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METHANOL, NATURAL GAS, AND THE DEVELOPMENT OF ALTERNATIVE FUELS

M.L. Kliman

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A-2361 Laxenburg, Austria

ABOUT THE AUTHOR

Dr. Melvin L. Kliman is Associate Professor in the Department of Economics, McMaster University, Hamilton, Ontario, Canada. When this paper was written he was an Associate Research Scholar in IIASA's Energy Systems Group.

PREFACE

This study arises out of two conclusions of IIASA's global energy study, Energy in a Finite World (Energy Systems Program Group 1981): (a) that a gap will emerge between the total demand for liquid fuels and the amounts supplied from conventional oil resources, with the difference made up by synthetic fuels; and (b) that natural gas reserves are abundant enough to play a greater role in world energy supply. There is a link between them because natural gas is a possible source of liquid fuel.

Methanol produced from natural gas, liquefied natural gas, and compressed natural gas can be and have been used as fuels for motor vehicles and other machines. Of these methanol appears to offer the most promise. The purpose of this paper is to explore the possibility that this option will help to fill the expected fuel gap.

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1. ALCOHOLS AS MOTOR FUELS

Alcohols are attractive as alternatives to oil based fuels because they are potentially abundant, flexible in both production and use, and relatively more compatible with the existing fuels system than other alternatives.* Other choices, such as liquefied natural gas (LNG), compressed natural gas (CNG), liquefied petroleum gas, hydrogen and vegetable oils, are lacking in one or more of these attributes and consequently do not, with the present state of technology, have the potential for a large impact on fuel supply in the way that alcohols do. For instance, while liquefied petroleum gas is already a proven commercial fuel for motor vehicles, its supply is physically limited to small proportions of the total petroleum and natural gas output.

The two alcohols most appropriate for use as fuels, methanol and ethanol, can be produced from a variety of feedstocks. Methanol can be derived from any substance that can be thermally

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*For summaries of technical information on the use of alcohols as fuels, see (Goodger 1975:220-6, Russell 1980, and Committee of Common Market Automobile Constructors 1980). For detailed information on recent developments, see the Proceedings of the Fourth International Symposium on Alcohol Fuels Technology, Guaruja-SP-Brazil, October 1980 (hereafter referred to as Brazil Conference 1980) and the Proceedings of the Fifth International Alcohol Fuel Technology Symposium, Auckland, New Zealand, May 1982 (hereafter referred to as Auckland Conference 1982).

decomposed into synthesis gas, i.e., a mixture of hydrogen and carbon oxides. Most current production is from natural gas, but in the context of a scenario for alternative fuels, coal, wood, and heavy crude oils are also relevant sources. As an alternative fuel, ethanol is produced by the fermentation of biomass, either from crops grown for that purpose or from wastes generated by the use of crops in other processes.

Since large reserves of both natural gas and coal are available and renewable feedstocks can also be used, alcohols can be considered for use under circumstances that differ widely through time and space. An obvious approach is to see natural gas as the basis of the initial development of an alcohol fuels market, with coal and renewable feedstocks to be phased in slowly when relative price changes make them more efficient. With such a scenario, alcohol fuels would be sustainable into the indefinite future. A variation on this would recognize the desire in many countries to reduce their dependence on imported energy. The variety of available feedstocks for alcohols offers them some help in the near term as well: if they do not have gas reserves, biomass or domestic coal could be used sooner.

A number of advantages make alcohols more compatible with the existing fuels system than other alternative fuels, though considerable adjustment would still be required if they are to be consumed in more than token quantities. A key advantage is that they can be used either as a separate fuel or in a blend with gasoline. In low-ratio blends they can be burned in vehicles designed for gasoline with little or no change. The maximum proportion of alcohol that can be used without vehicle conversion is not widely agreed upon, partly because it is influenced by local conditions (e.g., climate), and by the performance standards demanded. It can be thought of as lying in the 5-10 percent range. A Swedish report, for instance, claims that blends up to 5 percent "...do not significantly influence the driveability or volumetric fuel consumption of the existing European car population" (Auckland Conference 1982, Vol. 3:253). In the United States, a blend of 10 percent ethanol and 90 percent gasoline has already been marketed in some mid-western states (Auckland Conference 1982, Vol. 3:287).

Focusing specifically on methanol, a number of advantages and disadvantages will play a role in its prospects for adoption. When added to gasoline, it increases octane levels and is a de-icer. Its use would reduce the emission of air pollutants from automobiles (except for aldehydes, which would increase in the absence of special preventive measures). Work is also being done on the use of methanol in diesel engines. Its chemical properties are less suitable in the case of compression ignition engines, however, and the substitution of methanol for gas-oil may not be a practical prospect.

If methanol blends at concentrations higher than 5-10 percent are used in existing vehicles, or even if low-ratio blends are used in cold weather or under other adverse conditions, problems are encountered. Methanol corrodes some materials now used in vehicle fuel systems, separates from gasoline under water contamination, and can cause vapor lock (an interruption in the fuel flow). Cold weather starting is made more of a problem when methanol is used. Larger fuel tanks are necessary for pure methanol or high ratio blends because it contains less energy per unit volume. This disadvantage is partially offest, however, because it burns more efficiently in internal combustion engines than gasoline. Its higher thermal efficiency is sufficient to compensate for its lower energy content up to a point; and, as the Swedish report cited above indicates, some argue that in low-ratio blends methanol can replace gasoline on a 1:1 basis by volume without significant power loss. (For simplicity it will be assumed here that a 1:1 replacement is adequate in blends of 10 percent or less. This may be an overestimate.)

Since methanol is more toxic than gasoline and can be ingested through the skin its widespread use would require some changes in the handling of fuels. The fighting of fires would also be affected because methanol burns differently from oil-based fuels.

Some of these difficulties are easily overcome, while others are more serious obstacles to using high-ratio blends or pure methanol. Much research and development is underway to deal with them, however, and there is no suggestion in the literature that any of the problems relating to spark ignition engines are insurmountable.

2. NATURAL GAS AND METHANOL IN A TRANSFORMED FUELS SYSTEM

Since the link between natural gas and methanol is of particular concern here, it will be useful to have an overview of the interaction between the natural gas system and a hypothetical alcohol fuels system. This is summarized in a simplified flow chart in Figure 1. The horizontal boundaries in the chart are meant to suggest simultaneously different stages of production and roughly-defined geographical categories.

Level A refers to primary extraction and processing, and is usually geographically distant from the points of consumption (level D). Since natural gas is expensive to transport, the average distance involved has historically been short by comparison to that associated with oil. It is growing rapidly, however, as natural gas reserves more remote from the major markets are now being exploited. This has important implications in the present context, for methanol presents itself as a possibly efficient way to carry natural gas energy over long distances, especially where bodies of water must be traversed. Currently this is done by under-sea pipelines for short distances and by liquefied natural gas over long distances. LNG is relatively cheap to produce in energy terms, but is expensive to transport and store at the receiving end. More energy is used up in producing methanol, but it can be transported cheaply in ordinary tankers. (Estimates of the energy losses in production vary.

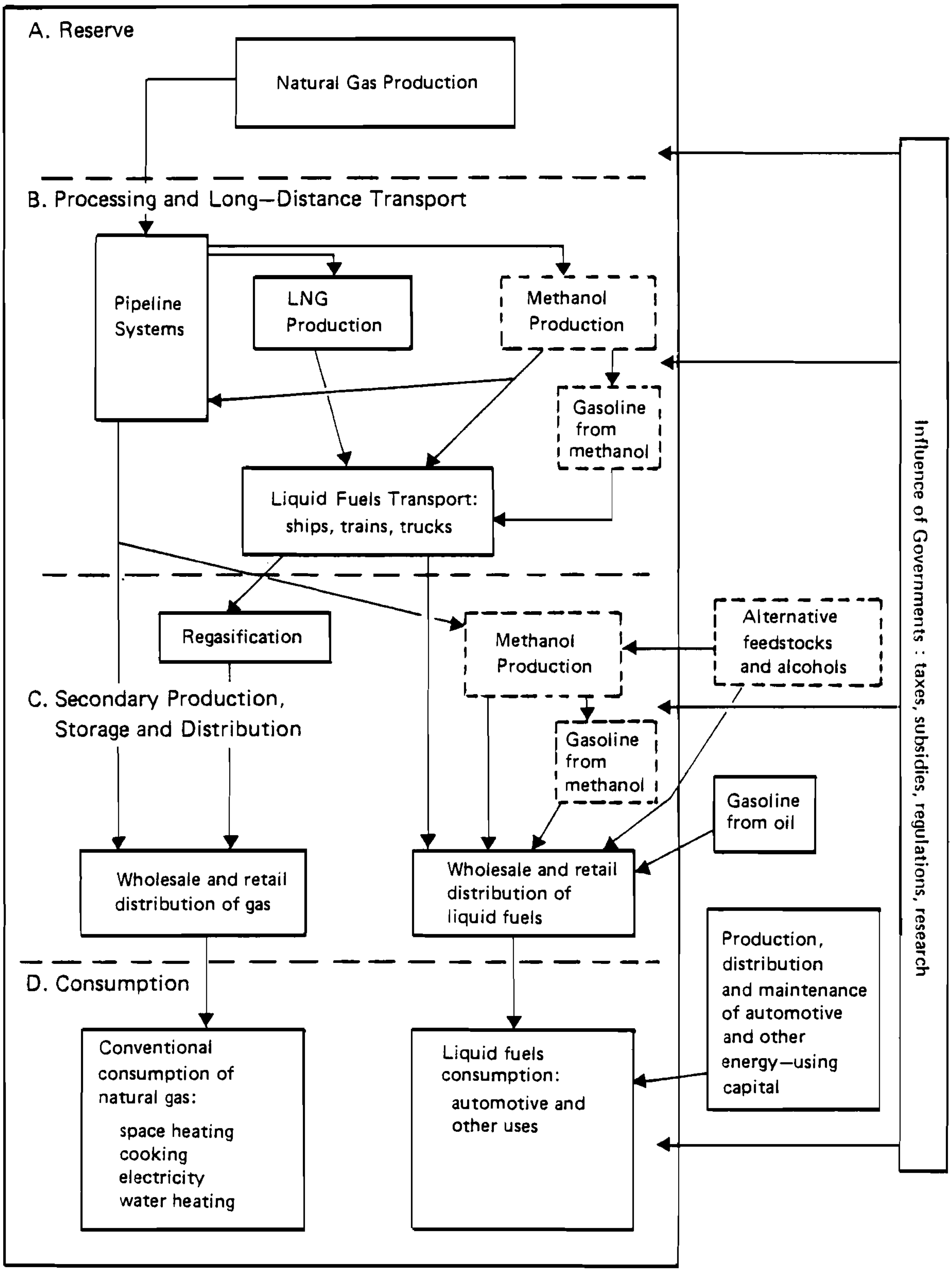

Figure 1. Natural gas in a hypothetical liquid fuels system including methanol.

A textbook on natural gas sets them at 25 percent for LNG and 40 percent for methanol (Tiratsoo 1979:327), though much lower losses are sometimes quoted in both cases.) Thus there are some combinations of natural gas prices and transportation distances for which methanol is the cheaper carrier. This is further explored in Section 5.

These considerations explain why a box for methanol production appears in both levels B and C of the flow chart. Level B refers to the transportation of gas energy from its source to a receiving point in the population center where it is to be used. In the existing system pipelines and LNG compete to carry it. In the hypothetical system conceived of here methanol becomes a third competitor.* Level C is closer to the consumption center-of-gravity and can involve another stage of production. For example, methanol could be produced closer to its market. This could happen if existing gas pipelines to major centers are found to have excess capacity, or if the piping of gas overland in a given situation is found to be cheaper than the piping of methanol. If LNG is used conventionally it is regasified at level C, as methanol produced at level B could be as well. The latter is considered an unlikely choice at the present time, but in a system that has thoroughly evolved in response to oil shortages it could be an efficient option. Plants producing gasoline from methanol might be located near the source of the gas or near the market to be served.

Finally, level D concerns the distribution to and use of fuels by final consumers.

If natural gas reserves continue to be used as they are now little qualitative change will take place in the existing natural gas system; it will only grow. The system will still be concentrated in the flows on the left side of the flow chart. If a methanol fuel market develops there will be considerable change, and the flows on the right side of the inner chart will begin to play a larger role. The process by which such change would take place can be envisioned. While detailed scenario construction is not attempted here, it is useful to outline a number of characteristics of the expected transformation, in part because it will help to focus the discussion of empirical matters that make up the remaining sections of this paper.

(a) There is a competitive relation between the two end use boxes in the flow chart, between the conventional use

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*In a wider context one could say that pipelines and LNG compete with any use of natural gas in which something is produced near the gas wells and exported to distant markets. Methanol is then one example of many such "energy carriers." Attracting secondary industry that is energy intensive is an important strategy in Arab oil countries at present. Trying to account for it in a fuller way in this analysis would, however, be going too far afield.

of natural gas and its use to produce synthetic fuels. Thus a comparison between natural gas supplies and the capacity of the conventional gas system to absorb increased gas flows bears on the likelihood of methanol development.

(b) In relative terms, the use of methanol as a fuel would not require a major modification of the overall fuels system. It would occur mostly by way of adjustments to the existing natural gas, petrochemical, gasoline, and automotive industries. By comparison with some other alternative fuels (e.g., solar power and gas or liquid fuels from biomass), methanol could be introduced more by gradual change of the present system than by construction of a massive new system.

In absolute terms, however, the required long-term adjustment would still be large. The changes involve research and development to overcome technological obstacles, institutional change as the boundaries of firms and industries adjust and as government policies accommodate themselves to the new system, extensive capital investment, and new marketing arrangements. If and when, beyond the initial stage of preparatory research, actual resource reallocation begins, the biggest adjustment is likely to be in the fuels industries, where large amounts of investment in methanol capacity will be needed. But this adjustment need not be the source of serious bottlenecks. Initial increments in methanol production are likely to be used in low-ratio blends. The period needed to build the capital required for more substantial production increases would presumably provide sufficient lead time for automotive producers to design and make vehicles that can run on higher-ratio blends or pure methanol, and for changes to be made in the distribution system.

In spite of the possibility of gradual adjustment and an apparently tractable development strategy, there are those who say that action is difficult because of a "chicken-egg problem" between the availability of synthetic fuels and the motor vehicles that use them. This might be explained by the existence of a threshold which must be reached during the stage of preparatory research before entrepreneurs are willing to make commitments. Since there are also paths to reduced dependence on oil that do not give a large role to alcohol fuels, they may face too many choices and too little hard information. Alternatively, the frequently made "chicken-egg" comment might simply disguise a belief that alternative fuels are not yet needed.

(c) The competition between using natural gas to produce methanol and using it in the conventional gas system is fought on unequal grounds, given the inertia contained in existing industrial structure and technology. New products typically suffer a disadvantage if they must compete with a well-established product. As a good is developed the cost of producing it generally falls and its quality increases. Thus a new substitute for an old product might be able to provide a similar or better service at a comparable or lower cost if it were to have a substantial share of the market, but it is difficult to achieve the necessary market expansion when these developments have not yet taken place.

This kind of unequal competition could take place in two separate parts of the energy system considered here. Methanol has to compete with LNG as a carrier of gas energy from remote reserves, and with gasoline and other petroleum products as a motor fuel. If it succeeds in one case its chances of success in the other are improved. As will be seen below, more developments are now taking place in regard to the use of methanol than in the long-distance transport area. If methanol should begin to penetrate the fuel market the production of methanol near the sites of remote natural gas reserves would undoubtedly be found more profitable than it now is. There is, however, still scope for either part of the system to lead the way.

(d) Observation (c) indicates a role for governments in the development of alcohol fuels in mixed economies. It suggests that the market left to itself could retard the introduction of substitutes for oil-based fuels. If having such substitutes is found to be desirable in a given society (if, for instance, it would bring about a reduction in the total cost of providing a country's energy needs), it is rational for that society's government to provide coordination, research services, subsidies, or other manner of support that would help to offset the competitive disadvantage to which the new fuels are subject. This assumes, of course, that alcohol fuels could effectively compete with oil-based fuels once they do have a share of the market or, if not, that the society in question is willing to pay something to have alternative fuels available even if they are more expensive than those currently used.*

This discussion suggests where one ought to look for signs that a methanol fuels industry is developing. The following areas are examined in turn: governmental programs in aid of the use of alcohol fuels, trends in the existing methanol industry, activities that relate to the long-distance transport of gas and methanol, and the supply-demand situation in the conventional natural gas industry.

3. NATIONAL PROGRAMS AS AGENTS OF CHANGE

3.1 An Overview

Government run or sponsored programs to research and support the development of alcohol fuels are underway in numerous countries. Much of the development activity in the private sector can be linked to these government programs, though no study is

*The argument of observation (d) is an application of the theory of market failure. As the alcohol fuels industry grows there will be external economies, or positive spillover effects, that bring benefits to people but are not paid for through normal market transactions. If the government does not finance them they will be underproduced and the society will be using its resources less productively than it could.

available that would allow one to infer whether the private activity is genuinely dependent on government support. The programs are usually contained within broader government efforts to develop alternative fuels and relate to both the production and use of methanol. More of these activities are, however, directed to overcoming obstacles in the way of using it than to producing it.

A number of elements appear frequently in these programs: the testing of both blends and pure alcohols in actual use, in some cases on a large scale; the search for alcohol-gasoline mixes most suitable for local conditions; attempts to use locally produced feedstocks; attempts to deal with the phase separation problem and, where necessary, to deal with cold weather starting; and the development of automotive equipment specifically designed for alcohol-fueled vehicles. In some countries there are plans, more or less tentative, to introduce or expand the use of alcohols on a commercial scale according to a projected timetable.

The most useful sources of information on these programs are the proceedings of a series of international conferences on alcohol fuels technology (e.g., Brazil Conference 1980, Auckland Conference 1982). The occurrence of these ambitious conferences and the progression in them from one to another are themselves some evidence that a major new fuels industry is taking shape.*

Although a full survey of national programs is not attempted here, some key aspects of a few selected cases will be given to illustrate the extent to which methanol has developed. Three programs that are interesting because they are extensive and concrete are those underway in New Zealand, California, and France.

3.2 New Zealand

The New Zealand program is highly conditioned by local characteristics: a small economy, without its own auto industry, an automobile population that is diverse and turns over slowly, a precarious balance of payments, and domestic reserves of natural gas (but not oil). It is a natural place for the first commercial attempt at applying Mobil Oil's well known technique of producing gasoline from natural gas via methanol.** The project, which is attracting worldwide attention, recently received government

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*The point is summed up by an American observer commenting on the attitudes of people involved in the development of fuel alcohols in the U.S. At the time of the Brazil conference in 1980 these people often prefaced remarks with "If alcohol fuels are commercialized..." At the Auckland conference in 1982 this had changed to "When alcohol fuels are commercialized..." (Auckland Conference 1982, Vol. 3:288).

**Another small methanol-to-gasoline plant is being built in the F.R.G. It will produce only 165 bbl/day and is intended to test a different version of the Mobil process, which would quickly be available on a larger scale if the test is successful. (See Oil and Gas Journal 1982:152, and Quinlan 1980.)

approval, after a period of controversy. Two plants will produce 2200 (metric) t/day of methanol each from natural gas. This will be converted into 570,000 t/year of gasoline at an estimated cost of N.Z.$490/t (Auckland Conference 1982, Vol. 3:246-247). This works out to roughly U.S.$0.29/l, based on the exchange rate in the first quarter of 1982. (Conversions to U.S. dollars have been made with average exchange rates published in the IMF's International Financial Statistics.) Just over half of the venture is owned by the New Zealand Synthetic Fuels Corporation; Mobil Oil, with a one-quarter interest will manage it; the rest belongs to BP, Shell and Caltex (Petroleum Economist 1982). It is expected eventually to provide about 30 percent of New Zealand's gasoline consumption (Auckland Conference 1982, Vol.3:316).

Even with this project approved, research and action is proceeding on the direct use of methanol as a fuel. A separate methanol plant with a capacity of 396,000 t/year is also to be built. Though the use of methanol-gasoline blends is considered to be uneconomic at present (Auckland Conference 1982, Vol.3:399), the possibility of using some of the output of the new plant for that purpose--should oil prices make it economic in the future--is clearly a part of the New Zealand strategy. Moreover, research into the use of high-ratio blends or nearly pure alcohol is underway (Titchener 1982). The government also provides incentives for the use of compressed natural gas. If its target is met, 10 percent of road vehicles will run on CNG by the end of 1985. The overall program (which has not been exhaustively described here) is expected to reduce New Zealand's transport fuel imports from their present level of 90 percent of total consumption to 50 percent by the mid-1980s (Auckland Conference 1982, Vol.3:399).

While the New Zealand program is more advanced and appears more deliberate than other national programs, it should not be presumed that it has flowed along smoothly, without setbacks. A study of nontechnical constraints on the introduction of alternative fuels--those having to do with consumer resistance, regulatory and other institutional barriers, information flows, and the like--indicates that difficulties have been encountered and points to the need for a carefully designed implementation program if government attempts to accelerate normal market processes are to be successful (West 1982). Neither is the program expected to remove the country's dependence on energy imports for all that long. The Maui gas field, on which the strategy is primarily based, is expected to reach its peak production in the 1990s and then decline. "In the longer term it is clear that natural gas will be no more than a stop-gap solution for New Zealand" (Titchener and Walker 1980:884).

Despite these qualifications, the New Zealand program is impressive, and of some importance as a bellwether for the rest of the world. The need for action is greater in New Zealand than in most other high income countries and, because it is small and isolated, fewer institutional barriers stand in its way. Its decision may provide some indication of what will be done in countries where change is taking place more slowly. Certainly other countries will benefit from knowing of its experience with the Mobil process.

3.3 California

The alcohol fuels program in the United States is large and complex. Between 1978 and 1980 numerous incentives, research projects and other supportive actions were initiated by both federal and state governments. The momentum of these programs has, however, been recently set back by reductions in the funds allocated to them by the federal government.

Among other things the programs helped to stimulate interest in the production of ethanol. While the aggregate amount consumed is small, about 10,000 service stations are now selling blends of gasoline and ethanol (Auckland Conference 1982, Vol 3: 336). The development of ethanol to this extent was in part due to a spontaneous interest in the agricultural sector that was bigger than expected. While ethanol may have an interesting potential in the long run, it is a curious choice for the U.S. as a source of alcohol fuel at the first stage of its use and is likely to give way to methanol. This is, for instance, the view taken by the Ford Motor Company: "Methanol is the nation's most likely alternative to gasoline... Both methanol and ethanol are equally good fuels, but we lean toward methanol because of our country's tremendous resources of coal and natural gas, and because methanol is cheaper to produce than ethanol..." (quoted by Shuttlesworth 1982). The U.S. National Alcohol Fuels Commission concurs with this position (Shuttlesworth 1982).

Despite these problems the activity that is going on appears to be laying the groundwork for the use of alcohol fuels in larger quantities. An aggressive program that can be offered as evidence of this is found in California (cf. Smith et al. 1982). Like New Zealand, though for different reasons, the need is perceived to be great here. Its vehicle population and density is very high and is likely to continue growing. Minor deficiencies in supply, of only 3-5 percent, caused great difficulties during the shortage that occurred in the 1970s. Alternative fuels offer some opportunities to overcome such shortages, as well as to combat California's uniquely serious air pollution problem.

The program is committed to encourage the use of alcohol-gasoline blends in the near term, to encourage the shift to pure alcohol fuels in the long term, to bring about supply increases, and to develop new uses of alcohol fuels. Methanol is the preferred alcohol, though ethanol will still have a small role due to the local availability of wastes from fruit and non-grain starch crops.

The program is broadly based, for, as the authors of a report given at the Auckland conference assert: "To be effective, alternative fuels must possess the capability to displace the majority of refined products from crude oil" (Auckland Conference 1982, Vol.3:372). If, for instance, only gasoline were to be displaced, the need for related products would continue to support the demand for petroleum refining. Since there is limited flexibility in breaking down crude oil, total oil needs would remain high and local gasoline surpluses could emerge, which would undercut the market for methanol. To this end, work on the use of methanol in diesel engines and in large stationary utility and industrial engines is underway.

For automotive use, low-ratio blends are to be de-emphasized in the long term. Such blends are thought to be a less efficient way to use alcohol and to have adverse effects on air quality relative to the use of neat alcohols.

The flow of methanol from existing Californian plants using piped natural gas is expected to meet fuel needs through 1987, unless its use by public utilities grows faster than expected. In the middle term, production at the sites of remote natural gas reserves is likely to be important, eventually giving way to coal gasification. There is also interest in the use of heavy crude oil as a feedstock, for large supplies are available within the state.

3.4 France

The French alcohol fuels program was begun in early 1981 and consists of two stages, the first of which is expected to run through 1985 (Institut Francais du Petrol, personal interviews, Enerpresse 1981a,b; and BIP 1981). It involves the gradual introduction of alcohol mixtures into premium gasoline up to a maximum blend of 10 percent. This stage assumes that it can be done without vehicle modifications or changes in the retail fuel distribution industry. A large research and testing program is underway. The second stage (1986-90), which will continue the evolution to higher blends, assumes that vehicles and the distribution system will be modified. At some point the motorist is envisioned as having a choice at the pumps, between old-style gasoline (perhaps with a low alcohol blend) and a fuel with a high alcohol content.

The major objective appears to be to develop a workable fuel that can be produced from domestically available feedstocks. Coal and various crops, some of which can be grown on marginal land, are the desired sources. The possibility of using natural gas is acknowledged--as is its current cost efficiency relative to other feedstocks*--but it does not appear to form an integral part of the final goals of the plan. Nevertheless, it is likely to play an interim role in providing methanol, until other sources become cost effective and available in sufficient amount. The timing of this is, of course, uncertain. What will surely be important is the supply-demand balance in the conventional gas sector. France is currently expanding and diversifying its gas

*For example, data provided by IFP in early 1982 indicate that methanol can be produced from natural gas at FF1400/(metric)t (assuming a gas price of U.S.$5-5.50/$10^6$Btu and a plant capacity of 600,000 t/yr), and from coal at FF1800/t (assuming a coal price of FF400/t).

supplies, though whether or not any of the expanded supply is foreseen as a backup feedstock for liquid fuel is not known.

The French program is likely to be important in the European context if the projected schedule is maintained. It will provide a nearby demonstration for other European countries that have not yet made a commitment to change. With its large auto industry it could also be important in initiating changes in vehicle design. In this regard, the extensive program of vehicle testing and development in the F.R.G. should also be noted (Meckel and Paulsen 1982). The question of leadership and coordination is important in the European context. The large amount of cross-country vehicle traffic requires some level of intra-European harmonization in alternative fuels programs.

4. THE EXISTING METHANOL INDUSTRY

4.1 Methanol Prices

A methanol fuel industry and the existing industry devoted to chemical production would overlap extensively. The substances and processes are basically the same; generally, methanol for chemical use is merely refined to a greater purity than is necessary for fuel use. Consequently prices in the existing industry provide some indication of what methanol fuel could sell for, though they presumably contain some upward bias due to the cost of extra refining.

Unfortunately, well-organized and comprehensive price statistics on methanol are not available. On the basis of the rough quotations that were found, however, it appears that methanol can be produced more cheaply than gasoline per unit volume in many countries. Estimates for France, the F.R.G., and the U.S. that apply to late 1981 or early 1982 all work out to about U.S.\$0.19/l. The French estimate was provided by researchers at IFP and is based on a natural gas price of U.S.\$5/10^6 Btu. The F.R.G. and U.S. estimates are found in (Auckland Conference 1982, Vol.1:16,112). Average pre-tax prices for gasoline in the first quarter of 1981 in the three countries were U.S.\$0.38/l, U.S.\$0.31/l, and U.S.\$0.35/l, respectively (Doblin 1982:46).

These price comparisons indicate that methanol is now a viable fuel if it is used to replace gasoline in low-ratio blends where it can be substituted on a 1:1 basis by volume. If pure methanol or high-ratio blends are to be used the prices must be adjusted to account for methanol's lower energy content. Since the technology that would be used to consume higher-ratio blends or pure alcohol is not yet known, the factor that should be applied to construct a comparable price is not available. If it were to be, for example, in the 70-80 percent range, methanol prices would no longer look so competitive with current gasoline prices. The likelihood that methanol-compatible vehicles will, at least initially, be more expensive than existing ones adds to the market barriers that would prevail. If this is not to dissuade consumers it would have to be possible to amortize the extra vehicle cost by way of a price discount on methanol sufficient to make the cost per kilometer of using methanol lower than the corresponding cost for gasoline.

Thus, market penetration beyond the range of 5-10 percent of gasoline consumption is not to be expected unless one or more of the following contingencies occur.

(a) Gasoline prices rise by more than methanol prices. Since there is a tendency for natural gas prices to rise with oil prices, albeit more slowly, this possibility may be considered unlikely. That is probably wrong, however, because of the possibility of producing methanol from coal. That is, the oil-coal price ratio may be the determining factor for high levels of market penetration.

(b) In the manner typical of new industries, the real price of methanol could fall due to cost decreases that occur as the new methanol fuels industry grows.

(c) Governments could choose to tax methanol at a lower rate per energy unit than gasoline in order to offset its initial competitive disadvantage or, even in the long term, in order to finance the resource cost of a more secure energy supply that comes with using a larger variety of fuels. This is a key factor because governments are searching not merely for a cost-efficient substitute for oil but one that can be produced domestically, and costs will often be higher as a result.

4.2 Production Forecasts

World production of methanol in 1980 has been estimated at 13 million tons. It has been growing rapidly--from 1974 to 1980 by roughly 60 percent or about 8 percent per annum. A survey of construction underway and planned, together with statements from forecasts in the petrochemical industry, indicate that growth in the range of 5-10 percent per annum will continue. Forecasts of annual capacity for 1990 fall into the range of 23-24 million tons. Excess demand is expected to continue until the mid-1980s, with more than sufficient supply available in the second half of the decade (Chemical Engineering 1980, Hydrocarbon Processing 1979, Ontario Ministry of Energy 1981).

Some of the new capacity is being built in the Middle East in an attempt to use associated gas that is now flared (in 1979 44 percent of the natural gas produced in OPEC countries was flared, OPEC 1979:14). Methanol production in Canada is also growing rapidly, with three new plants under construction and a fourth in the planning stage. They would add 5000-6500 t/day capacity to the Canadian industry, which has been small to this point (Oil and Gas Journal 1982:151).

Detailed information on end uses and product prices associated with existing and new capacity is not available. While small amounts of methanol are mixed with gasoline by a few scattered refiners (and in connection with the numerous test programs) the proportion of total world output currently used for fuel is negligible. Some of it does appear in fuel by another route, as additives, such as MTBE (methyl tertiary butyl ether, an octane booster for unleaded gasoline). This use is expected to grow. Methanol is mainly used to produce formaldehyde and other chemicals, as an industrial solvent, and as a denaturant. In the United States in 1979 only 1 percent of methanol consumption was in the form of fuel. Forecasters are, however, beginning to view fuel consumption as a significant component of methanol demand. A privately circulated forecast from E.I. Dupont predicts that by 1985 20 percent of the U.S. methanol demand will be for fuel consumption, with half of that consumed directly and the rest in the form of MTBE. While no one appears willing to be specific in print, the "chemical press" contains other references as well to the possibility that more of the industry's capacity will soon begin to be applied to the production of fuel grade methanol.

The indication that the methanol industry is beginning to turn its attention to the fuel market is important, but the signs of such attention are still very weak. Beyond vague statements in broadly defined forecasts of the type mentioned above, no strong commitment of any of the existing methanol firms to the fuels market has been perceived. This is borne out for the United States by the comments of a marketing strategist employed by a petroleum corporation: "In spite of (its) advantages, there has been no substantial effort in the United States toward increased methanol production motivated by use as a fuel" (Shuttlesworth 1982, in Auckland Conference, Vol.3:362). The only evidence of exceptions to this in other parts of the world is found in the New Zealand and F.R.G. gasoline projects and in a Norwegian paper given at the Auckland Conference (Pran 1982). There it is suggested that Norwegian natural gas could be used to supply a large portion of Western Europe's future methanol fuel demand.

It is possible that firms considering action, or even those with specific plans to supply the fuel that the forecasters are predicting will be demanded, are simply not yet willing to announce it in public. At the same time, given all the activity that is directed to preparing the way for the use of alcohol fuel, the absence of market development by those who are in a good position to supply the market means that its inception is still uncertain.

This is all the more so because a real commitment to methanol as a fuel, even in a low blend with gasoline, would effectively require the building of a new industry. One source estimates the current surplus of methanol over the demand for it in chemical use as less than 1 percent of world gasoline demand (Auckland Conference 1982, Vol.3:228). To have some idea of the magnitude involved, consider current gasoline consumption in OECD countries and the possibility of a 10 percent methanol-gasoline blend. The existing world methanol industry, if it were totally devoted to fuel production, would be able to supply only about one-quarter of the methanol required.* At the same time, there is a great

*This assumes a 1:1 replacement of gasoline by methanol. Gasoline consumption in OECD countries in 1980 was 458,734,000 t and methanol production about 13 million t.

deal of natural gas potentially available to produce methanol. For instance, two methanol plants being built in Saudi Arabia, with a total capacity of about 400 t/day (Oil and Gas Journal 1982), will require less than 3 percent of the gas flared in that country in 1979. If all of Saudi Arabia's flared gas were used for this purpose (as an illustration, since it could well be uneconomic to do so), the result would be equivalent to more than three times the current world methanol supply.*

5. ALTERNATIVE METHODS OF TRANSPORTING NATURAL GAS ENERGY

The construction of methanol plants in Saudi Arabia is an example of an increasing effort in energy exporting countries to use some of their resources to export secondary products instead of the primary energy itself. This effort is one aspect of the natural gas transport question that is relevant here. If developers of remote gas reserves increasingly choose to produce methanol, rather than to transport the gas by pipeline or LNG, the effect on methanol supplies would help to stimulate its use as a fuel. What is needed to explore this possibility is a comparison of the net returns to be gained by alternative methods of exploiting given stocks of natural gas. A small number of studies that approach this question are available, though they do not focus in sufficient detail on the issues that are relevant here.

5.1 Natural Gas Net-Back Values

An Italian firm involved in building natural gas infrastructure has prepared a study that compares ways of exporting natural gas from countries in the Middle East and Africa to Europe (Bonfiglioli and Cima 1980; Cima 1981). They computed "net-back values" for natural gas in different uses: starting from assumed average European market prices for gas and converted products they deduct capital costs, transport costs, conversion energy losses, and other charges to arrive at the amount left per unit of gas at the export point. (Costs of gas transfer from local wells to processing plants are not accounted for.) A forecast of European demand for the products considered is also required and this is extended to 1990.

The European price for methanol in fuel use is assumed to be U.S.$180/t, which is approximately U.S.$0.14/l. At roughly half the energy content of gasoline, this is equivalent to a pre-tax gasoline price in the U.S.$0.25-0.30 range. (Thus the authors have not accounted for the more favorable possibility

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*In 1979, 37,990 x $10^6 m^3$ of gas were flared in Saudi Arabia. A typical methanol plant using the ICI process requires 2.3 x 10^6 kcal of gas per ton of methanol (Hydrocarbon Processing 1981). For purposes of this illustration, a cubic meter of gas is assumed to contain 8905 kcal.

of methanol substitution in low-ratio blends.) The market for fuel use is assumed to be 1.5 x 10^6 t/yr, requiring 15-20 plants each with a capacity of as much as 5000 t/day. This would consume 1500 x 10^6 m^3/yr of gas and would generate a net-back revenue of U.S.$2.50-2.70/$10^6$ Btu (1980 dollars). This value is higher than they obtain for all the other products converted from methane, the major component in natural gas.

The assumed distance over which the methanol is to be transported has not been reported, but it appears that a single average has been used. Since the marginal cost per kilometer is low, the use of an "average site" may not affect the results materially. This is not so in the case of LNG or pipelines, and the authors do various comparisons over distances ranging from 3500 to 11,300 km. Assuming a natural gas value (as of April 1980) at the inlet of the European gas system of U.S.$4.10/$10^6$ Btu, they obtain net-back values for gas carried by pipeline and ship, all of which are lower than the net-back value of methanol. Thus, of all the alternatives considered that involve the use of large volumes of gas, methanol has the highest net-back value (Bonfiglioli and Cima 1980: Fig. 24). (The only ones still higher are ethylene, which is produced from ethane, a small component of gas, and the use of gas as refinery fuel. The latter is assumed to have a market 17 percent the size of the fuel methanol market, which was itself conservatively estimated.)

Rather than arguing for a great expansion of methanol production, the authors apparently see a methanol fuel market as something that will develop very slowly and that will utilize only limited quantities of natural gas in the producing countries considered. On the other hand, they perceive a wide market in Western Europe for the conventional use of gas from these countries (Bonfiglioli and Cima 1980: 219, and Fig. 25). A similar view is presented in a study by the International Energy Agency (IEA), in which they expand upon the results of the Italian study (IEA 1982:127-128). In part this is understandable in that such studies do not refer specifically enough to particular markets to allow one to infer that market development should begin if favorable results for methanol are calculated. They are based on average data which may have considerable variance. In a link between a particular importing country and exporting country the ranking of net-backs could be different from those reported for the hypothetical average. Thus the results of the study cannot be the basis for specific marketing strategies. At the same time, the conservative way in which they are treated by the authors suggests that initiatives from the gas industry in the development of a methanol fuel market are not yet to be expected.

5.2 Transport Cost Comparisons

Another methanol-LNG comparison (Humphreys 1977) sets out to compare the costs of delivering 165 x 10^{12} Btu/yr of gas into an importing country's pipeline system either by way of LNG carriers, or by methanol carried in ships and used to produce substitute natural gas at the receiving end. Though based on 1973 data, the results do illustrate some general relations that still apply. It is found that the costs of gas delivery vary with the length of the export route, the price of natural gas at the well, and the method of financing. As distance increases the cost of transporting LNG rises more rapidly than the cost of transporting methanol. For the two routes considered (from the Persian Gulf to the U.S. and Japan) methanol is the cheaper method.

Generalizing Humphreys' analysis, the effects of both transport distance and the price of natural gas for a given financing arrangement are illustrated in Figure 2. At a low gas input cost, the higher capital costs of LNG lead to a higher output cost per unit. But because of greater energy losses in production, methanol is more sensitive to higher prices for natural gas.* Thus the methanol relation has a higher gradient and can lose its advantage at a sufficiently high gas price. Given the expectation that natural gas prices will be tied to oil prices, this could be an important fact. It could help to explain why LNG has so far been the preferred method of trans-oceanic shipment, even over distances that would appear to favor methanol.

The curves in Figure 2 increase for longer distances, but the LNG curve rises more per unit change in distance than does the methanol curve. The crossover point for a given level of energy delivered thus occurs at a higher natural gas price--the methanol advantage is more robust with respect to gas input price increases the longer is the route.

5.3 Feasibility Studies

Another source of information on remote methanol production is provided by feasibility studies for particular projects. A well known one is a proposal to bring associated gas from Alaskan oil fields to the lower 48 states. So far the pipeline option has been favored, but the project has not yet been finalized and some argue that it is unnecessarily expensive relative to the methanol option.

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*Humphreys does not clarify his reasoning in regard to the relative slopes, but the difference in production losses must be the key factor. Let AC_i = the cost per unit of energy delivered over a given distance by liquid fuel process i, K_i = all costs per unit of output other than the cost of gas, P = the price of gas to the liquid fuel producer, and G_i = the gas required per unit of energy delivered via fuel process i, then $AC_i = K_i + PG_i$. Suppose that there is a 17 percent energy loss in delivering LNG to the gas system and a 35 percent energy loss in delivering methanol, then

$$\frac{\delta AC_M}{\delta P} = 1.23\frac{\delta AC_{LNG}}{\delta P} \quad .$$

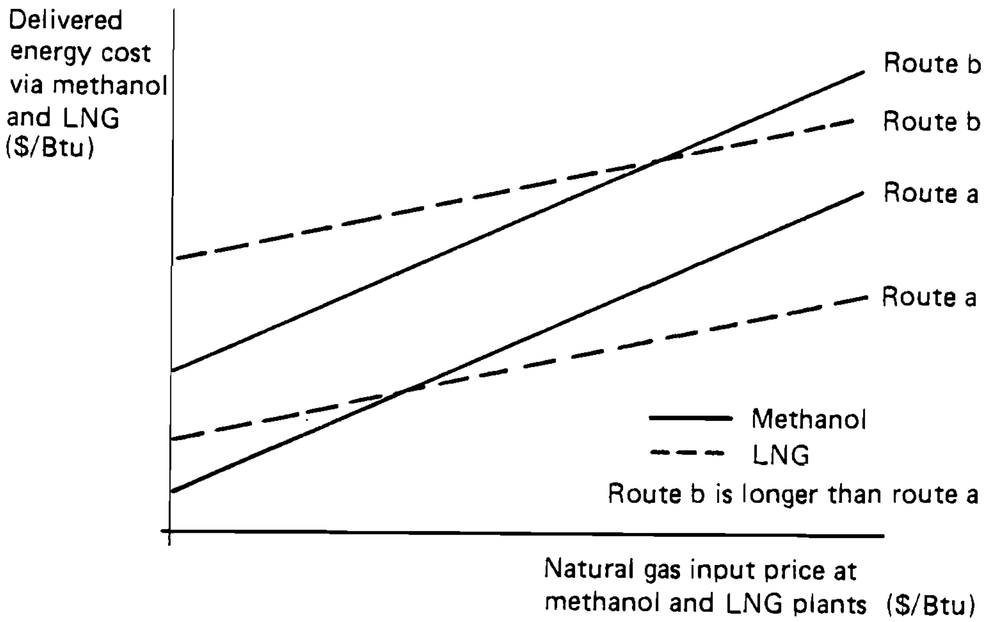

Figure 2. Delivered natural gas costs as a function of transport distance and gas input price.

According to the Alaskan plan--which has been examined by more than one group--fuel-grade methanol would be produced at Prudhoe Bay, the source of the gas, shipped to the existing tanker terminal at Valdez by an existing oil pipeline, which now operates at less than full capacity, and thence by tanker to the lower west coast. An early study concluded that this would not be the lowest cost method of moving the gas (Thomas 1978). A more recent proposal (Dubetz and Marsden 1981, and Dubetz 1981) involving new technology concludes that methanol can be delivered to the U.S. west coast from Alaska for about 16 U.S.¢/l (1981 values). The market price for methanol was at the time in the range of 18-24 U.S.¢/l.

If all of the available flow of Alaskan gas were to be converted to methanol, this approach would certainly encourage the use of methanol as a fuel, for it would add massively to the total methanol supply. The Dubetz-Marsden plan envisages up to 16 barge-mounted methanol plants, each with a capacity of 3000 t/day.*

*A 3000 t/day methanol plant is large by any standard; the planned facilities do not, that is, appear to be constrained in scale by the need to build them on barges. In a worldwide survey of petrochemical plants planned or under construction in early 1982, the largest methanol plant listed, under construction at Tomsk, Siberia, has a planned capacity of 2500 t/day (Oil and Gas Journal 1982:142-163).

Supposing that these plants were to operate for 300 days per year, this allows for a potential production of 14.4 million t/yr, more than the current annual world production. The proposal is not unrealistic, however, for one of the advantages of the barge-mounted module is the option of expanding production incrementally without building excess capacity into the system. This is an advantage over pipelines, which need to be large and operated close to full capacity to be efficient.

The same research group is in the course of researching alternative sites at which the barge-mounted methanol plants could, because of favorable geographical and economic features, be efficiently applied (Marsden 1982). A promising feature is the possibility of using them anchored near offshore oil platforms or linking them to specially designed facilities for the exploitation of offshore natural gas fields, thereby removing the need for field-to-shore pipelines. The mobility of these barges could also be advantageous in the exploitation of small gas reservoirs. These and other features lead to the belief that this technology could be economically applied, in addition to the Alaskan site, off the northern coast of Australia, along coastal Nigeria, in the Guajira Peninsula, Colombia, in Indonesia, and in northern Canada. So far some of these sites have been examined only superficially and some in detail (e.g., the Australian case).

If it is desirable to produce methanol at the site of remote gas reserves it could possibly also be efficient to go one step further and produce gasoline on site from the methanol. In Canada plans are developing to move some Arctic gas reserves in the form of LNG. A study published by Atomic Energy of Canada Limited suggests that the very high cost of transporting LNG under Arctic conditions could make it desirable to produce methanol with Arctic gas and transform it into gasoline before shipping it. The authors claim "...that Arctic gasoline based on natural gas at less than Cdn$2/$10^3$ft^3 (about US$ 1.67/10^6 Btu) would be competitive in the world gasoline market" (Symons and Miller 1981:22). There are currently cases of Canadian gas being sold at well-head prices within this range. The conceived project appears, however, to be still very speculative and to involve a considerable departure from conventional thinking.

6. METHANOL AND THE SUPPLY OF GAS

It remains to consider whether, in a broader context, producing methanol for fuel is likely to be found the best use of expanded natural gas production. Burned directly for space heating, water heating, and cooking natural gas is viewed as a premium fuel, mainly because it burns so cleanly. There is bound to be some resistance to applying large amounts of it to methanol production, especially when a third or more of the energy contained in each unit of gas is used up in the production process itself.

Among the studies surveyed in this report one finds some evidence for a prima facie case that fuel methanol is an efficient use of gas reserves. The Italian study, which finds that methanol delivered to Europe for fuel use will have a larger pay-off for the gas producer than most alternative uses, is one example. The claim that Alaskan gas can be used to deliver methanol to the continental U.S. at unit costs below current methanol prices is another one. Also relevant is that the use of natural gas as a feedstock could be only a transition stage to the manufacture of alcohols from other materials. Thus, the idea that the massive needs of the transport sector would dominate the use of natural gas need not be an overriding concern.

Such isolated bits of evidence as are available are still far from conclusive in regard to the relevant question at its most general level: for a given community of consumers, which application of natural gas brings the highest incremental return? That is a policy question that will be decided at the national level and could be quite different in different countries. In each case, whether or not natural gas is reserved for its current uses will depend on its supply-demand balance and the prices that are determined for it by that balance and by governmental actions. While detailed supply and demand forecasts are not attempted here, it is useful nonetheless to identify the major issues involved.

Obviously important are the total reserves available and their distribution. There is wide agreement that natural gas reserves are very large relative to the current usage rate.* Definitions vary, of course, but roughly agreed upon is a number in the vicinity of $70 \times 10^{12} m^3$ of proven reserves, equivalent to $400\text{-}500 \times 10^7$ bbl of oil or 40-50 years of gas consumption at current rates. Estimated total potential reserves place natural gas in the same order of magnitude as oil as an energy source. Figures given in this case are in the neighborhood of $300 \times 10^{12} m^3$.

Reserve estimates are being revised upwards as large new finds become known. There are various reasons for believing that this will continue. The ratio of proven-to-potential reserves is low relative to that for oil. One commentator puts it at 31 percent for gas and 60 percent for oil (Ait-Laoussine 1980:29). Thus the success rate in proving additional reserves will be high relative to expectations that have been conditioned by the experience with oil. In the past gas was generally found by accident, as part of the search for oil. Now prices are high enough to encourage gas exploration in its own right. There are many areas of the world that have not been explored, not because they are believed to be devoid of gas, but simply because demand conditions have not warranted exploration. Higher prices will influence not only the rate of exploration but also the rate of technological advance and development in gas exploitation. Thus one expects that some of the obstacles now in

*This is true in regard to conventional definitions of reserves. For information on unconventional possibilities see IIASA (1980).

the way of using less accessible reserves will be reduced or eliminated. Resource costs for complementary inputs will fall and more reserves will be economically deliverable.

About 30 percent of current world gas production is associated with oil and about one-third of that is flared (Ait-Laoussine 1980:31). The flow of this latter component, about 10 percent of total production, is regulated by oil production. If it is not exported, it can be used locally or reinjected into the wells. But both of these options are limited and, consequently, much gas continues to be flared. Such gas has a negligible supply price at the well head. Prices paid for it have to be high enough to cover the cost of complementary inputs, including a return on capital. But beyond that buyers should have more bargaining power in negotiating prices on associated gas than on nonassociated gas.

In sum, the supply situation in absolute terms is conducive to more rapid exploitation. The distribution of these supplies is, however, an obstacle in the way of their use, especially within the conventional gas consumption system. Table 1 shows the geographical distribution of reserves and consumption for broad categories of countries. The two distributions differ markedly.

The U.S. and Western Europe have accounted for large components of total consumption and have small shares of total reserves. Nonetheless, they have consumed mostly from domestic supplies and imports have come from nearby sources. That has been changing, as Table 2 shows. Imports are rising and have reached high levels is some of the countries.

In the European countries much of the gas has been imported from the Groningen field and, more recently, from the North Sea. For example, in 1975, 77 percent of the French imports, 87 percent of the F.R.G. imports, and 48 percent of the Italian imports came from the Netherlands (United Nations 1977:Table 2). Other sources have, however, been important as well--the U.S.S.R.

Table 1. World natural gas reserves and consumption, 1978 (10^9 m^3).

Country	Reserves	% of Total	Annual Consumption	% of Total
U.S.	5000	7.8	590	40.5
Western Europe	4000	6.3	215	14.8
Communist countries	24000	37.5	465	32.0
OPEC countries	25000	39.1	55	3.8
Others	6000	9.4	130	8.9

SOURCE: Ait-Laoussine (1980).

Algeria, Libya, Indonesia--and their importance has been growing. A rough indication of the shift toward long-distance imports is given by the time series in Table 3. It shows movements in a synthetic variable: the average distance over which gas is transported from its source to the point of consumption, with weights corresponding to the proportion of total gas consumption from each different source.* The exercise indicates a strong trend towards imports from more distant sources and, consequently, towards more costly imports.

These trends have, however, taken place in a period of relatively low natural gas prices. Long-term contracts and other institutional aspects of natural gas markets have tended to retard the rate of adjustment of gas prices to changing market conditions. The immediate effect of sharp increases in oil prices is to reduce the natural gas-oil price ratio. But, though adjustment takes place with a lag, it still occurs. In the industrial sector the lag can be quite short, while adjustment in the household sector tends to be slow. (Data from which such ratios can be computed for four countries are available in Doblin 1982:50-59.)

The factors so far discussed are at the base of concerns over gas supplies in a number of major consuming countries. Natural gas has been found to be a desirable fuel, but in these countries it has become a more expensive and less secure energy source. Gas consumption grew rapidly in the 1960s and early 1970s, and then generally declined, though in most of these countries market saturation had not been reached. (For a comprehensive source on natural gas consumption, see Valais et al. 1982).

This does not mean that conventional gas use will stop growing. New import contracts are still being negotiated, and increases in import prices and an end to the economic recession will induce exploration and development closer to home. There appears to be much scope for this in regard to Western European gas supplies, particularly since, in the view of some, Western

*In principle, this is a fully measurable variable. Here, however, it is constructed as a very rough and semi-arbitrary metric, though one that is internally consistent. Accurate statistics on domestic production and imports from each country were available. However, tracing gas through an increasingly complex pipeline and tanker distribution system, and even finding consistent data on distances within that system, are very difficult and too costly for the present analysis. Consequently some arbitrary assumptions were made. The distances used were the air kilometers from the capital of the country of origin to a large central city in the consuming country (Paris, Rome, London, and Frankfurt for the countries shown in Table 3). No attempt was made to account for distribution within the consuming country. Domestic gas was assigned a zero distance. The last assumption, plus the locations of gas fields in producing countries relative to the cities considered, imply that the numbers derived understate the true average distance.

Table 2. Net imports of natural gas as a percentage of gross consumption.

Year	F.R.G.	France	Italy	Japan	U.K.	U.S.	World Average*
1955	-	-	-	-	-	-0.2	0.5
1960	-	-	-	-	-	1.2	1.2
1965	1.4	3.6	-	-	98.6	2.7	2.2
1970	22.6	34.2	-	32.2	7.7	3.5	4.3
1971	29.7	41.5	0.5	34.5	4.7	3.8	5.4
1972	37.2	48.7	8.4	34.5	3.1	3.9	6.2
1973	42.0	56.3	10.5	49.3	2.7	4.2	7.3
1974	50.3	60.2	23.5	64.3	1.9	4.1	8.6
1975	57.1	61.8	37.4	71.3	2.5	4.4	9.5
1976	60.4	67.2	42.7	76.0	2.7	4.5	10.3
1977	62.2	67.6	48.5	77.9	4.3	4.8	10.8
1978	62.6	68.7	50.8	84.4	11.8	4.6	11.4
1979	66.1	70.7	52.1	87.8	18.6	5.7	12.6
1980	68.1	73.1	55.0	90.5	22.6	4.6	13.1

*International trade in gas as percent of world production.
SOURCE: Valais et al. (1982, Ch. 2, and 115).

Table 3. Weighted average distances of natural gas imports in kilometers.

Year	France	Italy	U.K.	F.R.G.
1955	0	0	0	0
1960	0	0	0	0
1965	48	0	1608	5
1970	198	0	114	83
1971	216	2	70	109
1972	258	86	46	136
1973	330	106	42	184
1974	357	294	27	277
1975	378	898	40	334
1976	435	1245	43	368
1977	618	1685	59	422
1978	667	1912	144	562
1979	669		222	598

SOURCE: United Nations (various years: Table 2); Eurostat (1982); and ABC (1982).

European governments have been unnecessarily conservative in promoting the development of indigenous supplies. (Cf., for instance, Odell 1980.) Furthermore, the use of incentives to encourage the substitution of natural gas in conventional uses for other fuels could increase, which would attenuate price rises or reduce costs indirectly for the consumer. This has been recommended by the IEA to several of its member countries (IEA 1980:24).

Published natural gas forecasts do not suggest that any overriding obstacles will be encountered in the supply of increased consumption. For individual regions and countries there are problems to be solved, but the general thrust of most forecasts is to support the contention that the use of natural gas can be expanded. A recent study of gas use in OECD countries by the IEA illustrates this contention (IEA 1982:Ch. 1). It concludes that the share of gas in total primary energy use will be relatively constant over the next decade, and could rise or fall in the 1990s. This still implies increases in consumption. In a scenario that assumes healthy economic growth it would require increases in supply in the range of 13-38 percent between 1980 and 2000. A hard prediction that this or one of the other scenarios will be the most likely to take place is not made, reasonably enough. Difficulties over pricing and security of supply are foreseen, but no warning is given that the postulated supply scenarios are unrealistic.

Studies of this sort do not account for the possibility that natural gas will be used to supplement liquid fuel supplies in any large way. The prospects for methanol are apparently not yet seen as strong enough by the forecasters to be given an important role in their predictions. Detailed forecasting exercises, especially those done by official bodies, are by their nature likely to be conservative. But if one is willing to speculate on the innovative use of methanol fuel it is safe to argue that insufficient supplies of gas will not be an obstacle. Growth in conventional gas use will be slower than it has been and proven reserves are expected to grow more rapidly. Methanol has an advantage relative to conventional usage when it comes to exploiting remote gas reserves. Thus it need not interfere with the conventional application of reserves that are more accessible to major markets. In short, some space will be open for methanol in the competition between conventional and new uses of natural gas.

7. CONCLUSIONS

The above account indicates that methanol has the capacity to play a significant role in substituting for oil based fuels. Furthermore, preparations for an actual market in methanol fuels are underway. If and when it begins to function, natural gas will be an important feedstock, certainly during a period of transition, but very possibly beyond that as well.

These conclusions are supported in a number of obvious ways. Methanol is now a cost-efficient competitor for gasoline in many countries if it is used in low-ratio blends. Assuming that the current softness of oil prices is a passing phenomenon, it is likely to become competitive for direct use in larger amounts and as a feedstock for the production of gasoline. Pockets of enthusiasm for market development exist and some initial activities directed to that end are proceeding. These are large enough and sufficiently well founded to be amenable to expansion into widespread development. Feedstocks with which to produce the required methanol are abundant. While coal has the capacity to become a major source material for methanol, natural gas is already technologically and economically well established as a feedstock. Increases in the stock of known gas reserves will strengthen that position.

At the same time there are some retarding forces in play. Expectations in the private sector regarding the need for alternative fuels are strongly influenced by what is happening right now, and that is not conducive to innovation. The pockets of enthusiasm referred to above are found mostly in governmental and academic circles. There is no evidence yet of a genuinely widespread commitment that includes numerous industrial actors. Some conflict of interest in the development of alternative fuels is likely to exist because some gas suppliers are also oil suppliers. This is heightened by the contention in oil circles that gasoline will not be in short supply for a long time. Finally, conventional gas use is still growing. Although there is likely to be gas available to supply both categories of use, this growth is occupying those who exploit gas reserves.

While the existence of these opposing forces makes methanol's market penetration uncertain, it is likely that it will develop into an important fuel. Even if gasoline supplies are expected to be stretched farther than previously forecast, the desire in Western industrialized nations for diversification and security of fuel supply is very strong. Short-run weakness in oil markets is not likely to destroy that momentum for governments, though it will slow it down.

If methanol were made only from natural gas the security-of-supply argument would not be very important, since for many countries developing the use of methanol would be a matter of trading one imported fuel for another. With a choice of feedstocks available, however, this is merely a reason why natural gas may be important in a period of transition but not in the long run.

The limited commitment to methanol fuel development in the private sector is understandable at present. An end to the current economic slump would prepare the way for increased interest. But whether it comes then is likely to depend on further government action to strengthen private expectations that alcohol fuels will be developed in a major way. That would help to eliminate the "chicken-egg" worry that holds back decentralized investment in production capacity and infrastructure. Such action will develop only slowly in the normal course of events. If, on the other hand, political happenings or actions by the oil cartel create new severe oil shortages in industrialized countries, the impetus for methanol development will be concentrated. The current preparatory activity will allow methanol use to get underway much more rapidly than would have been possible only a few years ago. A worldwide interest in alternative fuels arose because of turmoil in oil markets. It is quite credible to argue that the next stage of their development will come about in the wake of another oil crisis.

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