THE ECONOMICS OF COAL SUPPLY

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Rapid changes in bituminous coal markets since the end of World War II, especially the loss of its two largest markets--space heating and railroad fuel--have compelled substantial adjustments in the industry. In 1947, the year of peak bituminous coal production in the United States, railroad consumption and retail deliveries, representing primarily residential and commercial space heating, had already fallen well below their earlier peaks; nevertheless, together they still accounted for 206 million tons or almost 40% of total bituminous coal consumption. The loss of the railroad market to diesel oil was especially rapid and by 1960 total railroad consumption of coal had declined to about 2 million tons and was by then so small that separate statistical tabulation was discontinued. Between 1947 and 1963 these two markets combined--railroads and retail deliveries--represented a loss of over 180 million tons and dropped to less than 6% of a total bituminous coal consumption that had declined by 25%. During this same period significant, although more moderate, losses were sustained in the industrial and coke markets.

The coal industry responded to this challenge to its survival with the rapid introduction of mechanization and improved technology that has helped to maintain its relative position as the dominant source of primary energy in the highly competitive and rapidly expanding electric energy market. Since 1947 the growth in coal consumption by electric utilities of 123 million tons has exceeded the loss in the railroad market. An increasing, although small, share of this growth in the electric energy market actually represents the indirect re-entry of coal into the space heating market.

Progress in coal mining technology began to accelerate in 1950 and between that year and 1963 has achieved an increase in productivity of almost 125% from 6.77 tons to 15.19 tons per man-day. This, in turn, has made possible in this period a reduction of over 9% in the mine price of coal despite an increase of 62% in coal miners' wages and a 33% rise in the general price level as measured by the Gross National Product price deflators. But improved technology and reduced prices at the mine have not been sufficient to maintain coal's competitive position. Lower transportation costs were also necessary.

For coal, more than for any other fuel, the cost of transportation represents a major element of delivered cost, in many cases amounting to more than half the total cost to the consumer. Until about five years ago the cost of rail transportation, which accounts for over 70% of all coal shipments, tended to increase and to offset reductions in the mine price of coal. However, during the past five years growing recognition by the railroads that unless they succeeded in reducing the cost of coal transportation they were threatened with the loss of their most important single source of freight revenue, has resulted in significant reductions in coal transportation costs. This recognition was helped considerably by the advent of the coal

pipeline and, although only one such pipeline was actually built and even this one was finally shut down in response to a very large reduction in railroad freight rates, its availability as a potential competitor to rail transportation has had its effect on coal freight rates.

In the past three years particularly, railroad rate reductions have accounted for some important reductions in delivered coal costs. These rate reductions have been associated with large volume movements and have been the result in the main of changes in railroad management techniques and in rate-making that has given recognition to the economies of scale and the technological opportunities in trainload versus carload deliveries, although the contribution of technological changes has until now been by far the smaller element. The full benefits of technological improvement in rail transportation remain to be realized and offer the prospect of further substantial reductions in rail transportation cost.

The growing importance of the electric utility market to where it now accounts for over half of total bituminous coal consumption in the United States has significantly affected the coal industry's competitive environment. On the one hand coal must compete more intensively on a delivered cost per million Btu basis with alternative sources of energy. On the other hand, however, this has reduced the vulnerability of coal to shifts in consumer preference and the effect of the convenience factor in the choice of fuel, and it has also made possible more extensive exploitation of the economies of scale both in coal mining and in transportation.

In the case of fuels, perhaps more so than for any other natural resources, the opportunities for substitution among alternatives, especially for large-scale utilization of primary energy, are very high. The consumer of primary energy is not really interested in tons of coal, barrels of oil or cubic feet of gas. Ultimately the large consumer is concerned with purchasing the energy value represented by these particular forms of energy. The broader the range of opportunities for substitution among alternatives the stronger are the competitive forces affecting the market. While there may be some purposes for which it is not technologically feasible to substitute one energy source for another, several or all are effective substitutes for most purposes. In the two major areas of energy use where substitutes are not now entirely feasible technically--coke in the steel-making process and motor fuel--they may both be vulnerable over the long run. The use of coke per ton of steel has been declining as a result of the use of techniques such as fuel injection, and direct steel reduction, if it should become feasible, would virtually eliminate the use of coke. The development of the electric automobile of course would have a major effect on the use of motor fuel and, indeed, would provide a means for coal to enter this market indirectly. If one allows for conversion of primary energy to secondary forms, almost all energy use is vulnerable to competitive substitution.

In the electric energy market coal must compete with the other fossil fuels, all of which can be converted to electric energy, and with nuclear power now emerging as a vigorous competitor for this market. Therefore, to maintain its competitive position, the coal industry must continue its efforts to provide the lowest delivered cost. While this imposes on the coal and transportation industries the need to exploit to the fullest imaginative technology and marketing, it offers at the same time the opportunity to exploit economies of scale.

The growth in the electric utility industry has led to very substantial increases in the size of generating units and plants and thus to a corresponding growth in the level of fuel consumption at a single location. A one million kilowatt generating plant, for example, consumes approximately 2-1/2 million tons of coal a year. This trend toward greater concentration in the size of individual consuming units has been paralleled by a trend toward greater concentration of coal reserves and production in larger size units. Since 1950 the proportion of total coal production accounted for by mines producing over 500,000 tons per year has risen from about 40% to almost 53% in 1963. This increased concentration of production is making possible more rational mining development and exploitation of the more advanced technology and mechanization that is available to yield higher productivity and lower price. Similarly, in transportation, railroad shipments of coal can be organized to take advantage of trainload movements at high speed and to utilize railroad capital equipment much more intensively. This has provided important opportunities for further cost reduction.

Despite the efforts of both the coal and transportation industries to reduce the delivered cost of coal and to maintain coal's competitiveness in fuel markets, there are institutional factors that may inhibit the ability of coal to compete either by absolute restrictions on coal use or by the imposition of cost increases that would seriously impair coal's competitive capabilities. One of these that may be of particular interest and offer a special challenge to chemists and chemical engineers is the increasingly widespread public concern over the problems of air pollution control.

Governmental regulations to alleviate air pollution could possibly prevent, or at least limit, the use of coal and distort the structure of fuel markets. Unfortunately, our knowledge of the effects of the products of combustion on living organisms is meager and regulation, in the absence of solidly based information, therefore, may tend to be excessively stringent. A well-known illustration of the effect of air pollution on fuel use is the situation in southern California. Despite indications that it would be possible to deliver coal in large quantities for electric generation in this area at a lower cost than presently prevailing fuel prices, air pollution control regulations prevent coal from entering this market at the present time.

Among the challenges confronting the coal industry, and the other fuel industries as well, is the need, first to determine the effects of the products of combustion on the environment, and then to find an economical means to eliminate those effects that are found to be harmful. There have been some efforts in this direction, including some technological developments to make possible the removal of sulphur prior to combustion. However, these have all involved processes that result in substantially higher costs for the heat content of the coal. Keeping in mind that coal, more so than any other fossil fuel, needs to compete in markets with very high substitution possibilities and therefore must give particularly strong emphasis to cost, it is clear that the search for techniques to control pollution, including the removal of pollutants prior to combustion, must be directed toward achieving this result without increasing the cost of its heat content. There are clear indications that for a long time the problem of controlling the effects of sulphur or its oxides at the level of vegetable, animal and human life can be adequately and economically taken care of by diffusion into the upper atmosphere, and by resorting for this purpose to high stacks currently in the 800-900 foot range, but eventually rising to 1,200 feet or even higher. Nevertheless, as a matter of challenge, research efforts directed toward removal of sulphur or other pollutants prior to combustion need to be continued, keeping in mind that increases in the cost of using coal would adversely affect coal's competitive position.

The emergence of nuclear power as the most serious competitor in coal's largest growth market lends added emphasis to the need for continued reductions in delivered coal costs. Nuclear electric generation has made substantial progress toward achieving competitiveness in the electric utility market and can be expected to exert increasingly intensive downward pressure on competitive fuel prices in this market over the next several years. This is especially significant for coal, but far less important at the present time to the other fossil fuels because electric generation represents a relatively small share of their total markets. Nevertheless, it will also become increasingly significant for the fossil fuels other than coal over the longer run as electric energy continues to make wider inroads over the entire range of energy use. Indeed, the competitive battle between coal and nuclear power can be expected to help make possible the lower electric energy costs which would stimulate those inroads.

The outlook for a keen competitive struggle between coal and nuclear power would indicate that, looking ahead for a number of years, we can expect little upward pressure on coal prices, and in many parts of the country where coal costs have been especially high further cost reductions can be anticipated. Current trends toward reducing those costs through lower costs of coal at the mine, and especially through lower transportation costs, can be expected to continue so that regional differences in coal costs are likely to be narrowed. The effectiveness of the coal industry's efforts to reduce its costs and the concomitant efforts of the transportation industry, especially

the railroads, to reduce its costs will, in turn, exert strong competitive pressure on nuclear power and stimulate its technological progress toward lower costs, thus imposing a descending ceiling on coal prices.

The wide range of substitution capabilities among the several sources of energy, and most importantly the advent of nuclear power as a competitive source of energy in coal's largest market, can be expected to elicit the technical and economic responses from both the coal and transportation industries that will make possible a rising level of coal use without significant increases in real costs.