100-140</td>
<td>100-300</td>
</tr>
<tr>
<td>Total Investment ($/KW)</td>
<td>550-600</td>
<td>750-1,050</td>
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<tr>
<td>Total Generating Cost</td>
<td>53.8-54.7</td>
<td>53.3-55.0</td>
</tr>
<tr>
<td>At 10%</td>
<td>58.2-59.6</td>
<td>58.6-61.0</td>
</tr>
<tr>
<td>At 15%</td>
<td>59.2-60.6</td>
<td>61.3-64.3</td>
</tr>
</tbody>
</table>

/a Assuming that all investments are financed from borrowing at interest rates of 10% or 15% per year, amortized over the life of the plant (30 years).

Source: Compiled from data contained in IEA/OECD, World Energy Outlook, and Costs of Coal Pollution Abatement.
capital costs for environmental control. It is only under the highest capital expenditures for pollution control and a high rate of capital charge (15%) that the cost of electricity generated from imported coal in Western Europe and Japan approximates that of oil-fired electricity generation. The cost of nuclear electricity can vary from the least expensive to the most expensive among the alternatives considered, because of the uncertainty of investment requirements for enhancing reactor safety.
IV. COAL SUPPLIES AND TRANSPORTATION

This section presents estimates of coal mining and transportation costs that are used to specify the long-term coal supply function for the major coal-producing countries. The supply functions are used in WEPM to endogenously determine the levels of coal production and exports of each region on the basis of its cost competitiveness in the world market. It is shown that, although much more work needs to be done to estimate the supply function for several key producers, the available evidence strongly indicates that the long-term costs of coal mining are not likely to increase appreciably over the next 20 years.

Production and Reserves

The main advantage of coal, compared with petroleum and natural gas, is its relative abundance; proven worldwide recoverable reserves of coal amount to more than 200 times the current annual production (Table 4.1). There are three broad categories of coal: anthracite, bituminous and sub-bituminous coal, and lignite, classified according to the degree of carbonization. Slightly more than 5% of world coal production consists of anthracite, about 69% of bituminous coal and the remaining 26% of lignite. Compared to bituminous coal and lignite, anthracite has the advantage of being a clean-burning fuel. Bituminous coal has a higher heat value than sub-bituminous coal and lignite. Some bituminous coals have "caking" properties when heated in the absence of air. These are known as coking or metallurgical coal. About 27% of the coal produced outside the centrally planned economies consists of metallurgical coal. The non-coking coal is also known as steam or thermal coal. Technological advances have made it possible to blend to some extent coking and non-coking coals in production of cokes. Only a small number of countries have data on proven reserves of metallurgical coal. The total of these reserves (75 billion tons) amounts to 18% of the world's proven recoverable reserves of anthracite and bituminous coals. About 20% of the proven recoverable reserves in the United States is metallurgical coal. In Australia and West Germany, metallurgical coal reserves are close to 60% of their total bituminous coal reserves, while South African coal is mostly non-metallurgical.

1/ There are three broad categories of coal: anthracite, bituminous and sub-bituminous coal, and lignite, classified according to the degree of carbonization. Slightly more than 5% of world coal production consists of anthracite, about 69% of bituminous coal and the remaining 26% of lignite. Compared to bituminous coal and lignite, anthracite has the advantage of being a clean-burning fuel. Bituminous coal has a higher heat value than sub-bituminous coal and lignite. Some bituminous coals have "caking" properties when heated in the absence of air. These are known as coking or metallurgical coal. About 27% of the coal produced outside the centrally planned economies consists of metallurgical coal. The non-coking coal is also known as steam or thermal coal. Technological advances have made it possible to blend to some extent coking and non-coking coals in production of cokes. Only a small number of countries have data on proven reserves of metallurgical coal. The total of these reserves (75 billion tons) amounts to 18% of the world's proven recoverable reserves of anthracite and bituminous coals. About 20% of the proven recoverable reserves in the United States is metallurgical coal. In Australia and West Germany, metallurgical coal reserves are close to 60% of their total bituminous coal reserves, while South African coal is mostly non-metallurgical.
### Table 4.1: WORLD COAL RESERVES AND PRODUCTION

(billion tons of coal equivalent)

<table>
<thead>
<tr>
<th></th>
<th>Proven Recoverable Reserves</th>
<th>Production, 1978</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hard Coal /a</td>
<td>Total</td>
</tr>
<tr>
<td>NOAM</td>
<td>121.9</td>
<td>187.0</td>
</tr>
<tr>
<td>WEUR</td>
<td>71.0</td>
<td>81.5</td>
</tr>
<tr>
<td>JANZ</td>
<td>19.2</td>
<td>28.5</td>
</tr>
<tr>
<td>CSEX</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>CDOP</td>
<td>1.1</td>
<td>2.5</td>
</tr>
<tr>
<td>NOEX</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>OIDC</td>
<td>70.9</td>
<td>86.7</td>
</tr>
<tr>
<td>Total above</td>
<td>285.3</td>
<td>387.4</td>
</tr>
<tr>
<td>Centrally Planned Economies</td>
<td>205.8</td>
<td>246.7</td>
</tr>
</tbody>
</table>

/a Hard coal is broadly defined to include anthracite, bituminous and sub-bituminous coal.


Thirds of world production takes place in the United States, the U.S.S.R. and the People's Republic of China. Other important coal producing countries are Australia, Canada, South Africa, Poland, India, United Kingdom and Federal Republic of Germany. Important coal exporters are the United States, Australia, Canada, Poland and South Africa. Potential new exporters include Colombia, Indonesia and Botswana.

Coal is extracted by either open-cast (surface) mining or underground mining. Coal production has been steadily shifting to open-cast mining in
almost all countries with suitable coal resources. Table 4.1 shows that about 36% of world coal production in 1978 came from open-cast mines. Only a small number of countries have proven reserves of coal which can be surface mined--for the United states about 26% of the US proven reserves, for South Africa about 45% and for Australia about 24%.

The coal mining industry is basically competitive in the main coal producing industrial countries. 1/ In the United States, for example, there are more than 3,000 coal mining companies producing coal. The situation is similar in Australia, Canada and South Africa. In other major coal producing countries, the industry is either a part of the public sector (the United Kingdom, India and the centrally planned economies) or is subject to government participation and control (Federal Republic of Germany, Republic of Korea, and many Western European and developing countries). Government intervention in the coal industry is largely a result of the need for government subsidies to keep high-cost operations in production.

**Coal Cost Structure and the WEPM Coal Supply Model**

Mining costs differ widely between countries and mining regions, depending on the characteristics of coal deposits, factor prices, and the choice of the mining technique. The WEPM coal supply model 2/ distinguishes between underground and open-cast coal mining because of their widely different cost structure. Production costs of open-cast mines are usually

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1/ For a view that the international thermal coal market is less than competitive, see David S. Abbev and Charles D. Kolstad, "The Structure of International Steam Coal Markets," Los Alamos National Laboratory, LA-UR 82-1869, Los Alamos, New Mexico.

2/ For details, see Choe, _op. cit._, pp. 66-85.
substantially lower than those of underground mines due to higher labor productivity, greater economies of scale and faster development. In underground mining the cost of mining depends on the thickness, depth and grade of coal seams, roof and floor conditions, complexity of geological structure, extent of water and methane presence, etc. In open-cast mining the key factor is the ratio of overburden thickness to depth of coal seam.

Open-cast mining involves more capital and less labor than underground mining. As a rule of thumb, the cost of labor is approximately 50% of the total mining costs of underground mining in industrial countries. In the case of developing countries, the cost share of labor can be higher (e.g., India) or lower (e.g., South Africa) than in the industrial countries. In the case of open-cast mining, the cost share of labor is typically 15-20%, and that of capital around 40-50%. The wide variation in the cost share suggests that labor and capital are highly substitutable in coal mining, although productivity of capital is such that under a relative factor price configuration such as that in South Africa, fairly capital intensive mechanized mining could be the preferred choice if coal deposits are suitable for such mining methods.

In WEPM, the short- and long-run coal supply functions are defined by the short- and long-run marginal costs of production, respectively. Estimation of the long-run supply curve for the major coal-producing countries is described below. For the short run, it is postulated that the supply has unitary price elasticity, which closely replicates the actual export price movements during the 1980-82 price increases. Coal supply is assumed to take place along the short-run supply curve whenever world demand exceeds world production capacity by more than 5%. Capacity expansion is assumed to respond
to coal prices with certain lags (3 to 5 years). The coal mining wage rates are assumed to increase at the rate of growth of per capita GDP.

**United States and Canada**

Assuming constant factor prices and no technical progress in mining, Zimmerman 1/ developed a long-run coal supply model for the United States. From the known characteristics of the proven reserves in the United States and using historical and engineering data, he estimated the long-run supply function for different regions and for different sulfur categories. His main finding was that the costs of mining will increase at about 1.4% p.a. for the eastern low-sulfur coal over the next 20 years at the current rate of production; for the eastern high sulfur coal, mining cost will increase at 0.5% p.a. at the current rate of production, and for the western surface-mined, low-sulfur coal, at a 0.25% p.a. at five times the current rate of production. He also found that even under strict environmental controls 2/ and some increases in the rail transportation cost of the western coal, interregional competition will strongly favor the low-sulfur western coal to take the place of the high-cost eastern low sulfur coal. These adjustments would imply that the costs of the eastern low-sulfur coal will increase at a rate lower than 1.4% p.a. as the level of its production is projected to decline in the years ahead. On the other hand, the mining costs of the western low-sulfur coal and high-sulfur coal in the midwestern and eastern regions will increase at faster rates than the case when production remains static.


2/ The Best Available Control Technology (BACT) provision of the Clean Air Act favors the eastern high-sulfur coal.
The average annual rate of cost increases for US underground mining as a whole is estimated at about 0.9% p.a. over the next 20 years at the current rates of production for each region and sulfur category. However, if the share of the eastern low-sulfur coal declines while that of high-sulfur coal increases as in Zimmerman's low-sulfur-emission-standard scenario, \(^1\) the rate of underground mining cost increases is reduced to 0.7% p.a. at the current rate of total underground production.

In the case of surface mining, the average rate of cost increases for the United States as a whole is likely to be slowed down considerably by the shift of production to the low-cost western mines. The average rate of increase comes to about 0.45-0.50% p.a. at the current rate of total surface-mine production.

Results of several other studies \(^2\) of the costs of long-term US coal supplies do not deviate substantively from Zimmerman's findings. Although the gist of these findings is probably near to the true picture, it is difficult to arrive at precise estimates of the slope of the long-term supply curve largely because of the lack of sufficient geologic information for a large part of the proven reserves.

Significant coal reserves are found in the provinces of British Columbia and Alberta in Canada, which are not significantly different from the US western coal in terms of cost characteristics. Little, however, has been done to estimate Canada's long-term coal supply function. New mines planned

\(^1\) 1.2 lb SO\(_2\) per million BTUs.

\(^2\) Examples are the coal supply functions developed by the ICF, Inc. and the surface and underground mining cost equations developed by Science Applications, Inc. for the US Energy Information Administration.
for the near future show a cost structure that is closely comparable with that of the US western mines.

Australia

Australia's large coal resources are located mostly in the states of New South Wales and Queensland, which together accounted for more than 95% of its production in 1982. Surface mining provided about 54% of the total production. As in the US Appalachia, most of underground production comes from seams more than 3 meters thick and less than 500 meters deep. The overburden/seam thickness ratios of the Australian surface mines are comparable with those of the Power River Basin in Montana/Wyoming, but are at a disadvantage in terms of scale economies.

A recent study 1/ shows that the real cost of production in Australia increased by almost 20% between 1977 and 1982, mostly because of increases in the unit cost of inputs, particularly mining wages and royalties. These increases were mostly of short-term nature and reflected the fierce competition for a larger share of the rent between the suppliers of factor inputs to the Australian coal mining industry.

A survey of existing mines in the above study shows that the costs of thermal coal, FOB export terminals, currently range between A$35-55 per ton. It is also suggested that within this cost range substantial new capacities (as much as the existing capacities) are likely to be available. This information, however, does not lead us to the likely shape of the long-term supply curve.

Doherty estimated that Australian thermal coal exports can be increased from 25 mtce to 50 mtce if the export price (in January 1982 prices) is increased from A$50 per ton to approximately A$57. The order of magnitude involved here does not seem to be significantly different from that of the Longworth and McKenzie report. Again, however, it is difficult to translate this type of information into a long-run supply curve.

In the absence of tangible estimates, it is assumed that Australia's long-term coal supply curves should closely resemble those of the United States. This assumption is equivalent to saying that Australia will be able to maintain its current competitive position vis-à-vis the United States in the world export market in the years ahead.

South Africa

South Africa is probably the lowest-cost producer and exporter of thermal coal. Several factors make this possible: a generally favorable resource base, low wages, relatively small transportation costs, and favorable government policies.

Coal deposits in South Africa are found in isolated basins, in several flat layers of seams with an average depth of less than 200 meters and seam thickness of more than two meters. These characteristics permit highly mechanized mining under generally good mining conditions. Surface mining currently accounts for about 25% of total production. Coal quality, seam thickness, and mining conditions deteriorate gradually as production moves from the center to the periphery of the basins. The run-of-mine coal

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generally has high ash content but low sulfur content, and requires extensive upgrading to reach export quality.

Depletion of coal resources in South Africa asserts itself primarily in the form of deteriorating quality of raw coal. It is estimated that for the planned phase IV expansion of exports by 30-40 mtce for the period after 1987 the average washery yield of raw coal could be reduced by as much as 5% below the current level. 1/ This is equivalent to a 7% increase in the cost per ton of export quality coal.

The real coal mining wage rate of miners in South Africa has quadrupled between 1970 and 1982 and is expected to increase at a fast rate. It is also expected that these increases will be partially offset by continued improvements in labor productivity, which has slightly less than doubled during the same period. The increases in labor productivity, however, will require more capital than before.

The future of factor prices and costs is, of course, highly uncertain. Under a set of assumptions about future factor costs, Olliver 2/ estimated that the cost per ton of new capacities to come on stream by 1995 will be on the average 15% higher than the current level, and more than half of this increase will result from coal quality deterioration. However, one cannot rule out the possibility of much faster cost increases, considering the fact that the average wage rate of miners is still less than US$1.50 per


hour. Olliver assumed a 33% increase between 1979 and 1990 and another 10% increase between 1990 and 1995.

The Long-run Supply Function

It seems clear from the above studies that, as far as the three main coal exporters are concerned, the long-term coal supply curve is highly price elastic. Estimates of the long-run coal supply function for other major coal producers are only sketchy at this time. It would be reasonable to postulate that the long-run costs in Western Europe and Japan will increase at substantially faster rates than in the coal-exporting countries. Some of the potential exporters of coal among developing countries appear to be highly cost competitive with the established ones (for example, Colombia).

The above considerations, together with the estimates for the current major exporters, are reflected in the WEPM base-case assumptions about the long-run cost curve and production shares shown in Table 4.2. The cost is on an FOB mine basis, except that the cost of US western coal includes the transportation cost from western mines to eastern markets. The shares of open-cast production by the year 2000 are determined on the basis of historical trends, estimates of coal reserves extractable by open-cast techniques and the results of an interregional competition model in the case of the United States. The oil-exporting developing countries are assumed to follow the same pattern of long-run cost increases as the oil-importing developing countries.

Base-Case Supply Projections

Given the coal supply model described above, world coal production will be determined along the short- or long-run supply curve to clear the market. Total production of the market-economy countries equals their total demand minus the net exports from the centrally planned economies. The way
Table 4.2: LONG-RUN COST FUNCTION AND PRODUCTION SHARES OF COAL

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<td></td>
<td></td>
</tr>
<tr>
<td>NOAM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underground</td>
<td>34.7</td>
<td>0.68</td>
<td>30</td>
</tr>
<tr>
<td>Open-Cast</td>
<td>21.4</td>
<td>0.47</td>
<td>70</td>
</tr>
<tr>
<td>WEUR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underground</td>
<td>75.9</td>
<td>1.00</td>
<td>90</td>
</tr>
<tr>
<td>Open-Cast</td>
<td>28.1</td>
<td>0.80</td>
<td>10</td>
</tr>
<tr>
<td>JANZ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underground</td>
<td>38.0</td>
<td>0.68</td>
<td>35</td>
</tr>
<tr>
<td>Open-Cast</td>
<td>18.6</td>
<td>0.50</td>
<td>65</td>
</tr>
<tr>
<td>OIDC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underground</td>
<td>28.7</td>
<td>0.75</td>
<td>60</td>
</tr>
<tr>
<td>Open-Cast</td>
<td>16.9</td>
<td>0.60</td>
<td>40</td>
</tr>
</tbody>
</table>

/a Expressed as percent cost increases per year at 1978 rates of production.

Source: World Bank, Economic Analysis & Projections Department.

the total production is divided between the market economy countries depends on the costs of production; the countries with higher costs and faster cost increases will gradually give way to the countries with lower costs and slower cost increases.

Table 4.3 shows the base-case supply projections that are consistent with the base-case demand projection. As expected, the main source of
Table 4.3: BASE-CASE COAL SUPPLY PROJECTIONS (mtce)

<table>
<thead>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NOAM</td>
<td>755.5</td>
<td>750.6</td>
<td>759.0</td>
<td>780.0</td>
<td>900.0</td>
<td>1,070.0</td>
<td>1,300.0</td>
</tr>
<tr>
<td>WEUR</td>
<td>281.9</td>
<td>280.6</td>
<td>276.2</td>
<td>275.0</td>
<td>265.0</td>
<td>260.0</td>
<td>250.0</td>
</tr>
<tr>
<td>JANZ</td>
<td>97.7</td>
<td>110.2</td>
<td>116.0</td>
<td>132.0</td>
<td>164.5</td>
<td>205.0</td>
<td>263.0</td>
</tr>
<tr>
<td>OPEC</td>
<td>1.5</td>
<td>1.3</td>
<td>1.6</td>
<td>3.5</td>
<td>10.0</td>
<td>17.0</td>
<td>25.0</td>
</tr>
<tr>
<td>NOEX</td>
<td>5.2</td>
<td>6.0</td>
<td>6.0</td>
<td>6.8</td>
<td>8.5</td>
<td>12.0</td>
<td>18.0</td>
</tr>
<tr>
<td>OIDC</td>
<td>259.1</td>
<td>286.2</td>
<td>294.0</td>
<td>327.0</td>
<td>382.5</td>
<td>442.0</td>
<td>532.0</td>
</tr>
<tr>
<td>WORLD TOTAL</td>
<td>1,400.9</td>
<td>1,434.9</td>
<td>1,452.8</td>
<td>1,524.3</td>
<td>1,730.5</td>
<td>2,006.0</td>
<td>2,388.0</td>
</tr>
<tr>
<td>CPE Net Exports</td>
<td>25.4</td>
<td>17.1</td>
<td>15.2</td>
<td>25.0</td>
<td>20.0</td>
<td>20.0</td>
<td>15.0</td>
</tr>
</tbody>
</table>


Additional coal supplies to meet the future needs will be the current low-cost coal producers—North America, Australia and South Africa. Production in excess of domestic demand in these countries will be determined mainly by the cost competitiveness of each country relative to the others in the expanding international market for thermal coal. The supply projections here reflect the long-term cost structure built into the coal supply model. 1/

1/ The base-case supply projections for the key coal-producing countries are as follows:

<table>
<thead>
<tr>
<th></th>
<th>1982</th>
<th>1990</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mtce</td>
<td></td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td>724.8</td>
<td>835.0</td>
<td>1,180.0</td>
</tr>
<tr>
<td>Canada</td>
<td>34.1</td>
<td>65.0</td>
<td>120.0</td>
</tr>
<tr>
<td>Australia</td>
<td>98.7</td>
<td>148.0</td>
<td>245.0</td>
</tr>
<tr>
<td>South Africa</td>
<td>102.3</td>
<td>135.0</td>
<td>200.0</td>
</tr>
<tr>
<td>Total</td>
<td>959.9</td>
<td>1,183.0</td>
<td>1,745.0</td>
</tr>
</tbody>
</table>
Because of close cost competitiveness, market shares of these countries can be highly sensitive to changes in the relative cost configuration that can be brought about not only by changes in factor costs but also by exchange rate changes and transport costs. An example is the sharp decline in US production in 1982-83 which resulted, among other things, from the appreciation of the US dollar.

Western Europe and Japan, despite efforts to maximize domestic coal supplies, will face increasing difficulties in maintaining their current level of production. The share of Western Europe in world production is projected to decline from 19% in 1982 to 10% by the year 2000. Capital expenditures by the coal mining industry of Western Europe increased from less than 0.4 billion ECUs (European Currency Units) in 1974 to 1.15 billion ECUs in 1979 and 1.65 billion ECUs in 1980. The bulk of the increase was recorded in the United Kingdom in new mines in Yorkshire and the Midlands. Coal production, however, has not been commensurate with the increased expenditure because of rapid increases in capital costs per ton of new capacity. New capacities likely to come on stream in the United Kingdom will not be sufficient to offset the closure of inefficient old mines elsewhere in Europe. The lack of coal resources in Japan is also likely to limit production in that country to no more than its current level.

**Coal Transportation**

Costs of coal transportation constitute a major component of the CIF cost of thermal coal to the coal-importing countries. Table 4.4 shows the transportation cost components as of 1983 for the main international flows of thermal coal.
Table 4.4: TRANSPORTATION COST STRUCTURE, 1983
(USS/ton)

<table>
<thead>
<tr>
<th>To Western Europe</th>
<th>Inland /a Rail Transport</th>
<th>Port /a Charges</th>
<th>Ocean /b Freight</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern United States</td>
<td>16.5 ~ 17.6</td>
<td>0.6 ~ 1.0</td>
<td>4.5 ~ 6.0</td>
<td>21.6 ~ 24.6</td>
</tr>
<tr>
<td>Western United States</td>
<td>23.0 ~ 26.0</td>
<td>5.0</td>
<td>8.0 ~ 9.0</td>
<td>36.0 ~ 40.0</td>
</tr>
<tr>
<td>Australia</td>
<td>7.5 ~ 11.0</td>
<td>3.5 ~ 4.5</td>
<td>10.0 ~ 11.0</td>
<td>21.0 ~ 26.5</td>
</tr>
<tr>
<td>South Africa</td>
<td>5.8 ~ 6.9</td>
<td>2.8</td>
<td>6.0 ~ 7.0</td>
<td>14.6 ~ 16.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>To Japan</th>
<th>Inland /a Rail Transport</th>
<th>Port /a Charges</th>
<th>Ocean /b Freight</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern United States</td>
<td>16.5 ~ 17.6</td>
<td>0.6 ~ 1.0</td>
<td>10.5 ~ 12.0</td>
<td>27.6 ~ 30.6</td>
</tr>
<tr>
<td>Western United States</td>
<td>23.0 ~ 26.0</td>
<td>5.0</td>
<td>6.0 ~ 7.0</td>
<td>34.0 ~ 38.0</td>
</tr>
<tr>
<td>Western Canada</td>
<td>22.0 ~ 24.0</td>
<td>3.0 ~ 4.0</td>
<td>5.5 ~ 6.5</td>
<td>30.5 ~ 34.5</td>
</tr>
<tr>
<td>Australia</td>
<td>7.5 ~ 11.0</td>
<td>3.5 ~ 4.5</td>
<td>5.0 ~ 5.5</td>
<td>16.0 ~ 21.0</td>
</tr>
<tr>
<td>South Africa</td>
<td>5.8 ~ 6.9</td>
<td>2.8</td>
<td>7.5 ~ 8.5</td>
<td>16.1 ~ 18.2</td>
</tr>
</tbody>
</table>

/a Derived from the following reports to the World Bank:

/b Coal Week International, various issues. Representative freight rates of relatively large cargos, FIO (free in and out).

Coal is carried from mines to export terminals (ports) primarily by unit trains and then to import terminals by ocean bulk carriers. The rail and ocean transportation industries operate under widely different market and industry structures. The rail transportation industry, whether private or nationalized, serves captive markets and enjoys a near monopoly power. Alternatives to rail transportation (for example, coal slurry pipelines) have not yet imposed serious competitive pressure on the rail transportation
industry and are not likely to do so in the near future. As a result, the rail freight rate in most of the coal-exporting countries (particularly, the United States and Australia) has been maintained at high levels, considerably above cost.

The ocean shipping industry, on the other hand, can be characterized as being essentially a competitive industry. Ocean freight rates for coal have declined considerably in recent years not only because of global recession and reduced international trade but also because of increasing proliferation of large coal vessels of 100,000-150,000 DWT class. For example, it now costs less than $5.00 per ton to ship a large (100,000 tons and above) cargo of coal from the US east coast to the major Western European ports, compared with the lowest available freight rate of $15.00 per ton in early 1981 for the same route.

The coal supply/demand outlook presented here assumes no significant changes in the real costs of coal transportation. This is a reflection more of the lack of firm understanding of the industry than of an informed judgement. One can speculate, however, that the ocean freight rate can be further reduced as larger vessels (possibly in the 200,000-300,000 DWT range) are introduced. In such a case, a major upgrading of existing port facilities will be required, which will involve substantially higher port charges. This will make economic sense only when international coal trade volume increases far beyond its current level, perhaps in the late 1990s.

There is obviously some room for rail freight rates to come down, but such an eventuality is unlikely under the present industry structure. In the United States the real freight rate of rail transportation of coal has been increasing at an average annual rate of 4% in the 1970s. The rates have
reached the point where further increases would severely reduce competitiveness of US coal exports in international markets. A positive side to this story is that the rail industry over the years has accumulated sufficient capital to meet investment needs for future capacity expansion. In Australia, the rail industry is a state enterprise and the rail rates have always been set at high levels to expropriate a part of the economic rent of its coal resources. Despite industry complaints, this policy is not likely to change. In South Africa, on the other hand, the state-owned rail system has adopted cost-based pricing of rail rates. This policy is expected to be continued in future expansion of rail capacities, which incidentally are likely to cost more than the existing rail system.
V. INTERNATIONAL TRADE AND EXPORT PRICES

The future volume of world trade in thermal coal will be determined largely by the extent of increases in the demand for thermal coal in Western Europe, Japan, and several newly industrializing developing countries. Table 5.1 shows the base-case projection of net trade 1/ of coal for the major exporting and importing regions. The projected increases in trade will mostly consist of thermal coal, particularly in the form of net imports of Western Europe and Japan. The projected increases in metallurgical coal demand by the iron and steel industry of Western Europe and Japan amount to less than 25 mtce over its 1982 level through the year 2000. Even if domestic production of metallurgical coal in these regions declines in proportion to total coal production, the net import requirements for metallurgical coal by the iron and steel industry are not likely to increase by more than 35 mtce between 1982 and the year 2000. This implies that close to 90% of the incremental net import requirements by these regions over the 18-year period will consist of thermal coal.

The developing country net trade projections hide the anticipated increases in imports by newly industrializing developing countries (for example, Rep. of Korea, Turkey, Yugoslavia, Brazil, Mexico) for both thermal and metallurgical coal. A large part of these increases is expected to be met by increases in exports from Colombia, Indonesia, and South Africa.

Between 1982 and 1985, the net import demand for coal in Western Europe, Japan and the developing market economies other than South Africa,

1/ Net trade is defined as the difference between gross exports and gross imports for the 1982 actuals, but as the difference between consumption and production for the projections.
Table 5.1: NET IMPORTS AND EXPORTS OF COAL /a
( mtce)

<table>
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<tbody>
<tr>
<td><strong>Net Imports</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western Europe</td>
<td>85.8</td>
<td>85.0</td>
<td>115.0</td>
<td>180.0</td>
<td>280.0</td>
</tr>
<tr>
<td>Japan</td>
<td>78.7</td>
<td>86.5</td>
<td>105.0</td>
<td>139.0</td>
<td>179.0</td>
</tr>
<tr>
<td>Developing Countries excluding South Africa</td>
<td>35.5</td>
<td>35.8</td>
<td>46.0</td>
<td>60.0</td>
<td>76.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>200.0</td>
<td>207.3</td>
<td>266.0</td>
<td>379.0</td>
<td>535.0</td>
</tr>
<tr>
<td><strong>Net Exports</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North America</td>
<td>101.3</td>
<td>85.0</td>
<td>120.0</td>
<td>190.0</td>
<td>300.0</td>
</tr>
<tr>
<td>Australia</td>
<td>47.3</td>
<td>64.3</td>
<td>84.0</td>
<td>114.0</td>
<td>152.0</td>
</tr>
<tr>
<td>South Africa</td>
<td>27.5</td>
<td>32.9</td>
<td>42.0</td>
<td>55.0</td>
<td>68.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>176.1</td>
<td>182.2</td>
<td>251.0</td>
<td>359.0</td>
<td>520.0</td>
</tr>
<tr>
<td>CPE Net Exports</td>
<td>15.2</td>
<td>25.0</td>
<td>20.0</td>
<td>20.0</td>
<td>15.0</td>
</tr>
</tbody>
</table>

/a Net trade for 1982 is defined as the difference between gross exports and gross imports; for the projections, it is defined as the difference between production and consumption.

which together accounted for 80% of gross coal imports of the market-economy countries, is projected to increase only by 7.3 mtce, or by 3.7%. This figure, however, is misleading because the net imports in 1982 (gross imports minus gross exports) included speculative imports in excess of actual needs, particularly in Western Europe where coal stocks increased by 23 mtce in
1982. The net import demand in 1982, defined as the excess of consumption over production, amounted to only 174 mtce in 1982 for the three importing regions combined. In terms of import requirements (demand in excess over domestic supply), the projections imply an increase by 33 mtce between 1982 and 1985, or at 6% p.a. An increase of this magnitude is plausible in view of the expectation for substantial economic recovery by 1985 in these regions from the bottom of recession in 1982. The import demand for thermal coal in Western Europe was extremely weak in 1983 when the countries in the region worked off their excessive stocks. Stock drawdown in Western Europe probably will continue through 1984, leaving little room for an increase in imports for this year. A positive element from the point of view of the coal exporting countries is the prolonged strike by the UK coal miners which threatens to reverse UK's position from a net exporter to a net importer of coal. Japan, which does not have a high stock level, presents some room for expansion for both thermal and metallurgical coal imports in 1984. Prospects for developing country markets in 1984 are also not promising, with several key developing countries struggling with the problems of servicing large external debts. Modest increases may be expected from Korea, Turkey and Spain. As a whole, therefore, the international coal trade may see the start of a recovery in 1984, but the recovery is expected to be only in the order of 10-20 mtce increases in world exports.

During the second and third quarters of 1984, uncertainty surrounding the United Mine Workers' Union contract renegotiation in the United States, magnified in part by the prolonged and bitter strike by the UK coal miners, led to a highly unsettled situation in the international coal market. Precautionary stockpiling by the US electric utilities in fear of a prolonged
strike at a time of strong domestic demand resulted in substantial increases in US domestic coal prices and a sudden jump in June in the US export price of thermal coal by $10/ton (to $53.5/ton). The major importers of thermal coal in Western Europe and Japan, apparently unwilling to pay the high US export prices, have been attempting to tide over this period by turning to other exporters (mainly South Africa and Australia) and by drawing down on stocks. This has resulted in moderate increases in export prices of South African thermal coal by $6-7/ton between May and August, and for Australian thermal coal by $2-3/ton. Now that the contract has been settled without a strike, the US export price is poised for a significant drop during the rest of this year and early next year as the US electric utilities attempt to work off their cumulated stocks. It is, however, likely that the price will not be rolled back to its level in the first half of 1984, given the improvements in market fundamentals.

The prospects for 1985 look substantially better than this year. Steady recovery of demand coupled with substantial reduction of excessive stocks in the previous year point to the likelihood of a sizable increase in import demand in the major markets. The combined net imports of Western Europe and Japan are projected to increase by about 50 mtce in 1985 over their 1983 level. The US export price in current dollars, therefore, is expected to be significantly above its 1983 level, although probably not sufficiently so to catch up with inflation during the period. The recent 20% increase, however, is not likely to be sustained through 1985. In view of the severely depressed current level of US exports, an increase in the demand for US coal arising from US dollar depreciation is not likely to lead to a significant increase in US export prices. Instead, depreciation of the US dollar is likely to be
Table 5.2: INTERNATIONAL EXPORT PRICES OF THERMAL COAL, /a
1977-83 (Actual) and 1984-2000 (Projected)

<table>
<thead>
<tr>
<th>S/MT</th>
<th>Current $</th>
<th>1983 Constant $</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>MIV /b</td>
</tr>
<tr>
<td>Actual</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1977 /d</td>
<td>33.4</td>
<td>43.2</td>
</tr>
<tr>
<td>1978</td>
<td>39.6</td>
<td>43.6</td>
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<tr>
<td>1979</td>
<td>35.4</td>
<td>35.0</td>
</tr>
<tr>
<td>1980</td>
<td>43.1</td>
<td>39.4</td>
</tr>
<tr>
<td>1981</td>
<td>56.5</td>
<td>53.9</td>
</tr>
<tr>
<td>1982</td>
<td>52.2</td>
<td>50.6</td>
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<tr>
<td>1983</td>
<td>44.5</td>
<td>44.5</td>
</tr>
<tr>
<td>Projected</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1984</td>
<td>49.0</td>
<td>47.3</td>
</tr>
<tr>
<td>1985</td>
<td>49.0</td>
<td>43.8</td>
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<tr>
<td>1986</td>
<td>52.0</td>
<td>42.7</td>
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<tr>
<td>1990</td>
<td>70.0</td>
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<td>1995</td>
<td>100.0</td>
<td>45.3</td>
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<tr>
<td>2000</td>
<td>143.0</td>
<td>48.4</td>
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/a Spot price of thermal coal (12,000 BTU/LB, < 1.0% Sulfur, 12% ASH), FOB piers, Hampton Roads/Norfolk, United States.

/b Deflated by manufacturing unit value (MIV) index.

/c Deflated by US GDP deflator.


Sources: Coal Week and Coal Week International (Actual); World Bank, Economic Analysis and Projections Department (Projected).
absorbed mostly by raising the export prices of South Africa and Australia, which will help boost the US export volume relative to those of South Africa and Australia.

In the long term, world trade in thermal coal is projected to increase rapidly, particularly in the 1990s. The long-term pattern of trade is not likely to change significantly from what has transpired so far, except for the emergence of several developing countries as exporters and importers. The international market will continue to be dominated by the current major trading partners—Western Europe and Japan on the one hand and North America, Australia and South Africa on the other.

The international export price of thermal coal for the long term is projected at the level of long-run supply and demand equilibrium. The projected prices for 1990 and beyond are equal to the marginal cost of supplying the equilibrium level of demand in those years. The marginal cost of US coal exports is estimated to increase at 1.3% p.a. in real terms between 1985 and 1995, to meet US domestic demand and exports. This is equivalent to a 2.0% p.a. increase in the cost of mining, including mining wage rate increases at the rate of per capita income growth. The cost of transportation from mines to export terminals is assumed to remain constant at its present level.

In current dollar terms, the costs of coal production in the United States are expected to be pushed up by US domestic inflation. It is assumed that the effect of inflation on coal production costs will be neutral, i.e., a one percent inflation will result in a one percent increase in coal production costs. US domestic inflation is measured by the US GDP deflator; the long-term coal price projections in 1983 constant dollars are converted into those in current dollars by using the Bank's projected US GDP deflator.
Because of relatively small weight of international trade in the US economy, exchange rate adjustments usually have little impact on US domestic prices and hence on a measure of inflation such as GDP deflator. The MUV index, however, is significantly affected by exchange rate adjustments and the Bank's projection of the index assumes steady depreciation of the US dollar against major industrial country currencies, pushing up the MUV inflation by a cumulative 13 percentage points between 1984 and 1989. Under the basically competitive environment assumed for the international coal market in the long term, the impact of US dollar depreciation is likely to be mostly in the form of an improvement in the competitive position of US coal exports instead of an increase in US export prices. This will be a reverse of the process that resulted from US dollar appreciation in recent years. As soon as exchange rate adjustments are completed, the US export prices of thermal coal are expected to rise in real terms when the MUV index is used as the deflator, to register a net gain of 0.3% p.a. between 1985 and 1995. This much of a net gain for thermal coal prices would be warranted when the OPEC crude oil prices are projected to increase in real MUV terms at 3.4% p.a. between 1985 and 1995.
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