# Chapter 16

## CRITICAL COSTS AND PRICES IN DETERMINING COAL DERIVED ALCOHOL FUEL ECONOMICS3

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## INTRODUCTION

Although transportation fuels may be derived from coal either through direct or indirect liquefaction, this study will focus primarily on the later. It will attempt to describe the constraints and the economics associated with the use of and the production of coal derived transportation fuels in conjunction with any economic boundaries imposed by these constraints.

Coal derived transportation fuels can be generated by the indirect liquefaction of coal. The coal is heated in an entrained environment giving off a mixture of gases commonly called synthesis gas or syngas. The precise composition of this gas varies with operating conditions although the basic components remain essentially the same: carbon dioxide, methane, carbon monoxide, and hydrogen. This gas is then collected and reformed into alcohol which may serve as motor fuels. The commercial feasibility of this process thus becomes dependent upon the net cost of syngas as well as the value of the final product. Since syngas can be obtained from sources other than coal, such as natural gas, coal derived syngas must be obtainable at a cost less than any of the potential alternatives if it is to be an economical raw material. This cost may be partially offset by using alternative technologies which produce other products in conjunction with syngas.

The spectrum of potential by-products ranges from electric power to a vast array of value-added coal derivatives which are commonly used as feed stocks for the chemical industry. While the incorporation of one of these alternative technologies may provide the potential to offset production costs, it may also serve to generate numerous constraints by shifting this process into the realm of joint production. For example, marketing constraints may reduce the value of these potential by-products. The process

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may be further inhibited by the fact that external costs such as the social cost of using coal, which can be difficult to measure, must be taken into consideration.

This research suggests that if coal gasification is to be an economically viable source of syngas, the production of by-products may be inevitable. Tentative conclusions imply that in order for coal gasification to produce transportation fuels competitively, very inexpensive coal must be used, large quantities of high value by-products must be produced, or there must be significant reductions in processing costs.

## NEED FOR COAL DERIVED TRANSPORTATION FUELS

The socio-economic ramifications resulting from the oil supply shocks of 1973 and 1981 should serve as a reminder of the profound linkages that exist between energy markets and the United States economy. Since the United States economy remains heavily dependant upon foreign oil, its economy remains susceptible to future supply disruptions. One way to reduce this vulnerability would be to augment alcohol fuel production with coal serving as the raw material.

Currently coal provides energy to the United States economy in two ways: directly as a primary fuel or indirectly in the form of electricity. These forms represent an important source of energy to all sectors of the United States economy except for the transportation sector. This sector accounts for approximately 26 percent of all domestic energy consumption as illustrated in Table 1. Coal's contribution to this sector for all practical purposes remains negligible. Since the United States has a limited supply of petroleum that can be produced in competition with Middle East Oil, but has large quantities of undeveloped coal reserves, a rationale exists for investigating the use of coal to supplement imported oil for transportation use. However, simply having large reserves of coal and a desire to reduce petroleum imports provides no guarantee that coal will become a substitute for oil. This substitution, for practical purposes, does not appear to be in the near future given the current price of oil and the cost of these coal derived alternatives. Even if oil was more expensive, coal derived transportation fuel would still have to compete with similar fuels derived from natural gas. However, the relatively high degree of uncertainty inherent in the entire process due to speculation of future oil and natural gas prices makes it difficult to predict this outcome. This problem is further compounded by the fact that relative environmental costs and benefits associated with the use of both coal and oil-based transportation fuel must also be quantified within an environment of uncertainty due to possible policy changes.

## METHOD OF ANALYSIS

The economics of alternative transportation fuels may be approached from a two-fold perspective. The first perspective is to examine these fuels in a context relative to oil. Since numerous alternative transportation fuels have been developed, an inter-fuel analysis should also be conducted. Therefore, the second approach would be to consider the economics among the various competing alternative transportation fuels themselves. These alternatives include fuels derived from coal, natural gas, and the fermentation of

biomass materials such as grains. At this juncture, this study will primarily focus on the inter-fuel competition between coal and natural gas since the future of fermentation fuels is unclear due to expiring government subsidies. Therefore, this paper will attempt to address the question of "If alternative transportation fuels ever become economical with respect to oil, what factors will determine the economics of these products derived from coal?" Thus, a comprehensive analysis of alternative transportation fuels should include the following: (1) the cost differentials in manufacturing, storage and distribution, (2) the cost of using the fuels, including engine modifications, (3) the cost or savings associated with environmental considerations like pollution, and (4) the social and economic cost differentials resulting from the production of domestic energy as opposed to importing it.

Although the relative production and use costs of oil-based transportation fuels are essential to the economics of alternative fuels, they will not be addressed at this point due to a lack of consensus regarding their actual levels. Currently these costs are artificially low, since they fail to encompass the full realm of cost associated with using oil. Therefore the economics of alternative transportation fuels may be biased as a result of cost understatements. This makes determining the true relative economics of producing and using oil derived transportation fuels like gasoline difficult to compare with alcohol fuel in general and coal derived alcohol fuels in particular. This situation is likely to change as a result of policy implications which would cause the price of gasoline to reflect its true cost. Although the manufacturing cost of alternative fuels has been declining as result of technological improvements and operating experience, the relative economics may be influenced most through realistic pricing of gasoline. These important considerations are addressed by other researchers.

# METHODS OF REDUCING THE COST OF ALCOHOL FUELS

There are a number of ways to reduce the cost of alcohol fuels. These include producing co-products at both the alcohol and syngas production stages, decreasing capital and operating costs, and increasing benefits to consumers through the reduction of hydrocarbon and nitrous oxide pollution.

## Alcohol Production and Peak Power Demand

Since methods of storing energy are limited or are expensive, peaking power must be provided by generating technologies rather than power storage technologies. The question is whether or not it would be possible to produce alcohol fuel or coal-derived syngas in such a manner to take advantage of this situation.

A major problem confronting the electric power industry in the United States is how to most efficiently meet peak power demand both on a daily and on a seasonal basis. Currently, peaking plants often use natural gas fired turbines to provide the peaking power requirements. Although capital requirements of these types of plants are low, plant utilization may be only 5 percent significantly increasing the effective capital cost per kilowatt of power generated. Natural gas is also generally a more expensive fuel than coal for the generation of electric power. As a result, peaking power is much more

expensive than base-load power. However, if alcohol fuel plants were to produce both alcohol and electric power in such a manner as to produce more alcohol than electricity at night, the alcohol produced during the night could be easily stored and burned during the day in peaking units. This process would take advantage of storage potential of the alcohol thus providing relatively inexpensive means of storing power indirectly in order to meet peak demand. This arrangement would alleviate problems of using coal or natural gas for peaking power fuels, since coal cannot be easily used as a fuel for a peaking plant and natural gas cannot be easily stored in large quantities. In effect, this arrangement would allow coal to be used as a primary fuel source for peaking power and society could benefit by having access to a low cost source of energy to meet peak power demands.

## Joint Use of Coal and Natural Gas

Coal is deficient in hydrogen relative to carbon for gasification purposes. Therefore, gasifying coal may result in the venting of large quantities of $CO_2$. Environmental concerns with regard to global warming make this an unfavorable circumstance and may even result in financial penalties if the proposed $C0_2$ tax were to be enacted. To avoid these potential penalties, the level of $C0_2$ emissions may be reduced by supplementing the process with natural gas which is rich in hydrogen. This would make it possible to make the desired adjustments in the $H_2$:CO ratio of the syngas without having to vent large quantities of $C0_2$ and this would also simultaneously increase the volume of syngas. Therefore, less coal would be required to produce the same volume of syngas. The savings in coal cost should more than offset the cost of supplementing the process with natural gas because the process would require the addition of a relatively small amount of natural gas.

## Use of Coal Washer Refuse

Another alternative to reduce the cost of alcohol fuels would be to use very inexpensive coal. One source of inexpensive coal is old wash ponds. These ponds often contain significant amounts of coal left behind as a result of the coal preparation and cleaning process. This material could be fed into high temperature gasifiers in slurry form. The high operating temperatures of these gasifiers would essentially burn any combustible material and the remaining material would be discarded as slag. Coal refuse piles could also be another potential source of inexpensive coal for gasification. Although more expensive than the previous two sources, fine coal from continuous and long wall operations may also aid in this aspect of cost reduction. The coal from these operations could be screened and the fines could be used for gasification. This material could be purchased at a discount since it would not have to go through the expensive cleaning process.

While these low cost sources of coal may provide the potential to reduce alcohol fuel production cost, it is highly unlikely that they will significantly impact the overall economics of alcohol fuel production. The cost of coal is relatively small in contrast to

the overall cost of the process; therefore, a reduction in this area will have little impact on the cost of syngas and, in turn, the alcohol fuel.

## Co-Product Production

The production of coal-derived alcohol fuels can be divided into two stages. Stage 1 involves the conversion of coal (process A) or natural gas (process B) to syngas while Stage 2 deals with the conversion of the syngas to alcohol fuels. By-products can be obtained from both stages; therefore, the economics of joint product production becomes a consideration in the manufacture of coal-derived alcohol fuels. Production alternatives for the two processes can be analyzed separately and together.

Process A involves the production of syngas with or without the production of by-products such as electrical power, coke, coal tar products, and other coal derived chemicals. By-product production can be in fixed or variable proportions or some combination of both. At the extreme, the proportion of syngas can vary from 0 to 100 percent of the output excluding "waste" products such as slag. In the event that no syngas is produced, all resources would be devoted to the production of the by-products. Furthermore, if by-products are manufactured, it must be at the expense of syngas production. Thus, proportions of the various by-products can vary within certain ranges which are process and stoichiometrically determined.

Stage 2 involves the conversion of syngas into the alcohol fuel and waste products (such as sulfur and $C0_2$) and possibly by-products, resulting from alcohol separations. Again, by-product production can be in fixed or variable proportions or some combination of both. The proportion of fuel alcohol can vary from 0 to 100 percent, just as in the case of process A and the production of syngas. Also, if by-products are manufactured (at the expense of fuel alcohol production), the proportions of the various by-products can be varied within certain ranges. Since syngas can be obtained from sources other than coal, such as natural gas, the analysis of Stage 2 can be made independently of Stage 1.

The existence of joint product production presents a number of production and marketing difficulties. First, choosing the mix of goods to be produced and their quantities is a constrained optimization problem (not necessarily linear and possibly dynamic). Second, marketing the products in proportion to their production may be difficult and usually requires the cost of stockpiling one or more of the joint products or selling the excess production at a price lower than the anticipated market price.

An estimate of the required value of by-product credits to make the production of coal-derived alcohol fuels economic from process A can be obtained by determining the current or anticipated difference between the price of gasoline and the cost of producing alcohol fuels from process B. This simplified approach ignores all costs due to externalities, such as the reduction of pollution costs, and ignores related costs, such as required modifications of the transportation fuel distribution system or engine modifications.

## ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

The burning of coal-derived alcohol fuels may provide some environmental benefits; unfortunately, these benefits may be offset by the social and environmental costs of mining and gasifying coal. Therefore, if the net benefits of coal-derived alcohol transportation fuels are emanately negative, producers would inevitably revert to cleaner alternative raw materials like natural gas. However, if alcohol transportation fuels were to be produced from natural gas, a question arises about the source of the natural gas for the syngas feedstock. The vast majority of proven natural gas reserves are known to lie in-conjunction with oil reserves which are predominantly located in the Middle East. Currently natural gas is considered to be a waste product of oil production in this region due to the remote well locations. Consequently this natural gas is either flared or used to enhance production through well pressurization. If alcohol fuels should become the transportation fuel of choice domestically, then this natural gas would become valuable. Alcohol synthesis plants could be built in the Middle East to convert this natural gas to alcohol which could be easily transported by essentially the same means and cost as oil. Estimates suggest that this product would have a Gulf coast port price of approximately one-half that of its domestic counterpart. Provided these estimates are accurate, competition from the Middle East would have devastating effects on the domestic production of alcohol fuels. Thus, the United States would remain dependent upon foreign sources for its energy needs. However, this need not be the case.

## COST COMPARISONS

The relative economics of alcohol fuel from natural gas or coal relative to gasoline depends upon the relative initial costs and the relative rate of change of the costs over time. Figure 1 shows the results of an analysis of the relative costs of transportation fuel assuming coal costs of about $30 per ton, natural gas cost of $3.00 per mcf, oil at $22 per barrel, and current prices for coal gasification by-products. Also shown are the assumptions concerning the real annual increases in costs and prices over a twenty year period.

As can be seen, oil is the cheapest source of transportation fuel, followed by natural gas and then coal. However, different relative cost increases will change the ranking over time. According to DOE estimates, coal should increase 1.7 percent per year, natural gas 3.5 percent and oil 2.7 percent per year. If coal gasification costs decrease by 0.5 percent per year, overall coal costs would increase by 1.,2 percent per year. Under this scenario, oil would be the fuel of choice over the next 20 years and natural gas would be a cheaper source of transportation fuel than coal for the next 15 years or more.

Recognizing that oil prices do not fully reflect all of the costs associated with production and use of oil provides grounds to presume that the cost of oil will increase sometime in the future. If the cost of oil increases by a factor of two, as shown in Figure 3, transportation fuels from natural gas would become economical. However, this does not improve the economics of coal derived fuels.

Although the effects of $CO_2$ emissions on the welfare of the Earth are not known, one must consider the effects a carbon tax would have on the relative economics of transportation fuels. If a $10 per ton carbon tax were to be levied on all fuel, the relative economics of coal, oil and natural gas would not change significantly, as shown in Figure 4. These results assume that $C0_2$ produced in the gasification of coal is combined with hydrogen from natural gas to prevent a large quantity of $C0_2$ being emitted during the production of syngas. If this were not the case, costs of using coal to produce syngas would increase dramatically, making coal uneconomical relative to natural gas until around 2040.

# CONCLUSIONS

This preliminary investigation indicates that the economic production of coal derived alcohol transportation fuels will not be viable in the near future. The basic problem is that to use coal, a moderately priced commodity, for the production of transportation fuel, another moderately priced commodity, large capital and operating expenditures are required. While these fuels can be produced from coal which is in abundant domestic supply, it appears that a similar mix of final products may also be derived using natural gas at a fraction of the cost.
Therefore, it is anticipated that given the current economic and political climate, coal-derived alcohol fuels will require some form of subsidization.

If coal is to be used for alcohol fuel production, the production cost must be offset through the production of these by-products to the extent that these by-product credits equate the two alternative sources. However, the production of these by-products further complicates the issue by creating production and marketing problems. Thus, the potential cost associated with the production of the by-products may outweigh the benefits rendering the process infeasible.

While this study may not provide all of the answers to the questions surrounding the commercialization of alcohol fuels, it does make substantial progress in delineating their economic feasibility. Little information currently exists regarding the economics of alcohol fuels. Therefore, this study provides a significant contribution as a result of its identification of economic boundaries and potential constraints.