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Attachment IX

MASTER

METHANOL PRODUCTION FROM EUCALYPTUS WOOD CHIPS

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Economics of Producing Methanol from Eucalyptus in Central Florida

June 1982

Prepared by
Biomass Energy Systems, Inc.
Lakeland, Florida

For the
U.S. Department of Energy
Office of Alcohol Fuels
Under Grant No. DE-FG07-80RA50316

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METHANOL PRODUCTION FROM EUCALYPTUS WOOD CHIPS

Working Document 9

Economics of Producing Methanol from Eucalyptus in Central Florida

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June 1982

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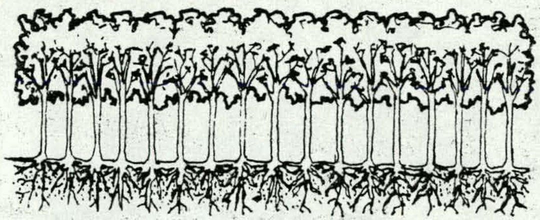

Economics of Producing Methanol
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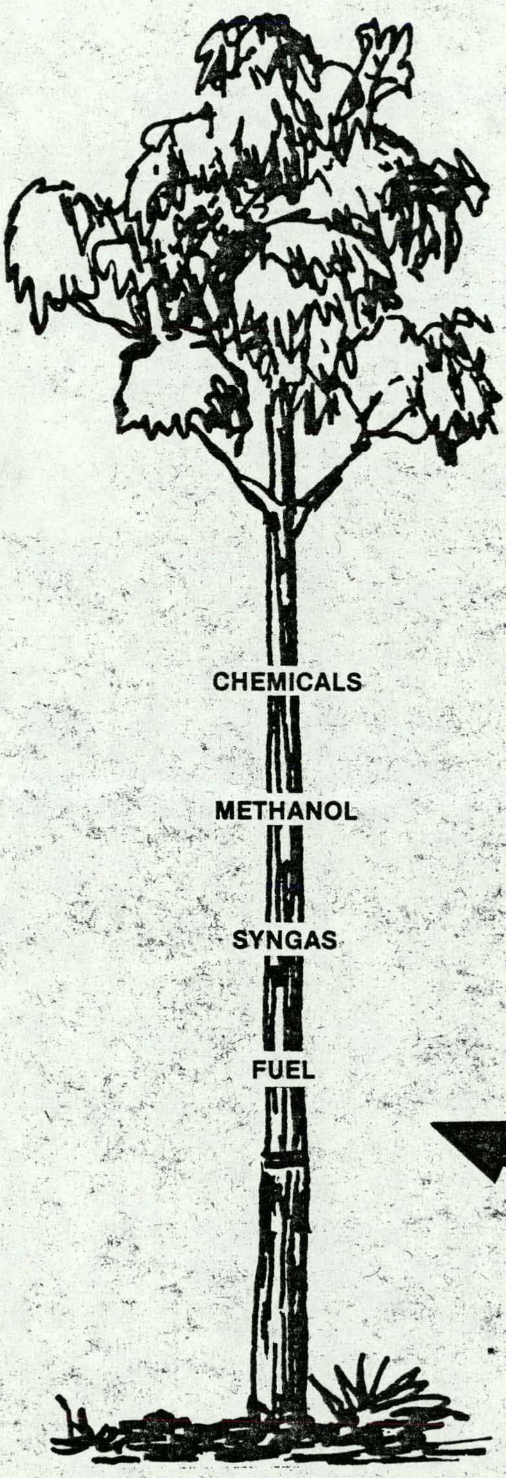

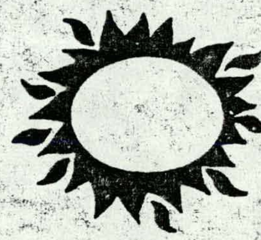

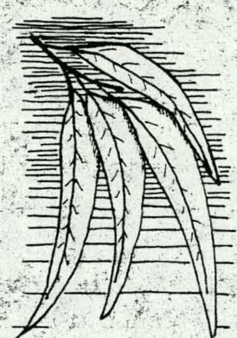

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"HARVESTING RENEWABLE ENERGY RESOURCES NOW"

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1.0 INTRODUCTION

1.1 Purpose

Pursuant to D.O.E. grant number: DE-FG07-80RA-50316, "Methanol from Eucalyptus Wood Chips," Biomass Energy systems, Inc. (BESI) conducted a detailed feasibility study of producing methanol from Eucalyptus in Central Florida. The project encompasses all phases of production--from seedling to delivery of finished methanol. The project includes the following components: (1) production of 55 million, high quality, Eucalyptus seedlings through tissue culture; (2) establishment of a Eucalyptus energy plantation on approximately 70,000 acres; and (3) engineering for a 100 million gallon-per-year methanol production facility. In addition, the potential environmental impacts of the whole project were examined, safety and health aspects of producing and using methanol were analyzed, and site specific cost estimates were made.

This report focuses on the economics of the project. Each of the three major components of the project--tissue culture lab, energy plantation, and methanol refinery--are examined individually. In each case we conducted a site specific analysis of the potential return on investment. Since this report deals only with the economics of the project, technical issues and environmental impacts are examined in the eight other companion working documents.

1.2 Overview of the Eucalyptus to methanol project

The project is designed to produce 100 million gallons-per-year of fuel grade methanol (1,000 tons per day). The methanol will be marketed to major oil refining firms for use as an octane enhancer and fuel extender, or it will be sold to bulk dealers for direct use as fuel for fleets. Methanol will be produced in Central Florida from Eucalyptus wood. The technology for producing methanol from wood is well know and involves: (1) gasification of wood, (2) clean-up and reforming of the resulting gas, and (3) catalytic conversion to methanol. This process along with two preliminary engineering designs are examined in engineering reports by Evergreen Energy Corporation (Working Document No. 8) and Davy-McKee, Incorporated (Working Document No. 7).

To produce 1,000 tons of methanol per day will require approximately 4,000 tons of Eucalyptus per day (green). This wood will be produced in a large Eucalyptus energy plantation which is described in Working Document 1: The Florida Eucalyptus Energy Farm--Silvicultural Methods and Practices. Eucalyptus seedlings will be produced via tissue culture as discussed in Working Document 2: Vegetative Propagation of Eucalyptus.

Figure 1.1 provides a schematic of the methanol from Eucalyptus project.

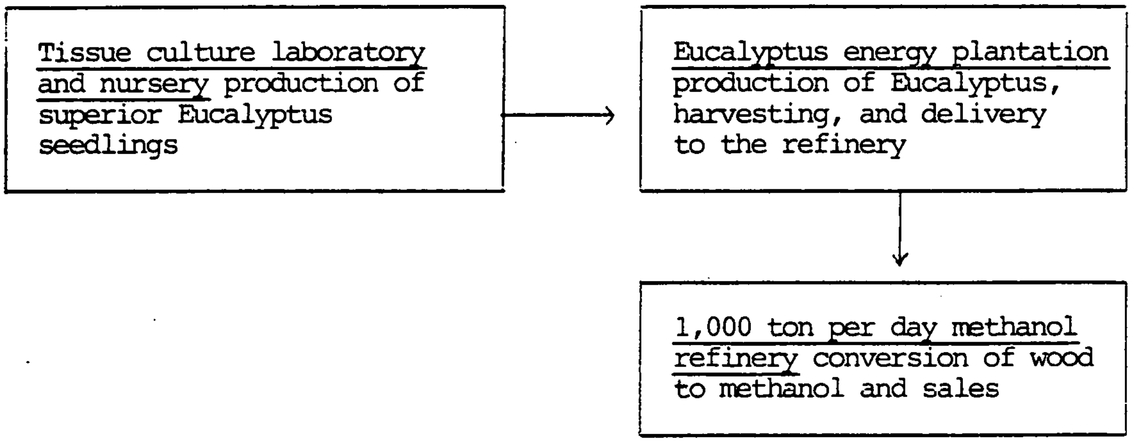

Figure 1.1.—Methanol from Eucalyptus

1.3 Organization

The analysis of producing methanol from Eucalyptus in Central Florida has five parts. Following this introduction, Section 2 describes the demand for methanol through 2000. First, current market conditions are examined and prices described. Then the future of methanol is discussed with a focus on the markets for octane enhancers and fleet fuels. Next, the results of BESI's survey of major oil companies is described and conclusions are drawn concerning the demand for methanol through 2000.

Section 3 examines the supply side of the methanol market through 2000. The current supply structure is discussed and conclusions drawn.

Section 4 provides a detailed financial analysis for the Eucalyptus-to-methanol project. The entire project is large and complex. It has three main pieces: (1) tissue culture laboratory and nursery, (2) Eucalyptus energy plantation, harvesting, and transportation of wood to the plant, and (3) the Eucalyptus to methanol plant.

Since each of these components must be financed at different points in time, perhaps by different investors, it is helpful to examine each component individually. This also makes the financial analysis much manageable.

Finally, the conclusins about the economic feasibility of the entire project are discussed in Section 5.

2.0 METHANOL DEMAND

The demand side of the methanol market is described in this section. First, current demand conditions and prices are reviewed. Next, future prospects for methanol are examined with particular emphasis on the use of methanol as an octane enhancer, fuel extender and direct use as fuel. Finally, the results of BESI's survey of major oil companies are discussed.

There is a very large body of literature exists on the methanol market (see the bibliography for examples). Numerous studies provide forecasts for demand and price. Beyond our survey of major oil companies, we have little original to add to this growing literature. Our purpose is to review the current status and future prospects for methanol as they relate to our project, the methanol-from-Eucalyptus facility.

2.1 Current conditions

Methanol (CH_3OH) is a versatile organic compound used in a variety of products ranging from formaldehyde to fuel. Table 2.1 displays the latest data on methanol use in the United States. The market is dominated by formaldehyde which constituted over 42 percent of U.S.

usage in 1979 and 1980. Solvents were the second largest identified use for methanol accounting for 10 percent of the market. The third larges use was for fuel additives at 8 percent. Other uses include the input to a wide variety of methyl halides, methyl amines, and other organic compounds.

Table 2.1.—Methanol use in the U.S.
(millions of short tons)

	1975[1]		1979[2]		1980[3]	
Use	Tons	Percent	Tons	Percent	Tons	Percent
Chemicals						
Formaldehyde	1,056.0	44.0	1,589.5	42.5	1,666.7	42.1
Solvent	222.6	9.2	351.6	9.4	396.0	10.0
Acetic acid	104.5	4.0	250.6	6.7	280.5	7.1
Other	1,036.9	42.8	1,249.7	33.4	1,304.2	32.9
Fuels						
Additives	0.0	0.0	299.2	8.0	297.0	7.5
Utility	0.0	0.0	NA	NA	16.5	0.1
Total	2,420.0	100.0	3,740.0	100.0	3,960.4	100.0

Sources: [1]Encyclopedia of Chemical Technology, Vol. 15, John Wiley:New York, 1981, pp. 413.

[2]Chemical Engineering, "Methanol supplies: too much or too little?," July 14, 1980, pp. 75

[3]Chemical Week, "Alcohol fuels? Ethanol's good, methanol's better," June 24, 1981, pp. 53.

Table 2.2—Annual average wholesale prices of methanol in the United States

Year	Price $/gallon	Year	Price $/gallon	Year	Price $/gallon
1965	.270	1971	.228	1977	.435
1966	.270	1972	.107	1978	.432
1967	.267	1973	.135	1979	.459
1968	.250	1974	.209	1980	. 642
1969	.254	1975	.390	1981	.654
1970	.267	1976	.430		

Source: U.S. Department of Labor, Bureau of Statistics, Wholesale and Producer Price Indices.

The market for methanol is a growing dynamic one. Sales have nearly doubled over the last ten years and the price per gallon has jumped by a factor of 3. However, these increases have not been smooth. For example, as Table 2.2 shows the price per gallon of methanol reached a peak of $0.267 in 1970. The introduction of a new process technology by Imperial Chemical Industries drove the price down to $0.107 by 1972. Then the oil embargo, inflation, and the decontrol of natural gas combined to push the price up to $0.654 by 1981.

These price variations, of course, do affect demand. Additional volatility springs from the cyclical sensitivity of many of the end-product markets for which methanol is an intermediate input. For instance, formaldehyde constitutes the largest use of the methanol, but formaldehyde in turn is consumed in the production of resins (56 percent) and a host of miscellaneous products. These resins are used in the housing industry to make plywood, particle board, and laminates, and they are used in the auto industry to make coatings and foundary resins. Therefore, the cyclical behavior of the housing and auto industries affects the market for formaldehyde which impacts the methanol market.[1]

Of particular interest for this study is the market for fuel activities and for direct fuel use. Very little methanol is being used now as a fuel. Research work is underway and this topic will be discussed below. Methanol is currently being used as an additive to enhance octane and reduce knocking. For example, Arco is now marketing Oxinal, a 1:1 blend of tert-butyl alcohol and methanol, which is added to gasoline at a concentration of 5.5 percent. In addition, methanol is a primary input for the anti-knock/octane-enhancer methyl tert-butyl ether (MTBE). Current production of MTBE is 450,000 tons, and the market is so strong that new MTBE capacity is coming on line quickly. By 1983 capacity will rise to 1.65 million tons.[2]

2.2 <u>Future prospects</u>

Forecasts of future demands and prices for methanol vary widely. Two major uncertainties face the methanol market: (1) what will be the price of petroleum and (2) to what degree will methanol be used as a fuel? Projections of fuel use are dramatically divergent. With this background we first review existing projections and then examine the use of methanol as a fuel.

Over the next few years through 1985 there is a broad consensus that the market for methanol will be strong and that direct fuel use of methanol will be low. Even in a relatively week market for chemicals in general, use of methanol expanded in 1980 (see Table 2.1). When the housing and auto industries rebound in late 1982 through 1984, demand for formaldehyde will strengthen boosting demand for methanol. However, future growth in the use of formaldehyde will be limited because of concerns over its health risks. Already use of urea-formaldehyde foam is banned for home insulation, and other product uses may be curtailed. Thus, formaldehyde demand is projected to grow at an average of 5 percent per year during the 1980s.[3]

Use of methanol for solvents is also forecast to grow slowly during the 1980s. The solvent market is mature, and concerns over the health effects of chlorinated solvents is growing. Growth projections of 4 percent per year seem reasonable.[4]

On the positive side, analysts expect methanol use to grow rapidly for acetic acid production. Growth of almost 15 percent per year is forecast.[5] Finally, the most rapidly growing market component is forecast to be for octane enhancement. Growth in this segment of the market is expected to exceed 30 percent per year.[6]

Table 2.3 displays a series of forecasts based on these assumptions.

Table 2.3.—Methanol demand forecasts for 1985
(thousands of short tons)

Use	Demand projections: Chemical Week[1]	Celanese[2]	Encyclopedia of Chemical Technology[3]	National Alcohol Fuels Comm.[4]
Chemicals				
Formaldehyde	1,964	NA	1,749	2,607
Solvent	425	NA	325	462
Acetic Acid	673	NA	737	462
Other	1,539	NA	1,513	1,601
Subtotal	4,601	4,954	4,324	5,132
Fuels				
Additives	1,010	1,122	1,095	1,089
Utility	0	82	0	82
Other direct use	0	0	0	0
Total	5,611	6,158	5,419	6,303

NA Not available.

Sources: [1]Chemical Week, "Octane Boosts fuel methanol demand," January 14, 1981, pp. 24.

[2]Celanese projections reported in Chemical and Engineering News, "Global methanol market to double in 1980s," April 7, 1980, pp. 16.

[3]Encyclopedia of Chemical Technology, Vol. 15, John Wiley: New York, 1981, pp. 413.

[4]National Alcohol Fuels Commission reported in Chemical Week, "Alcohol Fuels? Ethanol's good, methanol's better," June 24, 1981, pp. 53.

As noted above, the striking feature of these projections is how close they all are. At the high end is the National Alcohol Fuels Commission forecast of 6.3 million tons while at the low end is the 5.4 million tons projected by the Encyclopedia of Chemical Technology. However, the extremes are only 16 percent apart. In addition, none of these forecasts envisions a significant direct fuel sue for methanol by 1985.

In contrast both to the large number of forecasts for methanol demand in 1985 and to their consistency, there is great uncertainty about the demand for methanol after 1985 and few forecasts. Although the market for methanol as a chemical feedstock is well understood, the potential for methanol as fuel is uncertain. Since the market for methanol as a chemical feedstock is mature, continued rapid growth of methanold demand in the future will have to come from new applications such as fuels.

Since the fuel market potentially is a huge one—larger than the traditional chemical feedstock market, forecasts of future methanol demand after 1985 revolve around forecasts for methanol as a fuel. On this score forecasts can vary widely. For example, the National Alcohol Fuels Commission projects methanol fuel use in 1990 at 6.6 million tons,[7] the D.O.E. expects fuel use to reach 7.1 million tons,[8] and Collieries Management projects methanol fuel use of 9.9 million tons in 1990.[9]

Methanol will develop into an important fuel after 1985 when there is an assured supply of cost-competitive, useable methanol fuel widely available to consumers. This truism helps to identify six key facts which determine the future of methanol as a fuel: (1) petroleum prices,

(2) methanol prices, (3) methanol supplies, (4) distribution, (5) utilization, and (6) regulation.[10] Each of these factors is examined briefly below.

2.2.1 Petroleum prices and U.S. fuel markets

Since methanol is a liquid fuel with primary applications in the transportation sector, projections of future prices and quantities of petroleum and gasoline are crucial to any forecast for methanol. This is hardly a new idea.

> "In considering the possibility of alcohol as a fuel for automobile motors, it is impossible to avoid alluding, however briefly, to the economic conditions which must eventually determine its use as a fuel at all, and this independently of all technical considerations. Gasoline is the by-product of geographically limited and monopolistically controlled industry, and there are reasons to believe that the available supply is more than mortgaged by a worldwide and growing demand," Thomas White, 1907.

Since the early 1970s it was obvious that the demand for transportation fuel (largely gasoline) was straining domestic supplies of crude. By 1979 the transportation sector consumed 33 percent of all the end-use energy, and this consumption absorbed over 50 percent of the petroleum consumed in the United States. Furthermore, the rapid growth in energy consumption for transportation over the last 20 years was largely an increased use of gasoline. Thus, by 1979 almost 70 percent of the energy used in this sector came from gasoline.[12]

The rapid increases in gasoline and petroleum prices since 1973 have slashed the growth in consumption, and the trend toward ever greater energy conservation is projected to continue over the next 40 years. Even so, no responsible analysis of the U.S. energy supply-demand balance suggests that the U.S. will become energy self sufficient between now and 2000.[13] This is largely the result of the inability of the transportation sector to free itself from liquid fuels. Unlike most other energy using sectors of the economy such as utilities or industry, transportation technology depends on liquid fuels.[14]

The U.S. Department of Energy's forecast for petroleum and gasoline is displayed in Table 2.4. Oil prices are projected to increase throughout the period. In 1980 dollars (to abstract from general inflation) oil prices will increase from $34 per barrel to $67 per barrel by 1995. Thus, oil prices are forecast to rise faster than inflation, posting a compound real growth of 4.6 percent.

Continued increases in world oil prices have set in motion many gradual but significant economic changes. The stock of energy using capital in the economy is being slowly converted or replaced by more energy efficient capital. In addition, fuel switching away from costly oil to less expensive alternative fuels like coal is taking place. These trends are expected to continue throughout the next 15 years. Thus, under the pressure of steadily rising energy prices the growth in U.S. oil consumption is forecast to fall. This is a stark contrast to the 1950s, 1960s, and 1970s.

Gasoline prices will also rise significantly over the next 15 years posting a real growth of 4 percent-per-year. In response, gasoline consumption is forecast to fall from 276.2 million gallons-per-day in 1980 to 190.7 million gallons-per-day by 1995. Four factors account for this decrease. First, fuel efficiency is forecast to increase substantially. The fleet average miles-per-gallon is expected to jump from 14.2 in 1980 to 26.8 by 1995.[15] Second, the transportation sector is slated to grow more slowly over the next 15 years. Growth in the number of registered vehicles and miles traveled will slow significantly as fuel costs rise. Third, higher gasoline prices will prompt greater use of diesel-powered vehicles. Finally, rising gasoline prices will foster the development of methanol fuels.[17]

Table 2.4.—Oil and gasoline, 1980-1995
(1980 dollars)

	1980	1985	1990	1995
Oil				
Price per barrel	$34.00	$33.00	$49.00	$67.00
Millions of barrels per day	17.0	16.6	15.7	15.8
Gasoline				
Price per barrel	$1.22	$1.37	$1.75	$2.20
Millions of gallons per day	276.2	NA	NA	190.7

Source: Energy Information Administration, U.S. Department of Energy, 1981 Annual Report to Congress, Vol. 3, February, 1982, pp. xvi, xx, 42, and 44.

As a result, the transportation sector will absorb a declining share of the nation's total energy consumption throughout the 1980-1995 period. This reverses the trend begun in 1965 when transportation energy use began growing faster than overall energy consumption. Even so, the transportation sector will still consume the lion's share of U.S. petroleum. It's absorption of oil will increase from 53 percent of the total in 1979 to 56 percent by 1995. Thus, while other sectors can locate suitable substitutes for oil based fuels, transportation can not.[18]

The Department of Energy's forecasts for 2000 to 2020 do not display any sharp breaks with the trends expected for 1980-1995. In general, the adjustments to even-more-scarce and even-more-costly oil which began in the mid-1970s will continue through 2020. The future domestic supplies of oil and gas will be higher than if a lower price were to prevail, but their supplies are forecast to dwindle after 2000. Higher prices for oil and gas will encourage the use of alternative fuels, particularly coal, and spur continued energy conservation. By the year 2020 the U.S. is projected to be a net exporter of energy for the first time in over 75 years.[19]

One striking feature of the Department's forecast is the rapid expansion in consumption of synthetic liquid fuels such as methanol. The basic factors which promote the rapid development of a synthetic liquid fuels industry include: continued dependence on liquid fuels for transportation, the absence of other economically viable substitute fuels for transportation, the assumption of rapidly rising world oil prices, and the continued depletion of U.S. oil reserves.[20] By 1990 the Department forecasts methanol demand for fuel purposes will exceed 7 million tons and may rise to nearly 15 million tons by 1995.[21]

2.2.2 Methanol prices

For methanol to develop as a fuel it will have to compete successfully against petroleum based fuels, especially gasoline. To penetrate the fuel market, methanol will have to represent a real savings to the consumer after all relevant costs are considered including delivery, conversion and efficiency in use.

Since methanol is not used as a fuel in any significant quantities at this time, an established fuel methanol market does not exist. Thus, the price for fuel methanol is unknown. However, the price of chemical grade methanol can be used as a point of departure. At present posted prices for methanol on the Gulf Coast is 71¢ per gallon.[22]

Another point of departure for pricing methanol as a fuel is its price relative to gasoline against which it must compete in the transportation fuel market. Since methanol contains roughly half the heating value of gasoline, one might expect the price of methanol to be approximately one-half that of gasoline. This is at best a rough lower limit to methanol's value or price as a fuel for two major reasons. First, methanol has a higher octane rating than gasoline, and methanol is particularly useful as an octane enhancer. Second, simple BTU comparisons ignore operating efficiencies, conversion costs, and emissions. These factors can be crucial. For example, a gallon of fuel oil has a higher BTU content than does a gallon of gasoline, but gasoline sells for much more in the market. Why? Because gasoline is a premium fuel tied to an important end market—passenger cars.

There are three interconnected approaches to the question of methanol fuel prices: (1) demand or market approach, (2) supply or production cost approach, and (3) market equilibrium approach. Each will be discussed. The discussion immediately below focuses on the demand or market approach to forecasting methanol fuel prices. This establishes a target price. Section 3 addresses supply side considerations and market equilibrium.

The demand or marketing approach first identifies potential candidate markets which the new product, methanol fuel, can penetrate. In light of the discussion above on BTU comparisons, care must be taken to evaluate penetration based on specific end-uses. Two markets appear potentially attractive for methanol as a fuel: (1) utility peaking turbines and (2) automobile fuel.[23]. These markets are attractive because they require liquid fuel, and because they are currently dependent on petroleum.

The potential for methanol fuels in utility peaking turbines was extensively analyzed by Collieries Management (1980, pp. 95-105) and Bentz, et. al. (1980, pp. 105-107). Both studies conclude that significant market potential exists, but that the likely total volume of sales would be limited. A survey of Florida utilities generated no interest in methanol. In addition, the potential profits may be greater in the auto market because this is a higher valued end-use.

The automobile fuel market is a key market for methanol fuels because: (1) the market is large, (2) the price of gasoline is projected to rise rapidly and (3) liquid fuels are required. Even with escalating gasoline prices and greater energy conservation, the Department of Energy projects gasoline consumption will exceed 190 million gallons per day in 1995.

As Bentz, et. al. (1980, pp. 111) point out, the automobile transportation market is composed of a number of distinct submarkets including: dedicated fleets (government, business, etc.), diesel powered vehicles, and gasoline powered personal vehicles. The key markets for methanol fuel are fleets and personal vehicles powered by gasoline.

As noted above the potential penetration of methanol depends upon: (1) its price relative to gasoline, (2) assured supplies of methanol, (3) distribution, (4) the capacity of utilizing methanol effectively, and (5) regulations. We address only the first issue here, relative prices, and leave the discussion of other issues to the remaining sections of this chapter.

Methanol can be used in two ways as an automotive fuel. First, methanol can be used as a fuel substitute. Neat or 100 percent methanol (plus slight impurities) powered vehicles have existed for sometime. Second, methanol can be used as a blending agent with gasoline. Each of these two routes to methanol fuel use has quite different implications. For example, blends of up to 10 percent methanol can be used in today's autos raising the octane rating of the fuel and extending the supply of gasoline. By contrast, the use of neat methanol requires some significant engine and carburetor modifications, but offers the reward of greater economy and improved performance. Due to these differences in potential methanol fuel use, different automotive market segments will have different penetrations.

There are numerous studies of the market for methanol as a blending agent with gasoline.[24] Table 2.5 displays a sampling of the forecasts from these studies. Although the forecasts appear to differ significantly, they have the following common characteristics. First, extensive methanol blending is expected to occur after 1990 when supplies of methanol are assured. Second, subject to the concerns over distribution and utilization discussed below, methanol blends will not encounter any technological barriers. Finally, the three studies concur that it is limits on the availability of fuel methanol which restrict its use as a blending agent. Thus, the widely different forecasts for methanol use as a blending agent are the result of widely different projections of methanol supply levels and are not due to different views about methanol demand.

Table 2.5.—Forecasts of the potential market for methanol fuel in automobile gasoline blends

(10^6 barrel/year)

Market study	1980	1985	1990	1995	2000
Total U.S. projected gasoline demand on an annual basis[1]	2,810.5	1,409.0	2,077.5	1,788.5	1,679.0
Frost and Sullivan[2]	—	—	6.3	10.0	16.6
Badger[2]	—	—	0.8-5.0	0.9-8.0	0.9-8.5
Collieries[3]	—	—	59.5	95.2	157.1

Sources: [1]Energy Information Administration, U.S. Department of Energy, 1981 Annual Report to Congress, pp. 42 and Bentz, et. al., Factors that Affect the U.S. Market Demand and Utilization of Methanol-from-Coal within the Transportation Section, 1980-2000, pp. 115.

[2]Ibid, pp. 117.

[3]Collieries Management Corp., Methanol Alcohol Fuel Supply and Demand 1980-2000, pp. 93.

Bentz, et. al. (1980, pp. 117) note that an additional important demand for methanol as a blending agent was ignored by all three of these studies--its use as an octane enhancer in the form of MTBE (methyl tert-butyl ether). MTBE is an important octane enhancement additive for unleaded gas. MTBE is mixed with unleaded gasoline in concentrations of 3 to 5 percent. Since methanol is a major ingredient in MTBE (up to 50 percent by weight), a significant proportion of methanol can enter the gasoline market as MTBE.

To penetrate this market methanol will have to be competitive with wholesale gasoline prices at the mixing point. Our survey of major oil companies (discussed below) confirmed this and identified the mixing point as the refinery. Oil companies conceptualize the blending of methanol as a refinery process for two main reasons. First, by mixing at the refinery the oil company can tailor the resulting blend properly. Since gasoline is a mixture of hydrocarbons, the refinery run must be tailored to mesh with methanol blending. Otherwise excessive evaporative emissions can result (this issue will be discussed a greater length under the topic of regulations). Second, by mixing at the refinery companies can make use of their existing distribution systems.

In light of the conditions, for methanol to penetrate the gasoline market as a blending agent it must be priced to be competitive with wholesale gasoline prices at the refinery gate. Table 2.4 contains the U.S. Department of Energy's latest forecast for gasoline prices. Unfortunately these are retail prices and not wholesale prices. Thus, we must determine the relationships between wholesale and retail gasoline prices from 1980 to 1995. Fortunately Collieries Management Corp. (1980, p. 145) has analyzed the cost of transporting and distributing gasoline and methanol. Their research indicates that the ratio of wholesale-to-retail gasoline prices will be between 0.763 and 0.776 from 1980 to 2000.[25] Table 2.6 presents a forecast for wholesale gasoline prices based on these figures.

Table 2.6.—Forecasts of wholesale gasoline prices at the refinery gate (1980 dollars)

	1980	1985	1990	1995
Retail gasoline price per gallon[1]	$1.22	$1.37	$1.75	$2.20
Ratio of wholesale-to-retail price[2]	0.757	0.763	0.769	0.776
Wholesale price per gallon	$0.92	$1.05	$1.35	$1.71

Sources: [1]Table 2.4.

[2]Collieries Management Corporation, op. cit, p. 145.

To be a viable blending agent methanol will have to be priced at or below $1.05 per gallon in 1985 (using deflated 1980 dollars) and at or below $1.71 in 1995. These prices will have to include shipping and handling costs to a refinery where blending will take place according to the current thinking of the petroleum companies.

The potential use of methanol as a gasoline blending agent and octane enhancer is not the sole path by which methanol can penetrate the automotive fuel market. Methanol can also be used as a pure fuel in so-called neat (fuel grade) form.

Neat use of methanol differs substantially from the use of blends as a gasoline substitute. Significant engine modifications are required to take advantage of methanol's high-octane value and superior conversion efficiency while at the same time over coming methanol's disadvantages of hard starting and vapor lock. However, neat methanol is already in use as a fuel for race cars, and neat methanol is being actively tested as a fuel for fleet vehicles. Thus, the technological problems of burning neat methanol in automobile engines has been solved already, no new technology is needed.[26]

Since use of neat methanol requires significant modifications in engines and carburetors and because neat methanol fuel is not widely available, the use of neat methanol will be restricted to dedicated fleets. Fleet use also simplifies the distribution and handling of methanol fuel and insures a supply of neat fuel.

Two recent analysis of the market potential for neat methanol fuel were very optimistic. Bentz, et. al (1980, pp. 118-124) and Collieries Management Corp. (1980, pp. 93-95) concur that neat methanol will be used extensively in fleet operations between 1990 and 2000 because of its cost effectiveness. Each study indicates that the market will be limited by the availability of methanol fuel. Table 2.7 displays forecasts for neat methanol from Bentz, et. al. (1980) and Collieries Management Corp. (1980).

Table 2.7.—Potential market for the use of neat methanol (millions of barrels of methanol per year)

	1985	1990	1995	2000
Frost and Sullivan[1]	—	25.0	340.0	600.0
Badger[1]	—	—	46.8-58.5	104.2-130.2
National Transportation Policy Study Commission[1]	67.8	123.6	160.3	188.8
Collieries[2]	—	28.8	345.2	607.0

Sources: [1]Bentz, et. al. (1980, pp. 119).

[2]Collieries Management Corp. (1980, pp. 94-95).

Two facts are noteworthy about the forecasts for neat methanol use in Table 2.7. First, the total neat methanol market appears to be quite large--far greater than the market for methanol-gasoline blends. Second, the forecasts are constrained by limits on the supply of methanol not the demand.

All of this, however, begs the question of the price required to insure that the market penetration forecasts for neat methanol shown in Table 2.7 come to pass. A recent detailed case study involving a small neat methanol fleet owned by Bank of America sheds light on this crucial question. Bentz, et. al (1980, pp. 121-123) report on the success of neat fuels in Bank of America's fleet test. Bank of America's program involves a test fleet of 58 vehicles using both blended fuels and neat methanol. No significant problems with maintenance or operation has been identified. Table 2.8 compares the economics of gasoline and neat methanol vehicles in Bank of America's fleet.

Table 2.8.—Summary of the economics of neat methanol vs. gasoline in Bank of America's fleet test

Data	
Delivered cost of gasoline	$1.23/gallon
Delivered cost of methanol	$0.88/gallon
MPG gasoline vehicles	16-18
MPG methanol vehicles	13.7-14.0
Capital cost to retrofit gasoline-fired vehicle to neat methanol	$750.00
Average lifetime vehicle miles	100,000
Differences in other operating or maintenance costs	$0.00

Calculations Lifetime operating costs:	Gasoline vehicles	Methanol vehicles
Capital cost of conversion per (lifetime) miles	$0.00/mile	$0.0075/mile
Fuel cost per mile	$0.072-$0.077/mile	$0.063-$0.068/mile
Total cost per mile	$0.072-$0.077/mile	$0.071-$0.076/mile

Although methanol has a lower BTU value per gallon than gasoline, its lower price and greater efficiency give it an operating cost advantage over gasoline as a motor fuel. Fuel costs per mile ranged from $0.072 to $0.077 for gasoline vehicles compared to $0.063 to $0.068 for methanol powered vehicles. Against this saving are charges for engine and carburetor conversions costing $750 per vehicle. Assuming an average vehicle life of 100,000 miles, this translates into an extra charge of $0.0075 per mile for the methanol vehicles. The total operating costs for the methanol vehicle were essentially identical to that for the gasoline vehicle at then current fuel costs. This suggests that methanol is competitive with gasoline for use in fleets when its price is no higher than 71.5 percent of the price of gasoline.

The conclusions we can draw from this length discussions are as follows:

(1) Methanol can penetrate the automobile market as a blending agent when it is priced at or below wholesale gasoline prices, or equivalently when methanol is priced at or below 76 percent of the price of retail gasoline.

(2) Methanol is competitive with gasoline in fleet applications when it is priced at or below 71.5 percent of retail gasoline.

2.2.3 Methanol supplies

In addition to concerns over petroleum prices and methanol prices, the demand for methanol as a fuel depends upon a reliable, long-term, stable supply of methanol fuel. No fleet owner will convert his vehicles at $750 a piece if the supply of neat fuel is in doubt. Indeed, many of the forecasts of methanol fuel demand are constrained by expectations of tight supplies. Most analysts such as Bentz, et. al. (1980), Collieries Management Corp. (1980), and the Department of Energy (1982) expect that there will be large supplies of methanol available even if these are below the levels of future potential demand.

Section 3.0 of this report examines the supply side of the methanol market in greater detail. Thus, further discussion of supply will be delayed until then.

2.2.4. Distribution concerns

For methanol fuels to find wide application, especially as a partial replacement for gasoline, they must be moved to end-use markets quickly, reliably, and inexpensively. To do so they must use the existing infrastructure to the maximum degree possible.

The market for motor fuel is a highly tuned consumer oriented market serving over 100 million private cars consuming well over 20 million gallons of gasoline each day. The petroleum industry produces, refines, and distributes fuel through tens of thousands of outlets to car owners. The level of standardization is high, and the degree of flexibility is consequently low. Thus, changes of any magnitude are difficult to accommodate.[27]

However, the introduction of methanol into the fuel distribution system can be accommodated because methanol can utilize most of the existing infrastructure. Analyses by Collieries Management (1980, pp. 131-151) and Bentz, et. al. (1980, pp. 228-266) suggest scenarios by which large quantities of methanol can enter the fuel distribution system in a cost effective manner. While it is true that some of methanol's particular characteristics require come special handling (it is an excellent solvent and it is hygroscopic), this can be readly accomplished at modest costs according to the studies by Collieries and Bentz. Thus, distribution is not expected to be a major impediment to the use of methanol as a fuel.

2.2.5 Utilization

Methanol can be widely used as an automotive fuel if auto owners can burn it with a minimum of inconvenience and expense, while obtaining satisfactory performance. Safety is of course a paramount concern. These issues have received extensive study[28] and will be briefly reviewed below.

It is useful to separate the discussion of utilization issues into two parts: neat methanol and blends of methanol and gasoline. Since these two applications pose somewhat different problems, each is discussed individually.

The use of neat methanol as an auto fuel poses three kinds of utilization problems: (1) material compatibility, (2) vehicle performance, and (3) safety. Methanol is a strong solvent, and it acts on commonly used automotive materials such as plastics, polyester laminated fiberglass, epoxies, teflon and cork. In addition, methanol corrodes zinc, steel, aluminum, magnesium, low-tin solders and terne metal (used in the linings of fuel tanks. However, these problems can be readily avoided by switching materials both in the vehicles themselves and in the methanol delivery system. However, the cost of changing the materials at risk would be minor for new vehicles.

The second utilization concern relates to vehicle performance. When the temperature is below 50°, methanol will not vaporize sufficiently to allow the engine to start. Thus, either additives must be used or a cold-start device provided. In addition, the carburetor must be adjusted to optimize the air/fuel mixture. Three other modifications will enhance performance: (1) an increased compression ratio enhances the thermal efficiency of the engine boosting performance and mileage, (2) a larger fuel tank compensates for methanol's low volumetric heat content, and (3) modifications to the intake and exhaust manifolds provides for preheating the fuel improves fuel/air distribution.[29]

The third concern is safety. Safety has two aspects to it--environmental safety and consumer safety. The environmental concerns pertain to exhaust emissions. Here methanol fuel performs as well or better than gasoline. Using current engine configurations with the necessary carburetor adjustments, exhaust emissions from methanol are similar to those from gasoline for CO and unburned fuel. However, NO_X emissions are only half of those for gasoline. Aldehyde emissions are much higher for methanol than for gasoline, but these are currently unregulated.[30]

When engines are modified to optimize their use of methanol, significant reductions in emissions are reported. Boosting the compression ratio of the engine and heating the intake-fuel reduces aldehyde emissions to the level of gasoline while also reducing emissions of CO and unburned fuel.[31]

Consumer safety relates to the toxicity and fire hazard posed by methanol. Although methanol is toxic, it is significantly less toxic than gasoline. The fire hazard posed by methanol is different in nature but the same in degree as gasoline. Although methanol has a higher flash point temperature than gasoline, thus reducing the risk from spill or leak induced fires, methanol presents a greater risk of explosion because of its wider flamability limits.

The use of methanol as an octane-enhancing blending agent with gasoline poses a somewhat different set of utilization concerns including: material compatibility, vehicle performance, safety, and phase separation. When used as a blending agent at concentrations of less than 10 percent, methanol poses few problems of material compatibility.[32]

In terms of vehicle performance, few of the modifications required for neat methanol use are needed for blends of 10 percent or less. However, cold start-up can still be a problem. In addition, the use of methanol blends creates a new problem--vapor lock. Since methanol raises the vapor pressure of gasoline, fuel demands, especially on hot days, can not be met readily. This can be corrected by more careful blending and by adjusting the carburetor setting for the air-to-fuel ratio.[33]

The question of safety has already been addressed above. With blends the same arguments apply except that the positive effects of methanol are reduced by the lower level of use in a blend as compared to a neat fuel.[34]

The final issue is phase separation. This is the most serious obstacle to using methanol in blends. Although methanol is slightly miscable in gasoline, it is highly miscable in water. If small quantities of water come in contact with the blend (0.1 to 0.5 percent), the water is absorbed by the methanol and in effect the water extracts the methanol from the blend. This is called phase separation. Since water is constantly present throughout the fuel distribution system, this poses a real problem. In addition, methanol is hygoscopic and absorbs water from the air.

If phase separation does occur, it leads to poor vehicle performance. Corrosion and other materials problems are promoted. Additives can help ameliorate this problem, but they are expensive. Increasing the aromatic content of the gasoline is helpful because methanol is more soluable in those blends. The best way to avoid phase separation is to avoid water.

2.2.6 Regulation

The final hurdle which methanol fuel must jump is existing governmental regulation. Methanol fuels will have to meet requirements concerning movement, distribution and end-use in a timely cost effective manner. The National Transportation Policy Study Commission conducted two detailed analyses of the regulatory concerns related to the supply, transportation, safety, and environmental impacts of methanol fuels.[35]

In reviewing these studies Bentz, et al. (1980, pp. 223-226) identified only two areas of potential concern for methanol demand: (1) emissions standards and (2) fuel economy standards. As to the first, methanol will result in lower emissions than gasoline, so there are no apparent problems. However, the EPA must still approve all blends of methanol. Of particular concern is the increase in evaporative emissions which can occur in methanol blends. Waivers and improved blends can meet these concerns. Neat methanol would also have to be certified as an auto fuel.

The second issue relates to fuel economy. Federal fuel economy standards are based on gasoline. These standards are not strictly applicable to methanol, so some new rule making would be needed. However, procedural steps are already in place and no particular problem is likely to develop.

2.3 Survey of major oil companies

The lengthy analysis in section 2.2 above indicates that between 1990 and 2000 the demand for methanol fuel will grow rapidly. In particular methanol will be a very attractive fuel for fleet use, and methanol will also be competitive as a blending agent directly or indirectly through the additives MTBE. However, all of this analysis was macroeconomic or general in nature. No specific methanol buyers were identified. Since there will not be much, if any, methanol fuel supplied prior to 1990, the identification of customers is difficult, if not impossible.

Even so, we thought it would be helpful to contact the major oil companies to gauge their potential interest in methanol as a blending agent or as neat fuel. To this end we contacted most of the major domestic oil companies through their fuel supply or planning divisions. In general terms, this extensive set of phone interviews confirmed our macro analysis of the methanol fuel market described above. Most firms expressed some interest in purchasing methanol if it were: (1) of high quality and (2) priced competitively with wholesale gasoline prices when delivered to their refinery's gate. However, most firms found it difficult to be more definitive about such long range planning for a new fuel component such as methanol. However, two firms expressed strong interest in methanol and each expected to use over 100 million gallons-per-year after 1990.

3.0 METHANOL SUPPLIES

This chapter examines the supply side of the methanol market. The discussion begins with an analysis of existing methanol capacity in the United States. Future supply conditions are examined next. Here, the focus is on the potential for methanol supplies produced from coal. Conclusions are drawn at the end of the chapter.

3.1 Current supply conditions[36]

Methanol is an important chemical feedstock. It is produced by an integrated chemical industry where half of the total production is captive to the final, chemical, product manufacturers. As a result, the primary producers of methanol are chemical firms. Table 3.1 lists the major U.S. methanol manufactures, their location, type of process, and capacity. The market is dominated by Dupont, which produces 32 percent, and by Celanese, which produces 22 percent. Eight other chemical firms participate in the market.

Table 3.1.—U.S. methanol capacity, 1980

Owner and location	Process type	Production capacity: Tons/day	Production capacity: Gallons/year (millions)
Dupont			
Beaumont, Texas	HP	2,500	276.5
Deer Park, Texas	LP	2,000	221.2
Orange, Texas	HP	1,100	121.7
Celanese			
Bishop Lake, Texas	LP	1,500	165.9
Clear Lake, Texas	LP	2,275	251.6
Air Products and International Minerals and Chemicals			
Sterlington, Louisiana	LP	1,500	165.9
Pensacola, Florida	HP	500	55.3
Borden			
Geismas, Louisiana	HP	1,580	174.7
Georgia Pacific			
Plaquemine, Louisiana	LP	1,200	132.7
Monsanto			
Texas City, Texas	LP	1,000	110.6
Hercofina			
Plaquemine, Louisiana	LP	1,000	110.6
Tenneco			
Houston, Texas	HP	800	88.5
Rohm and Haas			
Deer Park, Texas	HP	225	24.9
Valley Nitrogen Producers			
Hercules, California	HP	80	8.8
Total		17,260	1,909

Source: Collieries Management Corp. (1980), pp. 23.

The domestic production capacity is 17,260 tons per day. Realistically, these plants can produce 15,000 to 15,500 tons per day (1.7 billion gallons-per-year). Since domestic consumption of methanol is expected to be in the 13,000 to 14,000 ton-per-day range and exports of up to 1,000 tons-per-day are expected during the early 1980s, the market for chemical grade methanol appears to be in balance.

The typical methanol plant contains one or two methanol synthesis trains (at 1,000 to 1,500 tons-per-day). Natural gas is the predominant feedstock. Capital costs for the typical plant are on the order of $0.50 per annual gallon of capacity. Today a plant operating on natural gas would cost about $1.50 per annual gallon of capacity. To produce methanol from feedstocks like oil, coal, or wood requires a more elaborate plant which costs more to build and operate.

3.2 Supply outlook 1981-1985[37]

In the near term methanol production will rise. First, the near-term outlook for demand is positive, and as Table 2.3 shows demand is forecast to rise by nearly 10 percent-per-year between 1980 and 1985 reaching somewhere between 5.4 and 6.3 million tons by 1985 with little or no demand for methanol as a fuel.

Second, producers are planning some expansions. Getty Oil is planning to open a 150 million gallon-per-year (1,350 tons-per-day) facility in Delaware City, Delaware and a consortium of firms plans a 200 million gallon-per-year (1,800 tons-per-day) facility in Louisiana in 1983-1985.[38]

If these plants come on line as planned, annual production capacity potentially could rise to 6.7 million tons-per-year assuming: (1) none of the existing plants are retired and (2) a 90 percent operating rate. However, a number of the existing plants are a number of the existing plants are old and small. Thus, if some of the existing plants do close and the demand forecasts turn out to be accurate, imports of methanol may have to rise. In any event, the domestic methanol markets will be tight.

3.3 Production costs

To simplify greatly, we can characterize the production of methanol as a two step process: (1) production of synthesis gas and (2) methanol synthesis. In step one an appropriate feedstock is converted to synthesis gas, a mixture of carbon monoxide, carbon dioxide, water, and hydrogen. In step two the synthesis gas is converted to methanol.

For most conventional methanol plants using natural gas as the feedstock, we can characterize the chemical processes as follows.

(1) Natural gas (CH_4) is converted into synthesis gas in a steam reformer. $CH_2 + H_2O \rightarrow CO + 2H_2$ and $CH_2 + 2H_2O \rightarrow CO_2 + 3H_2$

(2) The gas is desulfurized, cooled, cleaned of unreacted steam and impurities, and compressed.

(3) The cooled compressed synthesis gas is converted to methanol under pressure in the presence of catalysts. The process is characterized by the pressure at which it operates: High pressure systems use zinc-chronium oxide catalysts, low pressure systems use copper.

(4) the raw methanol is condensed, cleaned, and distilled.[39]

Just as in any production/cost analysis, it is useful to aggregate costs into three components: feedstock or raw material costs, operations and maintenance, and capital recovery charges. However, methanol has exhibited volatile and sometimes perverse price-supply behavior. In general, supply curves slope upward in the price, quantity plane—when prices are high producers supply more to their markets where as when prices are low suppliers provide less. This relationship did not hold for methanol between 1951 and 1972. Here, supplies grew even as prices fell. This perverse trend can be explained by three factors:

(1) plant sizes increased dramatically during this period and the resulting economics of scale reduced the capital recovery charge per unit of output—fixed costs were spread over more units so average fixed costs fell;

(2) technology changed as a new low-pressure lower-cost methanol synthesis process was developed, and

(3) increased competition.[40]

Although feedstock costs doubled between 1950 and 1959, the absolute increased was just 6.4 cents per MCF (from 6.5¢/MCF to 12.9¢/MCF). There after natural gas prices at the well-head increased by just 5¢/MCF. Since feedstock costs were such a small fraction of total costs during this period (feedstock cost represented less than 2¢ per gallon of methanol), these increases in feedstock costs were swamped by reduced capital costs and more efficient process plants.[41]

Since 1973 the entire supply curve—the price/supply relationship—has shifted. After the 1973 oil embargo the methanol supply curve shifted to slope upward. More supply came only with a higher product price. This occurred even though natural gas prices were rigidly controlled until the last few years. Although gas prices were controlled for existing gas supplies, and even though many existing methanol plants have long-term low-cost gas supply contracts, real market conditions made it nearly impossible to secure new gas contracts. Well head prices have escalated sharply, and they will continue to rise as deregulation and market pressures continue.[42]

It is noteworthy that the most modern methanol plant Dupont's Deer Park Plant, was designed to use a heavy oil feedstock and not natural gas. This says a lot about how major producers view the prospects for natural gas as a feedstock. At $3/MCF, for example, feedstock costs would be almost 33¢ per gallon of methanol while at $5/MCF feedstock cost would reach 54¢ per gallon of methanol.

Recent evidence suggests the methanol prices will rise over the next few years to 1985. Abstracting from the cyclical influence of the current recession which has temporarily depressed demand, methanol prices will rise because:

(1) feedstock costs for natural gas will continue to escalate,

(2) capital charges for the newer plants are higher than for the older plants because of inflation and the lack of any new technologies or scale economies, thus as old plants are retired industry average costs will rise, and

(3) the supply curve seems to be shifting upward resulting in higher prices for each unit of output.

This last phenomenon, the shift in the supply curve, reflects the fact that there has been a major shift in industry pricing practices since 1973. Methanol prices now rise with changes in feedstock costs, and producers have noticed that demand falls very little even as prices rise.[43]

Putting these factors together, Collieries Management Corp. (1980, pp. 29) forecasts that methanol prices will be between \$0.66 and \$0.91/gallon in 1978 dollars. To convert his estimate to current dollars we must account for the inflation in industrial commodity prices which has occurred between 1978 and 1982—a 45 percent increase. In addition, we must also allow for the likely rate of inflation in industrial commodity prices from 1982 to 1985. If we assume a 7 percent-per-year increase in industrial commodity prices, the Collieries analysis implies 1985 methanol prices of between \$1.17 and \$1.62 per gallon.

This forecast is consistent with the U.S. Department of Energy's (DOE) recent forecast for natural gas prices for industrial users. DOE (1982, pp. 82) forecasts a price of \$4.38/MCF in 1980 dollars. If we assume a 6.7 percent-per-year rate of inflation (which is DOE's forecast, pp. xiii), this produces a forecast of \$6.06/MCF. Since 1,000 cubic feet of natural gas can produce 9.23 gallons of methanol (Collieries Management Corp., pp. 44), the feedstock cost for each gallon of methanol would be 66¢. Finally, feedstock costs represented between one-third and one-half of the total cost of methanol in 1982. Thus, if this relationship holds in 1985, the DOE forecast for natural gas prices is consistent with Collieries projections for methanol prices.

We can draw three important conclusions from this discussion. First, the rapid increases expected in natural gas prices will drive up the cost of methanol, and by 1985 the price may be sufficiently high to promote the use of alternative feedstocks such as coal or wood. Whether or not these feedstocks can be competitive depends upon their feedstock cost, plant cost, and operations and maintenance expenses. These issues are addressed later. The point here, however, is that the rapid escalation in natural gas prices resulting in skyrocketing methanol prices opens up the possibility of using alternative feedstocks.

Second, rapid increases in natural gas prices coupled with dwindling supplies mitigates against expanded use of natural gas as a feedstock for methanol production. In addition, gas is forecast to bring a higher price in the residential heating market than in the industrial market. Thus, expanded industrial uses will be further limited.[44]

Finally, if methanol is to find a role as an automotive fuel, supplies will have to be greatly augmented. Existing capacity is insufficient for this purpose now. Some of the potentially higher demand for methanol caused by its use as an automotive fuel after 1985 possibly can be met through imports of methanol from Canada, Mexico and possibly Saudi Arabia, but domestic supplies will also have to expand. To do so will require the use of a new feedstock—either coal, wood, or both. These possibilities are explored next.

3.4 Methanol from coal, municipal solid waste, and wood

In theory most any carbonaceous material can be used as a feedstock for methanol production. However, in practice cost and availability limit the relevant alternative feedstocks to coal, wood, and municipal solid waste. Since each of these feedstocks could be used to produce methanol, the economic question is which will be the most competitive? This is a crucial issue since the feedstock which produces the lowest cost methanol, will be the feedstock of choice.

A number of recent studies have attempted to address this issue. The general consensus conclusion is that coal is by ar the least cost feedstock for methanol production. All of these studies are generic in nature and provide a valuable basis for general comparisons. However, they all suffer from some extremely optimistic assumptions about conversion efficiencies, capital costs, feedstock costs, plant operations, and environmental problems.[45]

The key questions to be addressed in this section are: (1) Can methanol be produced from alternative feedstocks at competitive prices? and (2) Can methanol produced from wood compete against methanol produced from coal?

To be competitive, methanol will have to penetrate the market for automotive fuel. The analysis of methanol prices in Section 2.2.2 above indicates that methanol will have to be priced at least 70 percent below gasoline to insure market penetration. Table 2.6 presented DOE's forecast of gasoline prices. On this basis the forecasted maximum target prices for methanol would be:

	1985	1990	1995
Constant 1980 dollars	$0.96	$1.22	$1.54
Nominal dollars with 7 percent-per-year inflation	$1.35	$2.41	$4.25

At these prices methanol from coal or wood will be able to readily penetrate the market according to estimates contained in the literature. Table 3.2 contains published estimates of methanol production costs from coal,wood, and municipal solid waste. While the table does not contain every estimate available, the major recent studies are include. The only adjustments made were to place all costs on a 1980 dollar basis to allow for comparability. In addition, we should point out that the estimates from the study by Collieries Management Corp. (1980) were taken from SRI International's work for DOE.[46] As Table 3.2 shows, methanol produced from wood or coal can readily penetrate the automobile fuel market by 1990. However, methanol from municipal solid waste is too expensive.

The next question is can wood compete with coal as a feedstock for methanol? The figures in Table 3.2 suggest that in general wood can not compete with coal. This conclusion is supported by the theoretical process economics involved in converting feedstock to methanol. The toal cost of producing methanol depends upon: (1) feedstock costs, (2) conversion efficiencies, and (3) plant costs. Coal appears to be superior to wood in each of these areas.

Table 3.2.—Methanol production cost forecasts—private producers (1980 dollars)

Study	Feedstock	Gasifier	$/gallon
Wan[1]	biomass	Battelle-Koppers-Totzek	$0.78-$0.92
Collieries[2]	wood	---	$0.98
	coal	Texaco	$0.52
	coal	Koppers-Totzek	$0.66
	municipal solid waste	---	$1.53
Wham[3]	coal	Lurgi	$0.61
Bentz[4]	coal	---	$0.56
Badger[5]	coal	Rummel/Otto	$0.24

Sources: [1]Wan (1982), pp. 27.

[2]Collieries (1980), pp. A9, A19, A33, A51.

[3]Wham and Forester (1980), p. 10.

[4]Bentz (1980), p. 95.

[5]Badger as reported in Paul (1970), pp. 130.

In Section 3.3 we noted that methanol production can be viewed as a two step process: (1) production of synthesis gas from the feedstock and (2) methanol synthesis. Step two is basically the same no matter what the feedstock is. Thus, we are concerned mainly about step one when coal and wood are compared as feedstocks. As a feedstock coal has the following advantages over wood:

(1) coal is available at very concentrated locations--mines,

(2) very large amounts of coal are available at the mine sites,

(3) coal contains more carbon and has a higher BTU value per pound than wood, and

(4) it is more efficient to convert coal to methanol.

Thus, compared to wood coal is easier and cheaper to handle, it offers a greater output of methanol per ton of feedstock input, and it costs the same or less on a BTU basis. In addition, because very large amounts of coal are concentrated at one location, very large plants can be designed to exploit the economies of sale.[47]

Although coal has a number of inherent advantages over wood as a methanol feedstock, it also has some inherent disadvantages. First, compared to wood coal will have a greater impact on the environment. Unlike wood, coal contains significant amounts of sulfur and very small amounts of dangerous impurities like arsenic and mercury. Since coal based methanol plants must be very large to exploit their economies of scale, they will use huge amounts of coal and thereby generate large quantities of effluents. Environmental protection costs will be high, and they appear to be understated in the literature (more on this below). Furthermore, very large coal-methanol plants will require large amounts of freshwater which may not be readily available.

Second, estimates of methanol costs from coal assume thermal conversion efficiencies from 50 to almost 60 percent.[48] However, thermal efficiencies at this level have not been proven commercially. In fact, in the two plant designs conducted by BESI pursuant to this research thermal efficiencies were below 50 percent (for wood) and well below expected thermal efficiencies published in the literature. Three is every reason to believe that the published data for the thermal efficiency of coal conversion is also over stated. Thus, the cost of producing methanol from coal will be higher than the current literature suggests.

Third, the coal-to-methanol plants achieve low costs per gallon of output in part because of their very large sizes. These conceptual plants are designed to produce between 6,500 and 7,300 tons of methanol per day. Thus, they are at least 3 times larger than the largest plant operating today. Since methanol plants of this scale have never been built, engineering scale up problems are inevitable and have been recognized (Paul, (1978) pp. 163). However, such problems do not appear to be reflected in the capital cost estimates for these plants.

In addition, massive coal-to-methanol plants pose large financial risks because of their sheer size and costs. For this reason alone, financing charges (including profit) may have to be higher than normal.

Finally, estimated of the cost for various plant components (such as material handling, oxygen, methanol synthesis, etc.) appear to be significantly under estimated in the literature. This imparts a significant downward bias to the projected cost of producing methanol from coal. To evaluate the reasonableness of the cost estimates for a coal-to-methanol plant we can compare these costs to the cost estimates

BESI received for a wood-to-methanol system. Only those items which exist in both the coal-fed and wood-fed plants can be compared. In addition, adjustments must be made to account for inflation and for different volumes of output. This is done in Table 3.3.

For example, the wood-to-methanol plant requires an oxygen plant to produce 1,000 tons-per-day of oxygen. It will cost $45 million or $45,000 per daily-ton of output. The two coal plants require much greater amounts of oxygen (6,000 and 7,300 tons-per day respectively), but even after adjusting for inflation they are estimated to cost $29,000 and $23,840 per daily ton of output. While there are likely to be some economies of scale at larger output levels, the estimated costs for the oxygen plants at the coal-to-methanol facilities seem to be much too low. As Table 3.3 demonstrates, most every component in the estimated costs for the coal-to-methanol plant appear to be underestimated.

Reviewing each of the four concerns raised above—environmental, conversion efficiency, scale, and capital cost estimates—it appears that any cost advantage a coal-to-methanol plant may have over a wood-to-methanol plan will be much smaller than reported in the literature. Thus, despite the literature, there is no reason to believe that a well designed wood-to methanol plant can not compete with coal to methanol facilities.

The cost estimates for Biomass Energy System's wood-to-methanol facility are described next. In addition, a detailed financial analysis is provided.

Table 3.3.—Comparative plant costs
(in thousands of 1982 dollars per daily ton of output)

Plant component	Evergreen estimate for BESI's wood-to-methanol plant[1]	Collieries estimate for lignite-to methanol[2]	Collieries estimate for coal-to methanol[3]
Oxygen plant	45,000	29,000	23,840
Acid gas removal	26,700	2,060	2,230
Methanol synthesis	25,700	14,470	13,870
Methanol storage	4,000	504	470
Wood gasification	65,500	14,430	21,700
Plant utilities	27,900	29,360	8,300
Feed preparation	43,600	5,880	4,635
Other	5,000	51,126	21,135
Total	243,400	146,830	96,180

Sources: [1]Evergreen Energy Systems (1982), pp. 18.

[2]Collieries Management Corp. (1980), pp. A-8.

[3]*Ibid*, pp. A-19.

4.0 Financial analysis - methanol from Eucalyptus

This section presents a detailed financial analysis for production methanol from Eucalyptus in Central Florida. To facilitate the analysis the project is examined in three parts: (1) the tissue culture laboratory and nursery for generating the required amount of Eucalyptus seedlings, (2) the energy plantation for producing and delivering the necessary wood feedstock, and (3) the methanol refinery for converting the wood into methanol. Each of these three components will be analyzed for profitability using a discounted cash flow approach.

To properly set the stage for the financial analysis of BESI's Eucalyptus-to-methanol project, we must first discuss the macroeconomic environment over the life of the energy project. This task is accomplished in Section 4.1 below. We follow Chase Econometrics' long-term forecast both because it is of high quality and because DOE used this forecast as an input to its projections for energy prices which we have used extensively.

A vital prerequisite for the project is the availability of a suitable site at a reasonable price. This issue is addressed first in Section 4.2. Section 4.3 examines the economics of producing the necessary numbers of superior Eucalyptus seedlings from tissue cultures. The profitability of the energy plantation is analyzed in Section 4.4. Section 4.5 investigates the economics of the methanol production facility using Eucalyptus as its feedstock.

4.1 Macroeconomic assumptions

Assumptions about macroeconomic trends (prices, interest rates, output, etc.) form the under pinning for all forecasts used in this study. For example, projections for future prices and availability of gasoline in the U.S. depend upon world oil prices and domestic economic conditions. Forecasts of future energy prices are a crucial input for this study, and we used forecasts developed by the U.S. Department of Energy extensively in Sections 2 and 3 of this study.[49] The DOE in turn based its energy forecasts on a long-run macroeconomic forecast developed by Chase Econometrics.[50]

Table 4.1 summarizes the Chase forecast for 1980-1995 and extrapolates the forecast to 2020. Although the Chase forecast contains cyclical episodes, these are obscured by the averaging process used in Table 4.1.

Over the entire forecast period from 1980-1995 Chase projects moderate economic growth at 2.7 percent-per-year measured by growth in real GNP. The growth rate slows toward the end of the period, and when it is extrapolated to 2020, the average growth for 1995 to 2020 is 2.6 percent. The Chase forecast envisions particular strength in the manufacturing sector over the forecast horizon. Here growth accelerates from the 3.3 percent rate posted from 1970 to 1980 to a 4.3 percent average in the 19780-1995 interval. Extrapolating out to 2020 the series grows at an average annual rate of 4.2 percent. Throughout the forecast period Chase expects the relative size of the government sector to shrink while manufacturing growth is spurred by higher levels of investment.

Real per capita income will post annual average gains of 2 percent-per-year through 2020. While this represents a marked improvement compared to 1979-1982, it is somewhat below average compared to 1970-1980. Inflation is projected to slow throughout the period. The pace of general price inflation will decline from almost 7 percent in 1970-1980 to 6 percent in 1995-2020. The deceleration of prices is even more apparent in the series on prices for nonresidential investments. After the rapid 7.7 percent average increase experienced during the 1970s, inflation in the price of investment goods should slow to an average of 5.5 percent between 1995 and 2020.

The first few years of the 1980s have witnessed unprecedented peaks in interest rates. Lately rates have moved down from their peaks, but they are still very high by historical standards. Chase forecasts that rates will decline to the 10 percent range by 1988. However, this implies an average AA bond rate of 12.5 percent and a prime rate of 12.8 percent for the 1980-1995 interval.

These forecasted values are important inputs to the financial analyses presented in Sections 4.3 to 4.5 below. In addition, by using the same national forecast as DOE used, the underlying assumptions for our analysis are identical to those used by DOE in forecasting energy prices.

Table 4.1.—General macroeconomic assumptions for selected economic variables

(growth rates per year, percent unless otherwise stated)

	1970-1980[1]	1980-1995[2]	1995-2020[3]
Real gross national product	3.2	2.7	2.6
Real industrial production, manufacturing	3.3	4.3	4.2
Real per capita disposable income	2.2	2.0	2.0
GNP price deflator	6.9	6.7	6.0
Price deflator for nonresidential investment	7.7	6.9	5.5
Population	0.8	0.9	0.8
AA bond rate	8.9	12.5	10.0
Prime rate	8.7	12.8	10.0

Sources: [1]Citibase: Citibank economic database.

[2]Chase Econometrics, Inc., Long-Term Macroeconomic Forecasts and Analysis, October 6, 1981 as reported in Energy Information Administration (1982), pp. xiii.

[3]Extrapolation.

4.2 Site availability

Approximately 70,000 acres well be needed for the energy plantation, laboratories, and methanol refinery. The land must be reasonably well drained, flat, have water available and be suitable for a large scale energy producing project. South Central Florida has many possible sites for this project. In general terms, the area is sparsely settled and largely agricultural in nature, except for the phosphate mining region centered in southwestern Polk County. Working Document 3: Background Environment describes the general land use pattern in greater detail.

Detailed area specific research identified two sites which are particularly attractive for our purposes. One site, in southwestern Polk County and owned by Agrico, is a former phosphate mine undergoing reclamation. The site consists of over 46,000 acres most of which is useable. The soils are quite suitable, abundant water is available, rail transportation is already in place, and zoning should not be a problem. The site is surrounded by lands of relatively low productivity, now in agricultural uses, or by other phosphate company holdings. Thus, additional land could be readily acquired.

The other primary site is in Southeastern Charlotte County and is owned by Babcock Florida, Inc. Babcock's nearly 90,000 acres are currently used for cattle grazing. The land is swampy in places, but it offers adequate area for our purposes, suitable soils, sufficient water, and access to water transportation. A zoning change would be required. However, the site is far removed from any human settlements, and the required zoning probably could be attained readily.

4.2.1. Site selection process

Our original choice for the site, on Lake Parker in Lakeland and adjacent to a municipal power plant, did not prove to be a feasible location. Problems with this site included: (1) land costs, (2) environmental restrictions, (3) transportation access, and (4) sub-surface structural problems. Thus, this site was not considered.

The research area for this task encompasses eleven counties in South Central Florida: Okeechobee, Hillsborough, Polk, Osceola, Manatee, Hardee, Highlands, Sarasota, DeSoto, Charlotte and Lee. The region contains over 6 million acres and covers more than 10,000 square miles. This region was selected because it provides suitable climate and soils for growing Eucalyptus, and it offers the opportunity for acquiring sufficient land for our purposes. To the north, the winters are too cold and to the south the land is generally too swampy.

The selection process focused first on identifying tracts of land of 10,000 acres or more to serve as the nucleus for the Eucalyptus project. Further screening was conducted for the following characteristics: (1) soil—well drained and relatively fertile, (2) topography—flat, (3) water—3 million gallons per day available, (4) transportation—road or water transport available to a suitable port, and (5) zoning—appropriate zoning or apparent ease in getting a zoning change.

The initial sources of information on land ownership were land atlases and plat books published for each county. Although the data for some counties was last updated in 1976, most of the data was available for 1980. Furthermore, since large tracts of land do not change owners very often, even when only older atlases were available, this did not pose a particular problem for this research. In addition to researching atlases and plat books, real estate professionals dealing in large tracts of land in the eleven county area were contacted.

4.2.2. Results

This research identified 17 potential tracts of land which meet the selection criteria and could serve as the nucleus for the Eucalyptus-to-methanol project. Table 4.2. describes the tracts which are shown in Figure 4.1.

Table 4.2.—Potential sites

Tract	Size (acres)	Location	Price per acre	Availability	Suitability
#1	40,000+	Polk Co. (S.W.)	$600-$900	For sale or lease	Good
#2	8,497+	Polk Co. (S.E.)	$882	For sale	Poor-fair
#3	10,140+	Polk Co. (S.E.)	$488	For sale	Fair
#4	11,814+	Polk Co. (N.E.)	$704	For sale	Fair
#5	300,000+	Osceola Co. (N.E.)	Unknown	Part may be available for lease	Fair
#6	10,990+	Osceola Co. (N.W.)	$647	For sale	Fair
#7	25,000+	Osceola Co. and Indian River Co.	$853	For sale	Fair
#8	10,450+	Osceola Co. (S.E.)	$861	For sale	Fair-poor
#9	10,400+	Osceola Co. (central)	$1,200	For sale	Fair-good
#10	10,337+	Osceola Co. (central)	$660	For sale	Poor
#11	40,080	Highlands Co. (S.W.)	Unknown	Part may be available for lease	Fair
#12	10,300+	Highlands Co. (S.W.)	Unknown	For sale	Poor-fair
#13	11,520+	DeSoto co. (S.E.)	$1,100	For sale	Fair-good
#14	88,960	Charlotte Co. and Lee Co.	$500-$700	For sale or lease	Fair
#15	25,000+	Okeechobee Co.	$1,000	For sale	Fair
#16	16,000+	Osceola Co.	$1,218	For sale	Good
#17	12,627+	Hillsborough Co.	$1,346	For sale	Good

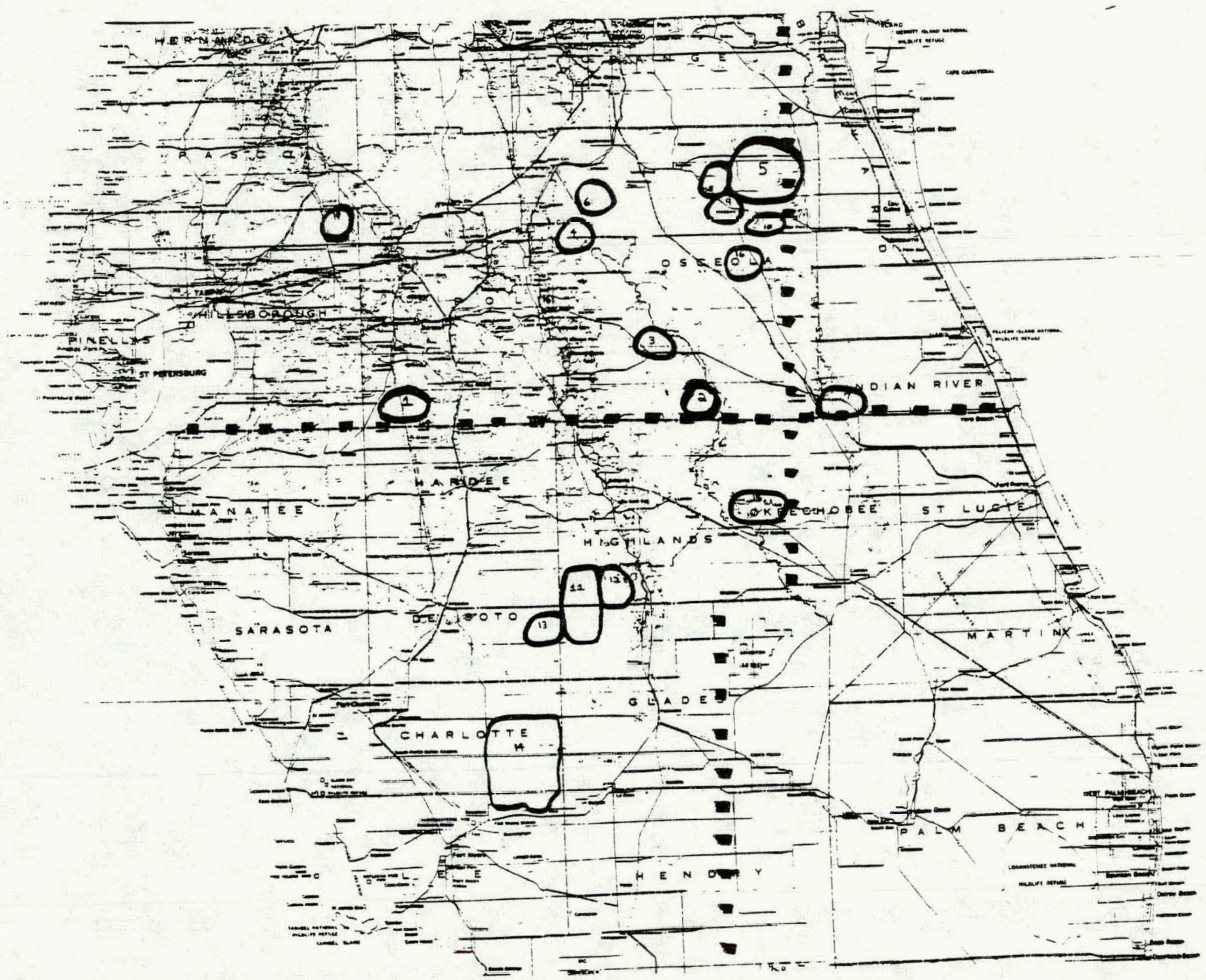

Figure 4.1.—Potential sites

One particular group of large land owners merit special discussion, phosphate mining companies. Phosphate mining companies own extensive blocks of land in Polk, Hillsborough, Hardee, Manatee and DeSoto counties. Much of this land is being held in reserve for future mining, mined out and undergoing reclamation, or part of an existing active mine. Eleven phosphate companies, each owning 20,000 acres or more, were contacted including Agrico, American Cyanamid, C. F. Industries, International Mineral and Chemicals, Borden, AMAX, Gardinier, W.R. Grace, Estech, Mobil, and Mississippi Chemical.

In general, however, only one firm expressed any interest in selling or leasing property. Of course, the mining firms will not sell land acquired for future mining or part of an active mine. In addition, most mining companies are not interested in long term leases. Standard industry practice is a one year lease with a thirty day escape clause. While this preserves the company's flexibility, it is not appropriate for our long term needs. For this reason all but one phosphate firm, Agrico, is excluded from Table 4.2 and Figure 4.1.

However, this still leaves the extensive lands which the mining companies are reclaiming or which have been mined and are being left as is. Prior to July, 1975 land reclamation was not required for phosphate mining. Thus, over 100,000 acres lie unreclaimed, mostly in Polk County. Much of this land is available for sale or lease, and it may be suited for the Eucalyptus-to-methanol project. Although the topography is sometimes a problem (unrestored strip mines can be quite rough terrain), by and large these problems can be overcome at a reasonable cost. This is especially true since the more disturbed the land is, the lower its price. Depending on the quality of the land, its price can range from approximately $1,000 per acre to $400 per acre for large parcels of over 1,000 acres.

Furthermore, a new land reclamation program sponsored by the State of Florida may provide significant financial aid for reclamation at certain sites. Chapter 16C-17 F.A.C. outlines a reclamation program for the unrestored phosphate mines and provides for 100 percent cost reimbursement in most cases. Since reclamation of the more difficult sites could exceed $2,000 per acre if extensive earth movement is required, state aid would be needed before any land reclamation could occur.

Thus, even though most phosphate mining firms expressed no interest in the sale or lease of their unreclaimed lands at this time, many firms appeared to be interested in discussing a sale when and if BESI reaches the point of active negotiations and offers to purchase. As a result, research to date will understate the true amount of land available for this project.

4.2.3. Primary sites

Two sites stand out among the 17 tracts identified by the screening process, Tract 1 in southwest Polk County and Tract 14 in southeast Charlotte County. Each of these is described in greater detail below.

Tract 1 contains 46,080 acres, and it is owned by Agrico. Agrico operates a phosphate mine and beneficiation plant on the site today. Mining operations are nearly completed, and the company is interested in selling the property. Since the land was strip mined, some of it is unuseable in its present condition. A portion of the property is currently a waste clay retention area (approximately 5,000 acres).

However, the remaining parcel of nearly 40,000 acres is very well suited for the Eucalyptus-to-methanol project.

The soils are well drained and reasonably fertile. BESI research has shown that Eucalyptus grows very well on reclaimed phosphate land (see Working Document 1: The Florida Eucalyptus Energy Farm).

Abundant water is available on the property. Agrico currently has a consumptive use permit allowing the withdrawal of 11 million gallons per day (MGD) and a maximum daily use of 14 MGD. In addition, the site is currently zoned "rural conservation" which is Polk County's general agricultural classification. Since strip mining and processing are now going on at the site by a special exception, zoning officials felt that methanol production could also gain the necessary special exception.

Transportation would not pose a problem from this site. The CXS railroad currently serves the site and provides service to Tampa where barge transportation is readily available. In addition, the site has five miles of frontage on State Road 37.

The final consideration is price. Since BESI is now in a research phase, it is difficult to get land owners to seriously consider pricing their property. Nevertheless, preliminary discussions point to prices between \$600 and \$900 per acre. Terms were not discussed. Research suggests that other tracts of land adjacent to this site are also available for sale at these prices.

Parcel 2 contains over 88,000 acres and is shown in Figure 4.1 as Tract 14. Babcock Florida currently owns the property and operates it for cattle grazing. The soils range from well drained sandly soils of reasonable fertility to swampy areas. Indeed, approximately 8,000 acres of the site are too swampy for our purposes. However, the parcel still provides more than enough land for the Eucalyptus plantation and methanol refinery.

Although the land does not use extensive amounts of water now, obtaining permits for water should not be a problem. The officials of the water management district for this parcel indicate that a consumptive use permit for up to 5 MGD would be no problem to obtain. Water appears to be abundant at the site.

In addition, transportation will not pose a problem. The parcel has almost 20 miles of frontage on State Road 31. In addition, the parcel has water access to the Caloosahatchee River suitable for barges. The parcel is zoned agriculture. However, it is quite far from any settlement, and a zoning change could be obtained.

Discussions about a sale were inhibited by the research nature of this project. However, the owners were interested in serious offers. Research on land prices in the area indicates that $500 to $700 per acre would be a reasonable price for the parcel.

4.3. Tissue culture lab and nursery

The tissue culture lab and nursery complex is described in Working Document No. 2, Tissue Culture Propagation of Eucalypts. Briefly the tissue culture lab and nursery must provide sufficient, high quality, Eucalyptus seedlings for BESI's extensive planting program. While there are a number of possible ways in which Eucalyptus planting stock could be generated for the project, only the tissue culture route is practical. Tissue culturing will allow us to select superior trees out in the field, gather some of their genetic material, and generate large numbers of seedlings with the superior traits of the mother tree.

To support the seven year planting program almost 7.5 million Eucalyptus seedlings will be needed each year. This will require the following facilities: (1) tissue culture laboratory, (2) lab equipment, and (3) nursery facilities. The first two items will have to be purchased while nursery space is available at attractive rents. As for the latter, the Speedling Company, a major grower of vegetable seedlings, can provide the necessary nursery facilities and produce the finished seedling at an attractive price. Table 4.3 displays the cost estimates for the tissue culture laboratory and lab equipment developed in Working Document No. 2. In addition, the table shows the major assumptions which influence the estimated cost per seedling.

As noted in Working Document No. 2 the most important variables in determining the cost for tissue-culture propagated seedlings are: (1) multiplication rates, (2) failure rates, and (3) labor costs. Multiplication rates have a dramatic affect on total cost per seedling because the higher the multiplication rate the lower the cost-per-plant for most lab operations. The reverse is true for losses—more losses lead to higher cost per finished seedling. Since labor costs account for over 50 percent of total costs, the affect is obvious on finished seedling costs.

The tissue culture lab and nursery facility (to be rented) are to serve the needs of BESI's planting program exclusively. Thus, the market for superior Eucalyptus seedlings is assured. The seedlings are priced to provide a 20 percent return after taxes.

Table 4.3.—Data and assumptions for the tissue culture lab and nursery (1982 dollars)

Tissue culture laboratory	$320,000.00
Laboratory equipment	$150,000.00
Tissue culture multiplications rates:	
Stage II a	multiplication 13x
State II b	elongation 10x
Estimated losses:	
Stage II a multiplication	5%
Stage II b elongation	5%
Stage II rooting	10%
Stage IV nursery growth	15%
Labor costs	$6 per hour
Price per finished seedling	$0.30

Table 4.4.—Financial analysis--Biomass Energy Systems, Inc. tissue culture lab and nursery

Assumptions—scenario	Internal rate of return
1. Base case: assumptions as per Table 4.3, Working Document No. 1, and Chase Econometrics	20.4%
2. Increased losses and lower multiplication rates: losses at each stage are increased by 5 percentage points and multiplication rates at Stage II are reduced by 10 percent	13.2%
3. Improved procedures: elimination of Stage III culture and automation of Stage II cultures	37.3%

Table 4.4 contains a financial analysis for the tissue culture-nursery operation. Under the base case assumptions outlined in Table 4.3 and in Working Document No. 2, the internal rate of return for the project is 20.4 percent after taxes. This rate of presumes a 30 cent-per-seedling price and was calculated on a discounted, cash, flow, basis.

As noted in Working Document No. 2, the estimates for cost-per-seedling are quite sensitive to variations in the multiplication and the failure rates. Scenario 2, "increased losses and lower multiplication rates" attempts to capture the downside risk. Here, the loss rates are all increased by 5 percentage points and the Stage II multiplication rates are reduced by 10 percent. Should this set of circumstances transpire, the internal rate of return would fall to 13.2 percent.

There is also significant opportunities for achieving lower costs by automating some Stage II processes and by eliminating the Stage III culture step. The resulting economics push the prospective internal rate of return to 37.3 percent.

Biomass Energy Systems, Inc. has operated a tissue culture lab for over two years now. This practical experience is the foundation for the cost estimates presented in Working Document No. 2 and used in this analysis. In addition, our experience indicates that an expanded tissue culture lab can provide the 7.5 million seedlings needed to support the planting program and be a profit center in its own right.

4.4 Eucalyptus energy plantation

The Eucalyptus energy plantation is the second major component of BESI's Eucalyptus-to-methanol project. Conceptually, this phase of the project takes as its inputs select seedlings from the tissue culture-nursery phase, installs the seedlings, maintains the Eucalyptus plantation, harvests the wood, and delivers it to the methanol refinery. Each of these steps was describe in Working Document No. 1, The Florida Eucalyptus Energy Farm--Silvicultural Methods and Considerations.

In this section we examine the economics of producing and delivering Eucalyptus wood to the refinery. Once again the analysis is conducted on a discounted, cash, flow basis. Table 4.5 contains the pertinent data and assumptions for the analysis. All of the assumptions about cost items were developed in Working Document No. 1 except for the following:

(1) rent and management fees are designed to provide adequate compensation for managing the plantation operation and for paying local taxes (which are minimal on a per acre basis);

(2) the market price for feedstock is designed to provide a 15 percent return after taxes--since the market and price are assured by purchases from the refinery, this return is adequate;

(3) the engineering report by Evergreen Energy Corporation, Working Document No. 8, Wood-Fueled Gasification System, estimates that 1,990 dry tons of wood will be needed each day of operation (330 days per year), at 50 percent moisture this means 330 x 1,990 x 2 = 1,313,400 green tons of wood are needed each year;

(4) approximately 15 percent of the total land available for growing Eucalyptus must be devoted to roads, staging areas, etc.;

(5) the land cost on an acre basis was estimated in Section 4.1 above;

(6) the net corporate tax rate is assumed to be 40 percent to reflect the various write-offs allowed for agricultural operations of this type; and

(7) a mortgage is obtained for the land with a 10 percent down payment at 1 percent above the prime rate.

Based upon the assumptions Table 4.6 presents the financial analysis. In the base case the plantation provides a 14.7 percent return after taxes. No revenues are generated for the first seven years of operation when land is acquired, trees are planted, and they grow. When the first harvest comes in year 8, substantial net cash inflows commence. Expenses for land acquisition (10 percent down and a 30 year mortgage), planting and management total \$92.5 million during the first 7 years of operation. It is assumed that all of these funds are equity capital. To the extent that debt is used in developing the Eucalyptus plantation, the internal rate of return will rise. However, to be conservative we have assumed 100 percent equity financing except for the land.

Table 4.5.—Data and assumptions for the Eucalyptus energy plantation (1982 dollars)

Cost per seedling	$0.30
Number of seedlings per acre	871
Installation cost per acre	$500.00
Fertilizing and herbicing per acre	$60.00
Survival rate for seedlings	70%-80%
Years to maturity	7
Harvest cost per ton	$10.00
Yield at maturity per acre every 7 years	154 green tons
Fixed cost for property taxes and management per acre	$30.00
Market price of feedstock per green ton	$20.00
Tons of wood required per year	1,313,400
Additional acreage need for roads, staging areas, etc.	15% of total acreage
Macroeconomic assumptions	Chase Econometrics
Land cost per acre	$750.00
Total net tax rate	40%
Mortgage rate	prime plus 1%

Sources: Working Document No. 1, The Florida Eucalyptus Energy Farm —Silvicultural Methods and Considerations, and Chase Econometrics (1981), op. cit.

Table 4.6.—Financial analysis—Biomass Energy Systems, Inc.
Eucalyptus energy plantation

Assumptions—scenario	Internal rate of return
1. Base case: Chase Econometric inflation, other assumptions BESI	14.7%
2. Low yield: 25 percent less yield to 115.5 green tons per acre per harvest	11.4%
3. High yield: 25 percent more yield to 192.5 green tons per acre per harvest	17.4%
4. Higher inflation: one percent above Chase	15.8%
5. Higher harvest cost: $12/ton in 1982	12.3%
6. Lower harvest cost: $8/ton in 1982	17.0%
7. Higher mortgage rate: prime plus 2	14.4%

To investigate the sensitivity of the rate of return estimate we examined an array of seven alternative financial scenarios in Table 4.6. BESI research suggests that Eucalyptus yields will be 154 green tons-per-acre per harvest (every 7 years). However, yields may turn out to be greater or smaller than this. Scenarios 2 and 3 explore these possibilities. If yields come in 25 percent below expectations (at 115.5 green tons-per-acre per harvest), the after-tax internal rate-of-return falls to 11.4 percent. By contrast, if actual yields are 25 percent higher than expected, the after tax return jumps to 17.4 percent.

Scenario 4 examines the impact of a higher than forecast level of price inflation. The total affect of a 1 percent higher rate of inflation is to raise the rate-of-return to 15.8 percent. This occurs because both costs and revenues are increased when inflation rises, and the revenue affect dominates.

Scenarios 5 and 6 explore the affects of harvest costs on profitability. Harvesting costs are the largest single cost item for the plantation. If harvesting costs are 20 percent above BESI's estimate of $10 per ton, profitability falls to 12.3 percent. By contrast, if harvesting costs come in at $8 per ton, profitability increases to 17.0 percent.

The final scenario involves a higher mortgage rate, prime plus 2 percent. The impact on overall profitability is small, and the internal rate-of-return declines to 14.4 percent.

4.5 Methanol refinery

Technical details about the methanol production facility are contained in Working Document 7, Feasibility Study Eucalyptus to 1000 STDD Methanol Plant in South Central Florida, by Davy McKee and Working Document No. 8, The Wood-Fueled Gasification System, by Evergreen Energy Corporation. These documents describe the engineering and operating aspects of the methanol plant. In addition, the two engineering studies provide capital and operating cost estimates for the methanol facility.

The Davy McKee study provides a complete preliminary engineering design for the entire methanol production facility from the receipt of wood at the factory to the load out of finished methanol. Davy determined the optimum size plant was 1,000 tons per day. The Davy design incorporates commercially proven components for every phase of the design. The major process risk involves the scale up of the Davy fixed-bed up-draft oxygen-blown gasifier to utilize wood. Otherwise the BESI facility is comparable in many ways to existing methanol plant except the feedstock is wood.

While Davy developed an excellent, preliminary, engineering, design study, methanol produced using this design was judged to be uneconomical for three reasons. First, overall thermal efficiency is very low, 33.3 percent. Second, the design generates excessive amounts of aqueous liquid, 1.5 MGD. Third, the design requires too much wood feedstock—over 6,000 tons per day (green). The main problem in the Davy design is the gasifier. The Davy gasifier operates at atmospheric pressure, at relatively low temperatures, uses steam to regulate the gasification process, and requires long residence time in the gasifier. These characteristics are wasteful from the perspective of thermal efficiency, they require increased wood feedstock and water, and they produce excessive waste water effluent.

To resolve some of these difficulties Evergreen Energy Corporation examined the preliminary Eucalyptus-to-methanol design and redesigned the gasifier and associated facilities. Evergreen selected the Texaco entrained-bed gasifier for the project. The Texaco gasifier operates at high temperatures and pressures and is an oxygen blown process. Residence times are short, and virtually no tars or oil are produced. Using this design thermal efficiency increases from 33.3 percent to 49.7 percent, required feedstock is reduced to 3,980 tons per day (a 34 percent savings), make up water declines by 46 percent of 2.2 MGD, and waste water is reduced by one-half to 0.8 MGD.

While the Evergreen design can produce methanol at a more competitive price, there are greater process risks involved. The increased risk relates to the use of the Texaco gasifier which has never been tested on wood. Evergreen plans such tests in 1983, but until then this does represent a major process risk.

Other aspects of the Evergreen and Davy designs are essentially the same, For example, the total capital costs for either the Davy or Evergreen design are virtually identical--$250 million Davy compared to $243.4 million for Evergreen's design. In addition, manpower requirements are identical. Thus, all things considered we shall adopt the Evergreen design.

4.5.1 Methanol prices 1985-2020

The future price of methanol and the size of the methanol market are crucial variables in any analysis of a methanol production facility.

Back in Section 2 we developed a forecast for the size of the future methanol market and upper limit price which could be obtained. The salient features of that analysis are:

(1) methanol must be priced to penetrate the automotive fuel market in general and the market for fleet fuel in particular,

(2) to achieve this penetration, methanol can be priced no higher than about 70 percent of the price of gasoline,

(3) if methanol is appropriately priced, it can penetrate a huge market on the order of 800 to 2,400 million barrels-per-year by 2000.

These prices represented the highest price at which methanol can be competitive. However, competition among methanol supplies is likely to drive the price significantly lower. To accommodate this likelihood we developed the three methanol price scenarios in Table 4.7. The future price of gasoline is the guiding mechanism, and we took the DOE's latest estimates (1982). Since the DOE's estimates were in 1980 dollars, we adjusted for the effects of inflation by utilizing Chase Econometrics (1981) long-term forecast for inflation. As noted above, the Chase forecast was used both because it is a good professional forecast, and it is the forecast used by the DOE itself. By this measure gasoline prices will grow at a compound rate of 10 percent per year through 2020.

Table 4.7—Methanol prices 1985-2020
(dollars per gallon)

	1985	1990	1995	2000	2005	2010	2015	2020
Gasoline [1]	2.00	3.00	4.98	8.20	13.51	20.14	36.66	54.66
Methanol								
Base case [2]	1.00	1.50	2.49	4.10	6.75	8.85	13.29	17.41
Low case [3]	0.90	1.17	1.56	2.18	3.05	4.28	6.01	7.88
High case [4]	1.10	1.65	2.74	4.51	7.43	9.92	15.31	20.45

Sources: [1] Energy Information Agency, U.S. Department of Energy (1982) adjusted by inflation rate for gasoline from Chase Econometric long-term forecast of October, 1981.

[2] From 1982 to 2000—50 percent of gasoline price; from 2000 to 2020—8 percent-per-year increase.

[3] From 1982 to 1985—45 percent of gasoline price; from 1985 to 2000—45 percent of gasoline prices - \$0.05 to \$0.10 per year; from 2000 to 2020—7 percent-per-year increase.

[4] From 1982 to 2000—55 percent of gasoline price; from 2000 to 2020—8.5 percent-per-year increase.

Three price profiles for methanol were developed. The base case assumes that between 1982 and 2000 methanol will be priced at 50 percent of gasoline. There after, methanol prices increased by 8 percent-per-year. The low price alternative foresees methanol prices at 45 percent of gasoline from 1982 to 1985. Between 1985 and 2000 methanol supplies will increase substantially holding price rises below the 45 percent-of-gasoline price level. Increased competition restrains methanol prices below the 45 percent-of-gasoline mark by 5 to 10 cents earch year on a cumulative basis. After 2000 methanol prices rise 7 percent-per-year. The high price alternative envisions methanol priced at 55 percent of gasoline until 2000. Thereafter methanol's price rises 8.5 percent per year.

4.5.2 Other assumptions and data

The other main assumptions and data for the financial analysis of the methanol facility are contained in Table 4.8. General economic assumptions for inflation, interest rates, and the like were drawn from Chase Econometric's forecast shown in Table 4.1. The engineering cost estimate for the plant is taken from Evergreen Energy Corporation's design (Working Document No. 8). A three year buildout period was assumed to being in 1987. Cash expenditures are timed at 20 percent, 60 percent, and 20 percent over the construction cycle. The initial cost estimate for their plant is escalated by the inflation rate for investments in plant and equipment (from Chase). During the construction cycle, the unbuilt fraction of the plant continues to escalate in price.

Table 4.8.—Data and assumptions for the methanol production facility

Economic assumptions	Chase Econometrics
Capital costs	
Plant costs (1982 dollars)	$243,500,000
Construction timing - three year building period commencing in 1987. Cash expenditures of 20 percent, 60 percent, and 20 percent for 1987, 1988, and 1989 respectively.	
Start-up costs	$10,000,000
Land	500 acres at $5,000 (1982 dollars)
Financing	
Equity investment	60 percent of installed plant costs
Working capital	2.8 percent of plant costs
Principal payments	20 year AA bonds 3 issues floated in 1988 and 1989
Interest payments	AA bond rate at issue date
Operating costs	
Feedstock	$20 per green ton and 1.3 milion tons-per-year required
Catalyst and chemicals	$4.10 per ton output
Labor	Davy McKee estimates of manpower priced accordingly by BESI
Utilities	Amounts from Evergreen at market prices
Shipping, handling and insurance	Market rates, delivery to Houston
Property tax and administration	2.25 percent of installed costs
Maintenance	5 percent of installed cost from Davy McKee

Start up costs were assumed to be $10 million, and start up is scheduled for the first half of 1990. Full production begins in the second half of 1990. Land for the plant and its wood piles requires 500 acres which cost $5,000 per acre in 1982. This cost escalates at the general inflation rate unit 1987 when the land is purchased.

The plant is financed with 60 percent equity capital and 40 percent debt (bonds). Any operating deficits are made up by contributions of additional equity. Working capital requirements are 2.8 percent of plant costs. Bonds are AA corporate debentures requiring semi-annual interest payments. Sinking funds are established to retire the bonds. These sinking funds accrue interest at the prime bank rate. Operating costs are dominated by feedstock expenses. Over 1.3 million tons of feedstock are needed per year. The 1982 price is $20 per ton, and this increases with inflation. Evergreen Energy calculates that $4.10 in catalysts and chemicals are used per ton of output. This price also increases with inflation. Labor requirements were estimated by Davy McKee. Labor costs escalate with inflation and run $4.7 million in 1982. Evergreen estimates the quantities of electricity and natural gas needed for the plant. In 1982 these would cost $5.6 million, and they escalate as follows: (1) electricity at the general inflation rate and (2) natural gas at an accelerated pace taken from Chase's forecast.

Shipping and handling charges are calculated from the plant site in Southwestern Polk County by truck to Tampa (1.1 cents per gallon) to Houston by barge (0.3 cents per gallon). The rates are current market quotes, so these prices increase with inflation. Insurance is assumed to cost 1 percent of the installed value of the plant.

Property taxes and administrative expenses are assumed to be 2.25 percent of the installed plant cost. This is similar to the figure used in Collieries Management Corp.'s report (1980). Finally, Davy McKee calculated that the maintenance expenses for the plant would run at 5 percent of plant's installed costs. All of these costs increase over time with inflation.

Table 4.9 displays the results of the financial analysis for the Eucalyptus-to-methanol facility. For the base case incorporating the assumptions from Table 4.8, the internal rate of return is 23.3 percent on an after tax basis (discounted, cash, flow approach). A 23.3 percent after tax return is certainly attractive. Total cash required until start up is $257 million.

Since the engineering cost estimate for the plant has a confidence band of plus or minus 35 percent, scenarios 2 and 3 address these alternatives. The high cost plant, 35 percent cost-overrun, is examined in scenario 2. If all the other assumptions listed in Table 4.8 hold, the project still provides an after tax interal rate-of-return of 19.1 percent. If, on the other hand, the plant ultimately costs 35 percent less than estimated, the internal rate-of-return after taxes soars to 30.8 percent.

To explore the affect of financing options on plant profitability we considered scenarios of 100 percent equity (No. 4) and 100 percent debt (No. 5). Maintaining the base case assumptions of Table 4.8 we find that the after tax return falls to 20.2 percent if all financing is by equity. Although profitability for this option is reduced by 3 percentage points compared to the base case, the effects are modest because the base case already used a significant portion of equity capital (60 percent of plant costs plus any operating deficits). By contrast, the 100 percent debt case causes the after tax internal rate-of-return to jump to 36.4 percent.

Scenarios 6, 7, and 8 examine the consequences of the lower profile for methanol prices drawn from Table 4.7. Under these circumstances the interest rate-of-return after taxes would be 9.8 percent for the base case, 6.7 percent for the high cost plant, and 15.1 percent for the low cost plant.

Finally, scenarios 9 to 11 explore the affects of the higher profile for methanol prices. Here profits range from 21.1 percent for the high cost plant to 33.5 percent for the low cost plant.

Table 4.9.—Financial analysis—Biomass Energy Systems, Inc.
100 MGY methanol facility

Assumptions—scenario	Internal rate of return
Base case	
1. Base case: Evergreen Energy plant costs, Chase inflation and interest rates, moderate methanol prices, and 60 percent equity investment in plant	23.2%
2. High cost plant: Evergreen Energy plant costs plus 35 percent	19.1%
3. Low cost plant: Evergreen Energy plant costs less 35 percent	30.8%
4. Full equity: 100 percent equity financing	20.2%
5. Full debt: 100 percent debt financing	36.4%
Low methanol prices	
6. Base case: Evergreen Energy plant costs, Chase inflation and interest rates, low methanol prices, and 60 percent equity financing	9.8%
7. High cost plant: Evergreen Energy plant costs plus 35 percent	6.7%
8. Low cost plant: Evergreen Energy plant costs less 35 percent	15.1%
High methanol prices	
9. Base case: Evergreen Energy plant costs, Chase inflation and interest rates, high methanol prices, and 60 percent equity financing	25.9%
10. High cost plant: Evergreen Energy plant costs plus 35 percent	21.1%
11. Low cost plant: Evergreen Energy plant costs less 35 percent	33.5%

5.0 Conclusions

The outlook for gasoline prices through 2000 is for rising prices at almost 10 percent-per-year. Domestic conservation will continue along its current trend. These twin forces will push gasoline consumption down from 7.7 million barrels per day in 1980 to 4.6 million barrels per day by 2000. These trends of rising prices and falling demands are expected to continue through 2020.[51]

Unlike other energy using sectors of the economy, the transportation sector must continue to use liquid fuels. Thus, even with conservation over 4 million barrels per day of gasoline or its equivalent will be consumed through 2020. These trends of rising prices and extensive demands create an environment in which methanol can be competitive.

Our research indicates that if methanol is priced at or below 70 percent of the price of gasoline, it can penetrate the market. Competitive pressures are likely to keep methanol prices around one-half those for gasoline. At these price levels we expect significant use of methanol in motor vehicles. Through 2000 it will be primarily the fleet fuel market although some gasoline blending will occur also. As methanol supplies increase, wider distribution of neat methanol will occur.

Can methanol produced from wood compete with methanol produced from coal? The existing literature suggests that wood can not compete with coal as a methanol feedstock. Coal is a more compact form of energy, it is concentrated in more specific locations (mines), and it is priced very competitively. Conceptual coal-to-methanol plants are estimated to produce methanol at around 50 to 60 cents per gallon. However, these estimates appear to be extremely optimistic. Capital costs are underestimated and process risks ignored. It is most unlikely the methanol from a coal plant will be so inexpensive. More realistically, methanol from wood can compete if the wood base plant is well designed and well located.

To produce methanol from Eucalyptus requires three conceptual steps:

(1) the tissue culturing and nursery growth of 7.5 million Eucalyptus seedlings-per-year to support the planting program;

(2) a Eucalyptus energy plantation on 70,000 acres to provide feedstock to the methanol refinery; and

(3) a 1,000 ton-per-day Eucalyptus-to-methanol production facility.

This integrated approach to methanol production from a renewable resource base reduces overall risk and insures that the optimal mixture of trees, land, harvesting, seedlings, and methanol production will be developed.

Total cash cost for the project is $350 million distributed over 7 years until the methanol plant comes on stream. No further cash is needed at that point. Cash expenditures can be broken out as follows:

(1) tissue culture lab and nursery	$ 500,000
(2) Eucalyptus energy plantation	92,500,000
(3) methanol production facility	257,000,000
total	$350,000,000

The project is projected to be quite profitable. On an after tax basis the internal rate-of-return figures (on a discounted, cash, flow basis) are as follows:

(1)	tissue culture lab and nursery	25%
(2)	Eucalyptus energy plantation	15%
(3)	methanol production facility	23%

Footnotes

[1]Encyclopedia of Chemical Technology (1981), John Wiley and Sons: New York, Volume 15, pp. 412.

[2]Chemical Week, "Alcohol Fuels? Ethanol's good, methanol's better," June 24, 1981, pp. 56.

[3]Chemical Week, "Octane boosters fuel methanol demand," January 14, 1981, pp. 24.

[4]Ibid.

[5]Encyclopedia of Chemical Technology, op. cit., pp. 413.

[6]Ibid.

[7]Chemical Week, June 24, 1981, op. cit.

[8]Energy Information Administration, U.S. Department of Energy, 1981 Annual Report to Congress, Vol. 3, February, 1982, pp. 165.

[9]Collieries Management Corp., Methanol Alcohol Fuel Supply and Demand 1980-2020, NTIS-PB81-176513, March, 1980, pp. 127.

[10]E. J. Bentz, et al., Factors that Affect the U.S. Market Demand and Utilization of Methanol from Coal, Within the Transportation Section, 1980-2000, NTIS-PB81-156457, October, 1980, pp. 91-92.

[11]Thomas L. White, "Alcohol as a Fuel for the Automobile Motor," Transactions, Society of Automotive Engineers, 1907, pp. 27-47.

[12]Energy Information Administration, op. cit., pp. 39.

[13]See Bents, et al., op. cit. pp. 34 for a good review of the projected U.S. energy balance. Also see Ibid, pp. 104.

[14]Ibid.

[15]Energy Information Administration, op. cit., pp. 41.

[16]Ibid.

[17]Ibid, pp. 94-95.

[18]Ibid, pp. 39.

[19]Ibid, pp. 103-104.

[20]Ibid, pp. 94.

[21]Ibid, pp. 165.

[22]"Alcohol Week Price Watch," Alcohol Week, April 19, 1982, pp. 4.

[23]Bentz, et al., op. cit., pp. 94 and Collieries Management Corp., op. cit., pp. 88.

[24]Bentz, et al., op. cit., reviews a number of these.

[25]These estimates are consistent with those found in Bentz, et al., op. cit., pp. 100.

[26]J. K. Paul, editor, Methanol Technology and Applications in Motor Fuels, Noyes Data Corporation: New Jersey, 1978, pp. 39-65.

[27]Collieries Management Corp., op. cit., pp. 9-10.

[28]For a good overview see J. K. Paul, op. cit., pp. 39-81 or Bentz, op. cit., pp. 125-133.

[29]Bentz, op. cit, pp. 126-127.

[30]Ibid, pp. 128.

[31]Paul, op. cit., pp. 51.

[32]Bentz, op. cit., pp. 132.

[33]Ibid, pp. 133.

[34]Ibid, pp. 133.

[35]E. J. Bentz, et al., Regulatory Factors Affecting the Demand and the Supply for Fuels for Transportation, NTIS, 1979. National Transportation Policy Study Commission, Transportation and Externalities, NTIS, 1979.

[36]This discussion was drawn from Collieries Management Corp. (1980), pp. 20-34.

[37]Ibid, pp. 28-30.

[38]Bentz, et al., op. cit., pp. 106.

[39]Collieries Management Corp. (1980), pp. B5-B7.

[40]Ibid, pp. 22.

[41]Ibid, pp. 22.

[42]Ibid, pp. 24.

[43]Ibid, pp. 27.

[44]Energy Information Administration, op. cit., pp. 69 and 82.

[45]A partial listing of the studies which project the costs of producing methanol from coal, wood, and municipal solid waste include: Bentz, et

al. (1980), op. cit., Collieries Management Corp. (1980), op. cit., Wham and Forester (1980), SRI International (1979), Wan (1979), and Wan (1982).

[46]Fred Schooley, et al., Mission Analysis for the Federal Fuels From Biomass Program, SRI International, 1979.

[47]Collieries Management Corp. (1980), op. cit., pp. 43-62.

[48]Ibid, pp. A1-A49.

[49]Energy Information Administration (1980), op. cit..

[50]Chase Econometrics, Inc., Long-Term U.S. Macroeconomic Forecast and Analysis, October 6, 1981 reported in Energy Information Agency, U.S. Department of Energy (1982), pp. xiii.

[51]Energy Information Administration (1982), op. cit.

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