Emerging Energy and Chemical Applications of Methanol: Opportunities for Developing Countries

EMERGING ENERGY AND CHEMICAL APPLICATIONS OF METHANOL: OPPORTUNITIES FOR DEVELOPING COUNTRIES

April 1982

ISBN 0-8213-0018-0

ABBREVIATIONS AND ACRONYMS USED

Btu	-	British Thermal Unit
CNG	-	Compressed Natural Gas
DCF	-	Discounted Cash Flow
DMT	-	Dimethyl Terephtalate
LNG	-	Liquefied Natural Gas
LPG	-	Liquid Petroleum Gas
MMBtu	-	Million British Thermal Units
MON	-	Motor Octane Number
MTBE	-	Methyl Tertiary Butyl Ether (high-octane gasoline additive)
MTG	-	Methanol-to-Gasoline Process
RON	-	Research Octane Number
SCP	-	Single-Cell Protein
TAME	-	Tertiary Amyl Methyl Ether (high-octane gasoline additive)
TBA	-	Tertiary Butyl Alcohol (gasoline additive)
tpd	-	Tons per Day
tpy	-	Tons per Year

EMERGING ENERGY AND CHEMICAL APPLICATIONS OF METHANOL: OPPORTUNITIES FOR DEVELOPING COUNTRIES

SUMMARY AND CONCLUSIONS

i. Methanol, or methyl alcohol as it is also called, is among the major basic chemical raw materials produced today. It is manufactured through a well-established chemical process based predominantly on natural gas, with a limited part of world capacity based on naphtha and residual oil. The renewed interest in methanol originates in the rejuvenation of its traditional market through the recent development of new chemical applications and, foremost, in its emergence as one of the major synthetic fuel options for reducing dependence on petroleum products.

ii. Methanol's prospects as a fuel are often discussed in relation to the possibility of eventually producing coal-based synthetic fuels on a large scale in developed countries. Due to a number of technical and economic considerations--pertaining primarily to the status of coal processing technology and to the large size of economic coal-based methanol units--it seems unlikely, however, that large-scale production of coal-based methanol will be initiated in developed countries before the end of the 1980s at the earliest. In contrast, many developing countries possess significant amounts of natural gas; frequently, the surplus availability and/or lack of economic transportability of the gas causes it to have an economic value below that which calorific equivalence with petroleum products would normally dictate. Methanol could therefore be economically produced in these countries based on plant sizes significantly smaller than those necessary for coal-based methanol production, in step with the development of the world methanol market.

iii. This report reviews the major chemical and, particularly, fuel applications of methanol as a basis for projecting the minimal methanol market size during the 1980s. It concludes that there is a significant potential for additional methanol capacity in those developing countries that possess low-cost gas resources. This additional capacity would be geared primarily to exports of methanol or methanol-based fuel products to the more industrialized countries, with some potential for fostering domestic methanol fuel uses in a limited number of these developing countries. This paper complements another World Bank report entitled Alcohol Production from Biomass in the Developing Countries (published in September 1980) which contains a review of the chemical and, particularly, fuel applications of ethanol, and of its production potential from renewable biomass sources in developing countries. The latter report focused on agriculturally rich but oil-poor countries; the emphasis in the present report is on gas-rich, yet in most instances, oil-poor developing countries.

iv. In terms of its applications, methanol is a particularly versatile product. More than 95% of today's world methanol market is in chemical applications; this includes traditional uses of methanol as a solvent and as a raw

material for a wide variety of other chemicals, as well as recently established uses of methanol as a raw material for acetic acid and single-cell protein (SCP). As a fuel, methanol has potential for being used in spark-ignition engines and for a variety of other purposes, including in compression-ignition (diesel) engines and in a number of industrial and household fuel applications. A more detailed summary of the various chemical and fuel uses of methanol along with an assessment of their general prospects is given in Table 2 on page 9.

v. The basic technology for producing methanol from natural gas is well established and has been improved upon to a point where no major breakthroughs in process efficiency or train size are expected. Typical plant sizes are 1,000 tons per day (tpd) to 2,000 tpd and a number of efficient designs are available. The level of difficulty involved in constructing and operating such plants is less than with many other chemical plants. Of particular interest for methanol production is the floating plant concept, which may enable a number of the developing countries to exploit offshore gas resources with little or no alternative economic uses.

vi. Methanol can be produced from a number of raw materials including natural gas, naphtha, residual oil and coal. The technical capability to produce methanol from renewable wood or biomass waste resources on an industrial scale, although in part demonstrated, is still not commercially developed and is not likely to be able to compete with ethanol production from these sources if one considers ethanol's more favorable end-use economics. Due to technical and economic considerations, natural gas will continue to be the dominant basic raw material for methanol production during the 1980s.

vii. World consumption of methanol as a chemical is projected to grow at an average annual rate of 4.8% from 10.1 million tons in 1979 to 17 million tons in 1990. The share of the developing countries would remain essentially unchanged at 8% to 9% of world consumption. These projections are based on: (i) modest but steady growth of the traditional chemical markets of methanol, in line with general economic growth; and (ii) significant growth in recently established chemical uses of methanol, i.e., its use as a raw material for acetic acid and SCP.

viii. World consumption of methanol as a fuel is projected to grow at a rapid pace from about 350,000 tons in 1979 to about 6 million tons in 1990, thus increasing its share of the total methanol market from 3% in 1979 to about 25% by the end of the decade. This projection is conservative, since it takes into account only two of the various fuel applications of methanol reviewed herein, both of which are spark-ignition engine uses, namely: (i) methanol as a raw material for high-octane gasoline additives such as methyl tertiary butyl ether (MTBE); and (ii) methanol in low-level methanol/ gasoline blends (i.e., with only a small percentage of methanol to avoid the need for changes in vehicles and in the distribution system). In these two fuel applications, methanol is most likely to have an economic value at par with, or in excess of, projected world methanol prices. A detailed summary of the potential and relative economics of various fuel applications is given in Figure 4 on page 54.

ix. The use of methanol as a raw material for MTBE (and for other similar octane-boosting additives) appears to be, by far, the most attractive fuel use.

MTBE is produced from methanol and from a coingredient, isobutylene, which is a byproduct in certain refinery or petrochemical operations, or which can be produced directly from butane or butylene. The analysis made in this report shows that the economic value of methanol as a raw material for MTBE exceeds the present and projected methanol market prices by a significant margin; this is true even in cases where additional isobutylene would have to be produced because byproduct isobutylene is unavailable. While this margin is projected to increase with further real term energy and gasoline price escalation during the decade, it was significant enough even at 1980 price conditions to warrant a rapidly increasing market for methanol in that use. In terms of MTBE demand projections, it has therefore been assumed that all the available byproduct isobutylene will be essentially exhausted during the 1980s; this will lead to a base MTBE production of about 5 million tons by 1990, with corresponding methanol requirements of 2 million tons. With respect to MTBE production capacity from additional isobutylene, it is projected that another 2.5 million tons will be added between 1985 and 1990 based on additional isobutylene production, for instance, from normal butylene in the U.S. and Europe and from normal butanes in possible methanol/ MTBE complexes in the Middle East and in the Far East. This would require another 1 million tons of methanol by 1990. These assumptions, which are meant to illustrate a minimum development, are reflected in the overall methanol projections presented in this report.

x. Low-level methanol/gasoline blending (up to 4% to 5% methanol) appears to be the next most attractive methanol use, with its currently somewhat marginal attractiveness improving with real term gasoline price escalation to a point where it would be expected to develop quite dramatically during the 1985-90 period. To be on the conservative side, it is assumed that this use would gradually develop from its small current base to an average 0.5% of the total gasoline consumption in 1990 in Western and Eastern Europe, North America and Japan. This assumption is also reflected in the projections presented in this report.

xi. The analysis presented in this report indicates that neither high-level methanol/ gasoline blending (up to 15% to 20% methanol) nor use of straight methanol in spark-ignition engines is likely to become economically attractive before the later part of the 1980s (with straight methanol use having an edge over blending use in economic terms), and only if gasoline prices do indeed increase significantly in real terms over the decade. These are, however, types of uses where considerations of security of supply and of diversification away from imported petroleum, rather than economics alone, might lead a few developed countries to decide to go ahead with such programs on a relatively large scale. At this time, a number of countries are involved in investigations to determine the feasibility of developing such uses during the 1980s; these include a number of Western European countries, in particular, Germany and the Scandinavian countries; a few Eastern European countries; the U.S; and some developing countries such as Brazil.

xii. While it is difficult to predict the outcome of these investigations, the analysis contained in this report shows that high-level methanol/ gasoline blending appears to be less attractive an option than low-level blending on one hand and straight methanol engine use on the other.

Compared with low-level blending, high-level blending is at an economic disadvantage, due to the vehicle and distribution system changes which would be necessary, particularly if part of the fleet would have to be custom-retrofitted (as opposed to assembly-line engine preparation). Furthermore, high-level blending cannot be expected to entail benefits significant enough, in terms of diversification and security of fuel supply, to warrant a de-emphasis of its economic disadvantage. No allowance has, therefore, been made for high-level methanol/gasoline blends in the overall methanol market forecast presented in this report, particularly in the absence of a definitive commitment by any of the above mentioned countries to go ahead with such blends. Straight methanol (85% to 100% methanol) spark-ignition engine uses, on the other hand, would require much larger tonnages of methanol and hence would imply a much more significant element of diversification away from petroleum, besides being a somewhat more economic use of methanol. Due to the lead time required for the large-scale manufacture of straight methanol engines (custom-retrofitting existing cars is not considered economic), the corresponding methanol requirements may become significant only toward the end of the 1980s. To be conservative, the corresponding methanol requirements were therefore ignored, but this should not detract from the basic finding that straight methanol engine uses might be attractive by that time.

xiii. The use of methanol as a raw material for gasoline appears to have an economic advantage over its use in high-level methanol/gasoline blending or straight methanol engines only in cases where custom-retrofitting of vehicles would be required. Even so, the production of gasoline from methanol will not generally be economic if one compares the value of methanol in this use to the market price range of methanol tentatively projected in this report. Although there might be exceptions to this in unusual circumstances, e.g., in a landlocked country, no allowance has been made for demand for methanol as a gasoline feedstock in the overall market projections.

xiv. The prospects for methanol fuel applications outside spark-ignition engine uses (i.e., outside the replacement of gasoline) are limited. Whereas methanol possesses good combustion characteristics in the spark-ignition type of engines, it has major technical drawbacks as a diesel substitute in compression-ignition engines and this use of methanol is not expected to be economic except perhaps for limited applications. Its use as a boiler or furnace fuel to replace fuel oil or natural gas does not exploit methanol's potential as a superior liquid fuel and is generally not economically attractive. It is still uncertain whether other considerations, such as for example methanol's lower pollution levels when applied to peak power generation in congested areas, will enable some of the latter uses to develop on a large scale. Again, no allowance has been made for these applications in the market projections.

xv. Based on the above projections for methanol demand in chemical and fuel applications, overall methanol supply and demand projections have been prepared. They imply an average annual growth rate of 7.5% for world methanol demand between 1979 and 1990, leading to a projected world consumption level of 23 million tons by 1990. Based on capacity projections reflecting projects under implementation or deemed to be firmly planned, a surplus effective capacity of about 3.25 million tons is projected for 1985 followed by the rapid emergence of a supply deficit of more than 2.5 million tons in 1990. This

would call for the installation by 1990 of at least 3 million tpy of additional nameplate capacity over and above the new capacity already included in the supply forecast. Less conservative assumptions with respect to MTBE and low-level methanol/gasoline blending, or the assumption of an even minimal development of straight methanol engine use before 1990, would significantly increase the supply deficit figure projected for 1990.

xvi. The breakdown of these projections by major regions indicates that the net interregional methanol trade will increase from less than 250,000 tons or 9% of world consumption in 1979, to about 4.5 million tons or 20% of world consumption in 1990. The U.S., Western Europe and Japan will become very large importers, with Canada, Mexico and the Middle East emerging as the largest exporters. It is likely that a significant spot market for methanol will develop.

xvii. Many developing countries possessing low-cost gas resources would be in a good position to produce methanol economically and help meet the world methanol deficit projected for the end of the 1980s. There are some three dozen gas-rich developing countries, of which six or so are able to use a significant share of their total gas production domestically. In many locations in these countries, gas is available in surplus quantities with no or limited opportunity for substituting it for fuel oil in the domestic economy, or with prohibitively expensive pipelining and distribution costs due to the remote, or offshore, location of the gas source. As most of this gas is methane, there are only few alternative uses for it short of non-exploitation, flaring or reinjection. The gas can be used among others in the production of: (i) ammonia and ammonia-based fertilizers; (ii) methanol and methanol-based products; and (iii) liquefied natural gas (LNG) for long distance transportation to receiving markets. In such situations, the economic value of the gas for use in methanol production can range from zero to US$2.5 per thousand cubic feet (or per million Btu) at 1980 prices. The exact economic value of the gas depends on whether LNG offers an alternative use for the gas or not, and on the characteristics of such and other alternatives (small or large size LNG scheme, higher or lower degree of attractiveness of ammonia production, and other considerations). This range of economic values of gas, to which the generally small incremental cost of connecting the methanol project to the gas source needs to be added, is low enough to offset the capital cost penalties that are incurred in many developing country locations as against the traditional, developed country sites hosting methanol plants. A number of developing countries should, thus, be able to implement methanol projects with attractive economic returns, at production costs that are competitive with those of new entrants from developed countries.

xviii. The scope for domestic methanol consumption in developing countries is relatively limited in the immediate future, except in a few developing countries. Hence, most new methanol projects in developing countries will initially have to be entirely or predominantly export-oriented. The main chemical application of relevance to developing countries is formaldehyde production, particularly in regions where wood processing is well developed and is a growing industry; some developing countries might also have limited markets for methanol as a solvent and as a raw material for acetic acid and

other chemicals. The use of methanol as a raw material for SCP, or as a basic petrochemical raw material, might become important in the long run in a number of developing countries that are rich in methane gas and have large internal markets for protein, or for certain petrochemical products which cannot be produced locally for want of ethane or other economically attractive petrochemical raw materials.

xix. Among the domestic fuel applications of methanol, low-level methanol/ gasoline blending would not amount to significant tonnages in most developing countries. As to high-level methanol/gasoline blending and straight methanol use in spark-ignition engines, only a few developing countries within the group of gas-rich countries have a gasoline market of a size that is adequate enough to justify the large-scale development of these uses, with all their logistical implications. Moreover, few of these countries possess a domestic automobile industry, so that adjustments or modifications of vehicles for methanol/gasoline or straight methanol use would have to be effected on a custom basis, with costly penalties. In many developing countries, the demand for petroleum distillates is heavily skewed toward middle distillates like diesel (automotive and industrial) and kerosene; the lighter ends, particularly gasoline, and fuel oil are generally in a balanced, or often surplus, supply situation. This makes the use of methanol in substitution of diesel and kerosene very desirable to help meet a gas-rich country's middle distillate requirements. Unfortunately, as mentioned earlier, these types of methanol uses are generally not economically attractive, particularly for automotive uses. However, it is felt that industrial diesel substitution in diesel engines operating under more or less constant speed and load conditions (requiring less costly retrofitting) warrants further study in oil-poor developing countries which might envisage methanol production from low-cost gas. This also applies to household kerosene substitution through methanol, or methanol/kerosene blends.

xx. As mentioned in several sections in the report, certain fuel applications of methanol are of special interest in landlocked or remote locations or countries. In such situations, the import cost of petroleum products is high due to the high cost of transporting these products over long in-land routes to their destination. All things equal, this would improve the economics of certain local fuel applications of methanol, such as its use as a raw material for gasoline, or as a substitute for kerosene and diesel, provided methanol can be produced at an acceptable cost in these locations.

xxi. In most cases, the main justification for methanol production in developing countries will, however, have to rest on the methanol export potential, with the prospects for the development of domestic chemical and fuel uses playing, perhaps, an important, but probably a not economically crucial role. The world market projections presented earlier appear to show significant room for increased methanol trade and exports, particularly beyond 1985. Since it would take a minimum of four to five years to plan, design,

and implement additional methanol plants in developing countries, the feasibility of predominantly export-oriented projects to be located in developing countries should be studied in the near future. The capacity and supply projections presented above already include relatively firmly planned, mainly export-oriented, methanol projects in such developing countries as Mexico, Trinidad and Tobago, Argentina, Indonesia, Taiwan and Bahrain. Further locations where possible methanol projects could be considered include Brunei, India, Bangladesh, Thailand, Colombia, Chile, Nigeria, Egypt and many others.

xxii. The analysis in this report has shown MTBE to be, by far, the most attractive use of methanol; this is so even in the case where the other MTBE ingredient, isobutylene, is not available as a byproduct of a refinery or petrochemical operation and where it would hence have to be produced from butane or butylene. Gas-rich developing countries with enough natural gas to justify LPG (butane, propane) separation plants, e.g., India and Thailand, should give careful consideration to methanol/MTBE production from natural gas for export purposes. These types of projects are likely to yield substantial economic returns and provide greater assurances that the full output could be marketed at an attractive price than in the case of methanol exports per se.

xxiii. From a government policy standpoint, developing countries interested in implementing methanol projects should pay particular attention to the investment policy and gas pricing framework. In many cases, joint ventures should be considered between a local, public or private sector entity and a foreign partner also involved in methanol or MTBE marketing. In some cases, there can be merit to gas pricing alternatives under which the pricing is adapted in a flexible way to the specific conditions of each project rather than attempting to fix ex ante an overall gas price; formulas with a low basic gas charge complemented by a device to recoup part of the profits could be one possible approach to achieve this. Governments should also insist that the sponsors of methanol or MTBE projects obtain firm offtake agreements for the bulk of the exportable output, under offtake price conditions following as much as possible international methanol or MTBE prices. Government-sponsored methanol research and testing programs should also be launched in parallel with the implementation of methanol projects to develop domestic fuel applications of methanol. Wherever possible, joint venture or export offtake agreements with a developed country engaged in a methanol fuel program should provide for assistance to the exporting developing country in promoting its own domestic methanol fuel applications.

xxiv. The World Bank can play an important role in assisting the developing countries in: (i) evaluating the potential, prospects, and viability of methanol or MTBE production; (ii) evaluating the prospects and assisting in the implementation of necessary research and pilot test programs for local fuel applications of methanol; (iii) developing appropriate policy measures, particularly on gas pricing and the sharing of benefits between the country and the foreign partner in joint-venture cases; and (iv) attracting foreign partners and/or foreign financing for the implementation of methanol or MTBE projects under the umbrella of its own financial participation. Initial work so far in a number of countries indicates that assistance from agencies such as the Bank is needed in these areas.

xxv. The Bank's decision at this time to actively support economically justified methanol projects will concentrate on a few countries. Even if active Bank support is limited to methanol programs in a few selected countries, it may encourage exploitation of this potential in a larger number of countries. The Bank can also facilitate transfer of experience with methanol programs among its member countries. Finally, this new area of activity will complement increased Bank lending for the development of conventional energy sources such as petroleum, gas, coal and hydroelectric power.

EMERGING ENERGY AND CHEMICAL APPLICATIONS OF METHANOL: OPPORTUNITIES FOR DEVELOPING COUNTRIES

This report was written by J.F. Rischard with the assistance of other staff of the Industry Department.

TEXT TABLES

TEXT FIGURES

EMERGING ENERGY AND CHEMICAL APPLICATIONS OF METHANOL: OPPORTUNITIES FOR DEVELOPING COUNTRIES

Chapter I: INTRODUCTION

1.01 Methanol, or methyl alcohol as it is also called, is among the half dozen major basic chemical raw materials in use today. It is produced through a well-established chemical process and is used as a solvent and chemical intermediate for the production of a large range of chemical products with applications across a variety of industries. While more than 80% of world methanol capacity is based on natural gas, methanol can be, and in fact is being, produced from other raw materials such as naphtha, residual oil and coal.

1.02 In the past, methanol was obtained in limited quantities through the distillation of wood (hence its familiar name of wood alcohol) and had a number of fuel applications. It was a well-established household fuel in certain parts of Europe during the last century and was one of the first fuels for internal-combustion engines. The availability of low-cost petroleum distillates put an end to these applications, and by the time a chemical process for the production of methanol was commercialized in the early 1920s, methanol was already being used primarily as a solvent and chemical intermediate. As a result of the introduction of this chemical process, methanol became available in much larger quantities, and world consumption grew from less than 150,000 tons per year in the mid-1920s to its current level of 10-11 million tons.

1.03 Starting in the early 1970s, several developments have significantly altered the prospects of methanol. Its traditional market has been rejuvenated by new chemical applications as a raw material for acetic acid, for methyl tertiary butyl ether or MTBE (a high-octane gasoline additive) and more recently, for single cell protein (SCP). Recent findings also suggest that methanol might become a raw material for a number of other chemicals currently made from other sources.

1.04 In parallel developments, investigations into the merits of methanol as an automotive and power-plant fuel have been undertaken during the last ten years. These investigations were motivated by growing concerns about the need to develop alternative fuels and about air quality, in regard to which methanol possesses certain distinct merits. Most importantly, there has been a dramatic change in the price relationship between methanol and petroleum products over the last decade. This change has come mainly as a result of the combined effects of significantly improved plant scale and process efficiency characteristics of methanol plants built since the early 1970s, and of the more than tenfold increase in petroleum prices. This price relationship is now such as to add an economic incentive for the renewed use of methanol as a fuel.