11. Comparative Economics and Potential for Increased Gas Use

11.1. Comparative Economics -- Transportation Fuels

In previous sections economic summaries were given for a variety of methods of converting natural gas into transportation fuels. The production costs for these processes will now be compared with market prices and recommendations will be made about the potential attractiveness of doing further research on these processes.

Methanol and MTBE are both established processes. Methanol is in wide use both as a chemical and as an intermediate for use in making other chemicals. Many people have discussed the idea of using it as a transportation fuel. MTBE is manufactured in a number of locations for use as a gasoline blend component used to enhance gasoline octane and to meet environmental requirements.

The Fischer-Tropsch process is a tested and commercial proven process. It has been used for gasoline and diesel oil production in South Africa. South Africa has been a special situation because the Fischer-Tropsch plants were built at a time when the international community was imposing an oil embargo on the country. Thus, the existence of the plants in South Africa should not be taken to imply commercial viability in other areas.

Direct conversion of natural gas to gasoline by oxidative coupling or oxyhydrochlorination plus oligomerization and the production of C_1-C_6 alcohols are in the research and development stage. All of the work on these processes has been done in the laboratory or pilot plant.

Exhibit 11-1 compares the costs of producing the transportation fuels discussed in Section 8.1 to 8.7, inclusive, with prices for comparable transportation fuels taken from price projection tables. All costs and prices are U.S. Gulf Coast, December 1993. Product costs are based on building a grassroots plant.

Exhibit 11-1 shows that methanol and MTBE can be produced from grassroots plants at costs comparable to the current market prices. Based on these results, further research to find methods of decreasing the cost of producing methanol and MTBE seems warranted but will undoubtedly be carried on by the vendors selling the competing commercial processes. It is estimated that by 1996, 52% of the methanol demand will be for conversion to MTBE. Research on methanol and MTBE will continue to be of great interest.

Exhibit 11-1. Market Prices and Production Costs for U.S. Production Facilities

Product/Process Name	Report Section Showing Product Cost Estimates	Production Costs $/Gallon	Product Market Prices $/Gallon
Methanol/LPMEOH Process	8.1	0.44	0.43
Gasoline-diesel mix/Fischer-Tropsch Liquids*	8.2	1.51	0.66
Gasoline by Oxidative Coupling	8.3	1.69	0.69
Gasoline by Oxyhydrochlorination	8.3	1.82	0.69
Higher Alcohols by IFP Process	8.4	1.20	0.90 (for MTBE) and 0.43 (for methanol)
MTBE by UOP Process	8.5	0.86	0.90
Compressed Natural Gas (CNG)	8.6	0.73/geg	0.84
Liquefied Natural Gas	8.7	0.85/geg	0.84

*Includes upgrading cost of Fischer-Tropsch liquids. Assumes 46% gasoline and 54% diesel oil in product.

The cost of gasoline and diesel oil by Fischer-Tropsch processing is more than twice as large as the market price for these same products when produced from crude oil. Fischer-Tropsch does not look attractive using lower 48 gas now, nor will it likely look attractive in the future. In fact it will probably look less attractive if the forecast of U.S. lower 48 gas prices growing faster than crude turns out to be correct. The potential attractiveness with gas as a feedstock lies with using remote gas resources. If the cost of natural gas is $1.00 per million Btu rather than $2.43 per million Btu as assumed in Section 8 economics, the cost of producing Fischer-Tropsch liquids would go down to $1.17 per gallon (see Section 10.6).

Due to the high cost of producing C_1-C_6 alcohols, research in this area is not recommended unless there is evidence of the potential for significant improvements. The processes developed up to this time produce alcohol mixtures which consist mostly of methanol and ethanol. These forms of alcohols are not good from a marketing standpoint due to problems with polarity and water attraction. It appears that production of higher alcohols from chemicals other than methane may be more profitable.

Due to the poor economics of producing gasoline by direct conversion processes such as oxidative coupling and oxyhydrochlorination an economic process may not be available for a long time. A lot of research in this area has been done and hope for a breakthrough is diminishing. The economics given for oxidative coupling were based on an ARCO design from 1987 and nothing superior has appeared in the published literature since then.

CNG and LNG are competitive in price with gasoline and therefore are simple, attractive methods of utilizing natural gas for transportation fuels. Further work is needed to make it convenient and readily available as a fuel. As can be seen in Exhibit 8-8, it is more expensive to produce LNG than CNG. There are trade offs in comparing CNG and LNG, such as energy density, transportation and distribution costs to consumers, and vehicle fueling and storage. Currently, CNG is primarily being considered for cars and buses whereas LNG is being considered primarily for large trucks and locomotives.

There is new promise for future commercialization of a process for converting natural gas to dimethyl ether (DME) via the syngas route. A group of companies recently announced that DME is a good diesel fuel because of its high cetane number and low emissions.

In summary, methanol, MTBE, CNG and DME currently appear to be the most attractive forms of transportation fuels that can be made from natural gas. At this stage, production of Fischer-Tropsch liquids, gasoline by direct conversion and C_1-C_6 alcohols are less attractive alternative methods of converting natural gas to transportation fuels from an economic standpoint.

11.2. Comparative Economics -- Chemicals and Power Production

In sections 9.1 - 9.6, economic summaries were given for a variety of ways to convert natural gas into chemicals and power. The production costs for these processes will now be compared with market prices, the economics of using low quality gas will be shown and recommendations will be made about the potential attractiveness of doing further research on these processes.

Exhibit 11-2 compares the cost of producing chemicals and power shown in Sections 9.1, 9.2, 9.3, and 9.6, with prices for chemicals and power taken from price projection tables. All costs and prices are U.S. Gulf Coast, December 1993 except for ammonia market prices. Product costs are based on building grassroots plants.

Exhibit 11-2.

Name of Product	Section Showing Product Cost Economics	Cost of Producing Product	Actual Market Price
Methanol	9.1	$0.44/gallon	$0.43/gallon
Ammonia	9.2	$240/ST	$140-145/ST (10/93) $230-232/ST (10/94)
Power by Combined Cycle	9.3	$0.037/kWh	$0.049/kWh
Methyl Chloride	9.6	$116/Ton	$0.335/lb

Exhibit 11-3 shows the value of the low quality natural gas when producing methanol, ammonia and power (Sections 9.1, 9.2, and 9.3). The LQNG contained 13% nitrogen. The value of the LQNG was calculated assuming the same product prices estimated for comparable plants which use high quality natural gas feed costing $2.43/million Btu. In addition, the price of low quality gas is shown when using it as a feedstock in a cryogenic nitrogen rejection plant to get high quality natural gas priced at $2.43/million Btu.

Exhibit 11-3.

Product Made Using LQNG Feed	Value of LQNG When Alternative High Quality Gas is 2.43 $/MMBTU
Methanol	2.27
Ammonia	2.24
Power by Combined Cycle	2.32
High Quality Natural Gas by Nitrogen Rejection	1.71

The potential for increased gas use in each of the markets will be determined by the economics given above and by growth in domestic production of the product. In the case of methanol, the economics of producing methanol using domestic gas as a feed is estimated to be competitive with foreign produced methanol, and additional methanol capacity additions are expected. Methanol demand growth in the U.S. has been very strong because of the mandate to provide oxygenated and reformulated gasoline. The rate of growth in U.S. methanol demand will decrease after 1995, but will still be sufficient to provide for increased gas use.

The U.S. demand for ammonia has been stagnant and the US production cost for a new facility are not competitive compared to imported ammonia. Increased use of natural gas for ammonia production is unlikely. The possible use of methane as a feedstock for ethylene production was reviewed. Production of ethylene is an intermediate step in some of the processes for producing gasoline and diesel from methane. In fact the economics of producing ethylene appear to be more attractive than going the second step of conversion to gasoline. The research on methane to ethylene has shown some promise but conversion and selectivity have not yet achieved levels to be competitive with use of gas liquids for ethylene production.

The use of natural gas for power generation has been growing in both the industrial and power sectors. Gas based power costs are extremely competitive, gas is environmentally attractive, and gas-based generators have great size flexibility. Future growth is occurring and will continue as long as gas's future price picture remains as bright as it is now.

Methyl chloride can be produced from natural gas but the production process, oxyhydrochlorination, is still in the research stage. Methyl chloride has a fairly small market demand but the oxyhydrochlorination process has added importance, since in a second process step transportation fuels can be produced. More work is needed to bring the methyl chloride manufacturing cost down. The market price of methyl chloride is six times the cost of producing it probably because its current price is based on production of small quantities.

11.3. Potential For Increased Gas Use

At present about 200,000 B/D of MTBE is being produced. This is made from methanol and butanes with the methanol being produced using natural gas as a feedstock. At present, MTBE and relatively small amounts of CNG and methanol comprise the total amount of transportation fuels made from natural gas.

This situation may change. Dimethyl ether (DME) is potentially useful as a new and superior diesel fuel. Compressed natural gas (CNG) is being demonstrated for use in fleet use as a clean burning fuel. Also methanol may increase in usage because of its environmental advantages. All of these would be made starting with natural gas. If by the year 2010 a total of 1,000,000 B/D gasoline and diesel is replaced with gas derived fuels consisting of MTBE, DME, CNG and methanol, approximately 1.6 trillion cubic feet of natural gas per year would be used.

11.4. Estimated Employment Generation of a Gas-to-Liquids Industry

As has been described, some natural gas-to-liquid processes are already competitive with crude derived products and other processes may reach that state with additional research and development effort. When those processes are economically competitive with crude based products, that is, there are no subsidies, then there are favorable economic benefits to the American consumer. When gas derived products produced from domestic gas replace crude derived products, then they have a beneficial impact on the U.S. trade balance.

Construction of gas conversion process facilities will result in employment benefits of creating jobs that are well above average in wages and salaries. The process industries are among the most capital intensive of the manufacturing industries and wages are relatively high. According to API statistics [140] in 1992, the U.S. refinery industry employed 118,919 workers to produce approximately 14.8 MMB/D of products or about 8 workers per thousand barrels per day of product.

By 2010 DOE's Energy Outlook [8] forecasts that U.S. demand for transportation fuel will increase by about 3 million barrels per day. If it is assumed that all of that increased demand were met by gas derived products, an estimate of the increase in process industry employment could be developed. Based on the economic analysis of this report, methanol and MTBE facilities would require only about 80-100% of the total employment of the average U.S. refinery on a per product barrel basis and a Fischer-Tropsh plant would require about 2 times the refinery employment. For new gas-to-liquid facilities, we have estimated that an average of 10 employees for a thousand barrel per day of production would be required. For 3 million barrels of incremental production, the total new process employment would be 30,000 employees. These higher paying jobs in the process industry would also indirectly create additional employment in the plant areas through the multiplier effect.

11.5. Potential Improvements and Cost Reductions for New Gas to Liquids Projects

The natural gas to liquids projects discussed in previous sections are in various stages of development. Some processes such as direct conversion of methane to gasoline via oxidative coupling and conversion of methane to higher alcohols are in the research stage. Other processes such as conversion of methane to methanol and MTBE are established commercial projects with numerous plants. In this section, some guidelines are provided to show what might be expected to happen to costs as a process is developed and commercialized.

Rand made an extensive study of cost growth in pioneer plants [141]. They looked at information supplied by 34 firms and covered pioneer process plants through R&D, project definition, engineering/construction and start-up. Results showed that the ratio of estimated costs to actual costs ranged from 49% in the R&D stage to 93% in the construction stage. Most of the variation in cost-estimation error can be explained by (1) the extent to which the plant's technology departs from that of prior plants, (2) the degree of definition of the project's site and characteristics and (3) plant complexity.

Rand also did several studies to show the improvement cost obtained by building a number of plants patterned on a first-of-a-kind process plant [142, 143]. When they compare costs of a second plant with costs of a first-of-a-kind plant, their results showed that with respect to overall unit product cost/price, the effective range of improvement appears to be between 5 and 40 percent with a norm between 20 percent and 30 percent. Improvements in design and construction cost accounts for a 5 to 10 percent decrease in costs. Improvements in plant performance with successive plants is also a significant factor. An illustration is the three SASOL plants. SASOL I took 4 to 5 years to reach 75 percent of design capacity, SASOL II took 2 years to reach 75% of design capacity and SASOL III reached 90% of design capacity in nine months. The best improvements in costs of successive plants resulted from use of the knowledge of the owner-operator and his experienced personnel and taking time to fully analyze the operation of the first plant before building the next plant. Another factor resulting in maximizing cost improvements in successive plants is based on maintaining similarity between the pioneer and follow-on plant.

Section B.5.3 of Volume I of the EPRI TAG Manual [144] is generally in agreement with the results of the Rand study. Figure B.5.1 shows capital costs/unit of capacity versus time. It shows that the capital cost based on incomplete data is about 30% of the actual capital cost of the first plant whereas capital cost for a plant available for commercial order is about 75% of the actual cost. After building the first plant, the third plant built would cost about 75% as much as the first plant and the fifth plant would cost 50% as much as the first plant. Not much change in plant cost is expected after building the fifth plant.

These studies may be used as a guide in making decisions about the development and demonstration of new processes. If the costs for a new process at the engineering/construction are 25% above the costs for a mature competitive process, it is probably advisable to build a first-of-a-kind plant. Later plants for the same process can be built at significantly lower costs and can reach capacity more quickly and thus compete with the mature process. It is therefore justified for government to subsidize and sponsor the building of such a plant.

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