METHANOL – THE *OTHER* ALCOHOL

A BRIDGE TO A SUSTAINABLE CLEAN LIQUID FUEL

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The purpose of this article is to acquaint proponents of renewable energy with the "other alcohol" and to explain how it can serve as an effective bridge between the cleanest source of fossil energy, natural gas, and the eventual use of biomass as the source of the "other alcohol." The other alcohol, of course, is methanol.

Major changes in energy use do not occur overnight. It takes time to convert users from familiar or traditional energy sources to new ones and to make the transition from the many applications of traditional energy sources to new forms of energy that will serve all of the existing applications and new ones as well.

Now we are engaged in what may be the last major transition in energy sourcing as we move from heavy dependence on fossil and nuclear fuels to truly significant use of direct solar (electric and thermal), wind and biomass energies. Many believe that this will allow us to reach a final, stable state in the way that we generate and use energy. Even with fossil fuels we have been making a transition over the last half-century to cleaner forms of energy, from coal to petroleum to natural gas. This transition is occurring primarily because of the quest for cleaner combustion to achieve cleaner air. Natural gas is widely regarded as the most likely bridge between fossil fuels and the new energy sources (Serchuk and Means, 1997).

Interestingly enough, we can make "natural gas" from biomass now by bacterial action, much as it must have been made millions of years ago when it was stored in the earth. Unfortunately, when we do this, we get two-thirds CH_4 and one-third CO_2 with the result that the favorable 4/1 hydrogen-carbon ratio of CH_4 by itself drops to 2.7, not far from that of petroleum. Nevertheless, this method of disposing of waste biomass, if the gas is recovered and used to replace fossil fuels, is far preferable to letting the waste decompose uselessly to CH_4 and CO_2 vented to the air. Much of our natural gas resource as produced today contains varying amounts of CO_2, which verifies the probable origin of natural gas. It is of further interest to note that methanol can be made easily from biogas and that part of the CO_2 is used to produce a higher yield of methanol.

Methanol is a close relative of ethanol, the more familiar alcohol usually referred to when we speak of alcohol. Great hopes have been pinned on ethanol as a renewable energy fuel, and rightly so. It has been made and used for one purpose or another for some 5,000 years. Over its history, and still today, it has been made mainly from biomass. We learned to make it synthetically from ethylene about a century ago and still do; however, this is a costly synthesis. Ethanol can also be produced synthetically as a co-product with other alcohols from carbon monoxide and hydrogen, also an expensive process because of lack of selectivity. Because it is very useful as a motor fuel and as a fuel-blending component for internal combustion engines, the U.S. and Brazilian governments have heavily subsidized ethanol production since the first world oil crisis of the 1980s. Similar subsidies are also provided in several other countries.

Almost unknown to the public is methanol, the “other alcohol.” This, in spite of the fact that the world produces and uses roughly *five times* as much methanol as ethanol and does so at a cost for methanol of about one third that of ethanol when both are priced without subsidy. As it happens, methanol is also an excellent motor fuel and fuel blending component. It has long been used in racing cars because of its high performance. Methanol can be used to fuel diesel engines, combustion turbines and fuel cells. Methanol is the preferred fuel for fuel cells when, for logistical and cost reasons, direct use of hydrogen is not feasible. This is so because methanol is very easy to reform to hydrogen.

Methanol was made originally from biomass when it first became an article of commerce in the second half of the nineteenth century. It was known as "wood alcohol." The yield as a coproduct was on the order of a percent or so. Its synthesis for commercial use began in the 1920s when it was made from the carbon in coke made from coal.

$$C + H_2O = CO + H_2 \qquad \text{Reaction [1]}$$
$$2H_2 + CO = CH_3OH \qquad \text{Reaction [2]}$$

To obtain the correct ratio of H_2/CO, some CO was converted by:

$$CO + H_2O = H_2 + CO_2 \qquad \text{Reaction [3]}$$

with the CO_2 being rejected.

Indeed, methanol can be made and has been made from a variety of carbonaceous materials: lignite, coal, heavy oils, light oils, LPG and natural gas. Today for economic reasons, virtually all methanol is made from natural gas by almost the same process steps needed to make H_2 from natural gas:

$$CH_4 + H_2O = CO + 3H_2 \qquad \text{Reaction [4]}$$
$$2H_2 + CO = CH_3OH \qquad \text{Reaction [2]}$$

Reactions [2], [3] and [4] require catalysts. If hydrogen were the desired product, Reaction [3] above would react the CO with H_2 rejecting all the carbon in methane to the atmosphere. This today is the way we make hydrogen, a process far from favorable from a global warming standpoint. Reactions [1] and [2] together reject no CO_2 to the atmosphere. The excess hydrogen from [4], with a little natural gas, fuels the process.

Thus, CO_2 rejection is low compared to methanol recovered. However, when the methanol is burned, it obviously results in CO_2 emissions, which have been delayed, not avoided. Nevertheless, where methanol increases efficiency (as it does in fuel cell vehicles compared to gasoline in normal engines or as a cooking fuel compared to fuel wood), then CO_2 savings are very significant.

The manufacture of methanol can very easily be returned to biomass by the reaction:

$$\underset{\text{wood}}{CHxOy} + H_2O \overset{\text{heat}}{=} CO + H_2 + CO_2 \quad \text{(not balanced)} \qquad \text{Reaction [5]}$$

with the CO and H_2 being separated and converted by reaction [2] to methanol.

Reaction [5] can also be carried out as:

$$\underset{\text{wood}}{CHxOy} + O_2 + H_2O = CO + H_2 + CO_2 \quad \text{(not balanced)} \qquad \text{Reaction [5a]}$$

where the O_2 burns some of the wood to supply the heat for the reaction. When properly renewed (regenerated) biomass is the source of methanol, the CO_2 problem is solved.

Reaction [2] to make methanol is the most selective organic synthesis known, being about 99.8% selective to methanol. If we try to modify the catalyst and operating conditions of Reaction [2] to make ethanol, we unfortunately get, instead of just ethanol, a mixture of alcohols from methanol through hexanols with some ketones and esters. This lack of selectivity to ethanol makes the process hopelessly uneconomical for ethanol even though the process has been researched for at least 75 years.

The manufacture of methanol from biomass is also quite selective. It produces as net products only methanol and a small amount of ash, with all of the gasified biomass either being recycled to methanol or converted to power. This power is used in the process, with some power available to sell. Thus, it becomes in reality a cogeneration operation where the coproduct with power is methanol rather than steam. If hot water is recovered as well, the combined heat, power and methanol efficiency of the process will approach 70%. This is to be compared with most simple biomass power plants with efficiencies of around 18% on power alone. Only methanol among the alcohols lends itself to very selective synthesis from CO and H_2. This is a very important point. The trend in fuels and chemicals technologies is toward ever more selective reactions. Methanol synthesis is in that category.

In order to make ethanol today with even reasonable selectivity, we have to rely on fermentation of expensive biomass raw materials such as corn. The sale of financially incentivised raw materials (corn and other feed grains) into the process is essential to achieving economics good enough so that a subsidy can then be applied to the ethanol to allow it to reach a commercial price range. When all subsidies are considered, the cost of fuel ethanol is really quite high. Added to this is the fact that it is made in relatively small plants because of raw material logistics, and so is inherently more expensive than methanol, whether the methanol is made from natural gas or from biomass. If Reaction [2] could be made selective to ethanol, the fermentation process would become obsolete, except, of course, for making ethanol for the various alcoholic beverages where flavors are important.

Why do we suggest that methanol can be the bridge to sustainability?

The answer is very simple. Methanol can be made from anything containing carbon and therefore can be produced from biomass when we learn to produce enough biomass sustainably at a low enough cost. Methanol is a nearly ideal fuel in internal combustion engines or for fuel cells, and an equally ideal fuel to replace the still enormous consumption of wood as a cooking fuel in developing countries. It is also very attractive as a replacement for the more expensive and valuable kerosene, which has enormous liabilities as a household fuel.

The use of methanol as a cooking fuel has been totally overlooked by the methanol industry as well as by energy policy makers, whether in or out of government. This is because the methanol industry has always regarded methanol as a commodity to be sold into the chemical markets, not the fuel market, and there has been no impetus in the industry to depart from this orientation to the chemical markets. Moreover, there is a host of competing fuels in the liquid fuels market. Yet, methanol gives us perhaps our best chance to ameliorate the deplorable conditions in which some 2.5 billion people find themselves today because of their dependence on dangerous, dirty and scarce domestic fuels.

Why not simply use ethanol in place of kerosene or fuel wood? There are two reasons. First, ethanol is too expensive in most instances to make and the resource base on which it rests is not large enough. Methanol, from its present gigantic resource base – natural gas – is far cheaper and is already produced in much larger quantities than ethanol, and is distributed by a far more efficient system, including tankers comparable to the largest gasoline tankers in service. Second, methanol can be produced right now from whole trees – cellulose, lignin and all – and the process will cost less on a large scale than making ethanol from cellulose with a lignin byproduct, once this process is perfected.

Of course, neither alcohol will be made from trees as long as we have cheap natural gas to make methanol and as long as the manufacture of ethanol from sugar and grains is heavily subsidized. The day when we will grow plantation biomass as cheaply as it will cost to exploit fossil fuels is still a long way off. Many years of tree selection and increasing plantation efficiency is yet required to reach this desired state of affairs. It appears that two or three forest growth cycles will be required to achieve the gains necessary, which is on the order of 40 to 60 years for the tree species likely to be used. Many believe the use of canes and grasses can shorten this period. The authors of this paper believe that the best economic opportunities exist with multiple-use species like timber and pulpwood trees, sugar cane, rubber trees, oil palms, etc., where coproducts of higher value will subsidize the biomass that is diverted to fuel. Indeed, that is where most of the fuel use of biomass arises today, with one major and notable exception: the use of wood as domestic fuel. Today, something like one billion tons of wood per year, or about 12 quads, are used for cooking fuel either directly or indirectly by first making charcoal by a very inefficient and polluting process.

It appears that a grain other than corn, namely sorghum, may be the optimum raw material in the long run for ethanol.[1] If sorghum were instead used in a dual-purpose fashion – the grain harvested for sale and the remainder of the plant used to make methanol – then the cost to produce methanol would be far less than the cost to produce ethanol. The grain would go to feed humans or animals and the rest of the plant would go directly into the methanol process. In the end, there would be three products, grain, methanol and a little ash, the last to be recycled to the field for its mineral content.

History shows that forests disappear to fuel use in countries that do not have access to cheap fossil fuels and that they begin to reappear in countries that obtain fossil fuels. That cycle of replacement and regrowth needs to be replicated today in countries that have rapidly depleted their forests and that have some 3 billion people, half of the world's population, to support.

Methanol, almost alone among fuel choices, offers the opportunity to accomplish this cycle of replacement and regrowth in developing countries. At the end of the cycle, renewably harvested trees and waste from agricultural crops and the higher uses of trees can be converted to methanol, replacing natural gas, and methanol produced from natural gas. Perhaps even more important than the provision of clean, renewable energy will be the creation of a self-sustaining, environmentally friendly local economy, based on the growing and harvesting of biomass not only for its agricultural and industrial products, but also for its energy.

With U.S. DOE support, a process has been developed and commercialized in the U.S. to reform wood endothermically into a raw synthesis gas that can easily be re-reformed to make the exact synthesis gas needed for methanol in Reaction [2], above. Long in use in Germany is the Winkler fluid bed steam-oxygen gasifier converting lignite to synthesis gas, which is today being made into methanol in Germany. Substituting ground wood or other biomass for lignite is only a feeding, not a process problem, and it is a problem we know how to handle today, not sometime in the future. However, as long as there is a vast, worldwide resource of natural gas exploitable at very low cost, methanol will be made from natural gas and transported to the market at very low cost in large ships, as occurs today. In those countries fortunate to have all of the natural gas they need, such as Nigeria and Bangladesh, the methanol will be made locally, not imported.

[1] Grassi, G., May-June 2000, "Bioethanol–World Perspectives for an Industry," *Renewable Energy World*.

In Australia, a well-financed company highly successful in high-efficiency biogas-based power plants has spent some $40,000,000 in developing and commercializing a process to convert municipal solid waste (MSW) into a raw synthesis gas for energy production.[2] This raw synthesis gas, like biogas, can readily be reformed into methanol synthesis gas. This is a very exciting development when one considers the huge MSW waste piles accumulating around the cities of many developing countries and the increasing urbanization of the developing world (by 2020 it is predicted that 50% of all people in the world will be urban dwellers). The EDL/BrightStar process operates equally well with green waste, sawdust, wood chips, bark, etc.

Methanol will enter the consumer fuel system at the most upscale end of the market by about 2004 when the first fuel cell passenger vehicles enter the market. The entry at the low-income end of the marketplace – as domestic (household) fuel – could occur equally soon if the right development initiatives are started now.

Having explained what the “other alcohol” is, how it is made today from cheap, plentiful natural gas, and how it can be made tomorrow from biomass, we would like to discuss briefly how it could bring the fuel function of natural gas and LPG to the populations of developing countries. While the transition to methanol is justifiable economically, this transition is also desirable because it can become part of a cycle of return to biomass as the methanol source. This can lay the foundation for the building of large, sustainable local energy industries in countries most in need of rural enterprise. A recent article in *Renewable Energy World* on the use of biomass fuels in China clearly points out how closely energy choices and uses correlate with socio-economic development and improvements in the quality of life:

> “Several reasons are motivating a growth of interest in development of renewable sources of energy, in particular of bioenergy. Using biomass fuels in a sustainable way is a basic requirement for a country as densely populated as China. In recent years, for example, in the Northern Chinese County of Kezuo people have cut down most of the trees around the agricultural lands and are now turning to less efficient fuels (straw and dung) while wealthier households are using coal. Deforestation has other undesirable effects on energy production: in Yonchun County, Fujian Province, lands and forests became so degraded by 1983 that the situation had reduced the annual hydroelectric production from the 1960 level of 5000 hours to only 2200 hours.
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> Modern bioenergy will be of great relevance for developing countries. In this context, the identification of a flexible and sustainable integrated complex for the supply of energy, food and animal feed could provide a significant contribution.” [3]

If we accept this, the question then arises: how do we develop a sustainable bioenergy system? The Chinese have resorted to a fossil fuel, coal, as a bridge between the

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[2] Energy Development Ltd., Brisbane, using the BrightStar gasification technology. Dr. Charles A. Stokes, an author of this paper, was instrumental in the development of this process.

[3] Chiaramonti, D., and Grassi, G., May–June 2000, "Rural Village Strategy, Biomass for Rural Development—China," *Renewable Energy World*.

present badly depleted forests and the day when forests can be brought back as a sustainable provider not only of energy but also of lumber for local use and export. China is fortunate to have vast coal resources. Unfortunately, the coal fuels used domestically are a source of pollution, although perhaps less so than the straw and dung used by poorer people, if only because of the much lower efficiencies obtained with straw and dung.

Many developing countries do not have a bridging fossil fuel, let alone an economical improved fuel such as methanol. Methanol can reach the shores of any country in the world economically and, indeed, already reaches nearly every country in some quantity or is made locally in the country. For example, in South Africa methanol is made from coal as a byproduct of making conventional hydrocarbon fuels from coal using CO/H_2 chemistry. It is also made from coal as a direct product. It is made today in the U.S. from coal in one plant. A project is underway now in South Africa to study the use of methanol as domestic fuel.

Once methanol reaches a country's shore for fuel use, it will start to generate wealth locally. A terminal owner will profit. The trucker who takes the methanol to the village will profit. At the village, a dealer will profit. The householder will carry his or her fuel home from the dealer just as he or she now purchases kerosene or purchases or gathers fuel wood to bring home. Bringing the methanol home will take minutes rather than hours and will require carrying a load of only 8 kg in a clean plastic safety container, while carrying fuel wood home typically involves carrying 15-20 kg of sticks on one’s back after spending 4 to 6 hours of labor to cull, cut and gather it. Replacing fuel wood with methanol will free the energy consumer's time and allow more time for gainful employment or other wealth producing enterprise.

When the areas surrounding villages can be reforested, a small local methanol plant can be built to make methanol from wood and other biomass, employing 20-30 people in the plant. However, it is in the plantation operation that most of the jobs will be created. It will take at least ten times the number of people employed at the plant to produce and deliver the plantation wood to the methanol plant. Indeed, the creation and operation of biomass plantations could provide abundant employment for people in rural areas, providing there is a crop to be harvested and a market sufficient in quality and value to accept the crop that is produced.

The first step in developing the methanol fuel system will be, in most instances, to import methanol. Simply replacing wood or biomass burning with the burning of methanol in a suitable stove will achieve a 5- to 6-fold reduction in CO_2 emissions from home cooking fires. Eventually, when methanol is manufactured from renewably harvested wood and biomass, the problem of CO_2 production will disappear entirely. Meanwhile, the use of imported (or locally made, if available) methanol from natural gas will provide the householder and the larger community with these bonuses:

(1) No increase in cost to the household if fuel wood and kerosene are already being purchased, and possibly some savings over these fuels,

(2) Complete elimination of smoke, fumes and soot,
(3) Reduction of CO_2 emissions, which in time may produce a tradable credit that, if monetized, could pay for the methanol fuel or its stove,
(4) Arrest of deforestation, encouragement of the replanting of forests, which will reduce soil erosion and general environmental degradation,
(5) A saving of 4 to 6 or more hours of labor daily, which, at 25 cents/hour, will pay for a family's daily methanol use in one hour with the remainder of the earnings available for other uses,
(6) Boosting of the local economy,
(7) Faster and safer cooking, and less fuel wasted because of the ability to control the stove,
(8) Laying of the groundwork for a future local fuel manufacturing industry and the infrastructure to support it.

All of this is possible because there is a new stove ideally suited for use with methanol. This is the ORIGO® stove manufactured by the ORIGO division of Dometic AB, a Swedish company. Mr. Bengt Ebbeson, an author of this paper, first developed the ORIGO stove in 1979. Since that time, the ORIGO stove has become one of the most popular stoves in the boat and recreational vehicle (RV) market where safety and cleanliness of the flame are held at a premium. Acquired by the Electrolux Corporation in 1986, the ORIGO stove and its company are now part of the newly formed Dometic company, which is constituted in part of the former alcohol appliance division of the Electrolux Corporation.

The ORIGO stove is *appropriate* technology for developing countries. It is a non-pressurized, alcohol (liquid fuel) stove that retains the alcohol in a manner that prevents spilling, leaking, fires and explosions. The stove is equipped with a refillable fuel canister containing a permanent, porous, refractory mass that absorbs the alcohol and makes it available to the flame by capillary action. Thus, the stove possesses excellent safety characteristics. The fuel canister is durable and will last the life of the stove (10 or more years), but can be easily replaced. Each canister holds 1.2 liters of methanol, sufficient for the cooking needs for a family of five for one day (on average).

The fuels for which this stove is designed are methanol and ethanol, both of which burn much cleaner than kerosene and are much safer than kerosene because they are miscible with and therefore easily extinguishable by water. Methanol out performs ethanol because of its superior inherent burning characteristics, and because it will produce neither soot nor trace amounts of eye-irritating aldehydes when it burns. The ORIGO burner mixes the alcohol fuel with air very effectively, producing a hot flame. The flame is adjustable, which allows the user to economize on fuel use. The efficiency rating of the burner exceeds that of a pressurized kerosene stove and approaches that of an LP gas stove (approximately 54%). The typical efficiency rating of a conventional solid fuel stove is 10% or less, and that of an improved solid fuel stove, 23 to 25% at best.

The ORIGO stoves that are built for the boat and RV market are too expensive for the developing country marketplace. However, Dometic has redesigned the stove to reduce the cost of its manufacture to less than half the cost of the boat and RV stoves. This economy stove will retain all of the safety and durability features of the more expensive stove. For example, it will be of all-stainless-steel construction and will be designed to bear the weight of a heavy cookpot. It will prove to be one of the least expensive stoves available in the developing world marketplace when the life of the stove is considered, that is to say, when the cost of the stove is amortized over its expected life.

To introduce these new stoves with their new fuel into a chosen area, a local NGO, a state, or a federal government sponsor is needed to facilitate the distribution and testing of these stoves on a trial basis. As one plans for the pilot testing of stoves, one needs to identify the methanol pathway from distant manufacturing plants to the villages where the stoves are to be pilot tested. Once the populace chosen for the testing is acquainted with the stoves and their use, the next step is to stimulate local entrepreneurs to take over stove and fuel distribution at the retail level. The stove manufacturer, Dometic AB, would initially take charge of the wholesale step required to make stoves and fuel available. Eventually, methanol companies could assume the fuel distribution business using local employees. They might also sell stoves at very low cost in order to promote the use of methanol fuel, similar to the way in which cellular telephones are promoted in order to obtain service contracts.

Once methanol use is underway for cooking, a next step is to introduce other appliances, such as appliances for refrigeration and air tempering/air conditioning. Dometic sells heat-operated refrigerators around the world. They are normally fueled by LPG, but kerosene is also used. They have been tested on methanol, which has proven to be the best of the three fuels. There are also alcohol-fueled lanterns now available, including a lantern that has been designed to serve as a cooking stand, thus permitting the recovery of heat for such useful purposes as water sterilization. The final step would be to use methanol fuel for electrical energy generation in the household, perhaps as a supplement to solar PV power. Methanol will be the chosen fuel for fuel cells, and it is an ideal fuel for small, clean-burning internal combustion engines.

The two keys to building this entire system are the methanol-burning stove and of course the methanol fuel itself. Both are available and both have been proven in use together. Should a country have excess ethanol, the ethanol can be blended in any proportion with methanol for use in the stove, refrigerator or lantern. If fuel cells are in use, however, only methanol, not ethanol, can be used in them.

The widespread availability of methanol and, now, the availability of the new ORIGO stove designed for developing country households represent, together, an opportunity to address the many problems of developing nations that spring from household energy use and unmet energy needs. Methanol itself creates the opportunity for us to bridge the gap between now, when we must rely on fossil fuels to meet the demand for household energy, and the time when we can perhaps satisfy that demand sustainably with biofuels. Today, we have much better ways to make the transition from forest depletion to forest sustainability than we did a century ago when we were dependent on coal and other dirty fossil fuels. We can now look to methanol from natural gas as the bridge to reliance on this same clean fuel, but derived from biomass.

CONCLUSION

Alcohols are by no means a complete solution to the need for convenient energy carriers; however, they can be an important part of the total solution both in the short and long range.

We should regard ethanol as a way to balance agricultural markets by using surplus and off-quality fermentable materials. Ethanol, however, can only emerge as a major domestic fuel when we learn how to manufacture it at relatively low cost from a large, sustainable resource that itself is relatively low in cost, something that we have not yet learned how to do.

For all practical purposes, the day when we can grow energy out of the ground on a very large scale at relatively low harvested and delivered cost is still far away. As time elapses, the real costs of fossil fuel will rise while the costs of plantation-grown biomass will come down.

Methanol, unlike ethanol, is relatively low in cost now and is derived from an enormous resource base, natural gas. This resource may last well over a century if we learn how to exploit the so-called unconventional resources of gas. From conventional gas resources, we estimate at least a half-century of reliable supply. We have shown how methanol can readily be made from biomass and that it is now being made from lignite, which closely resembles wood in composition. Methanol should be regarded simply as a way to package the clean energy of natural gas so that it can be distributed where it is uneconomical or impracticable to distribute and use gas. The best example of this is the use of methanol in developing countries as a household fuel, first for cooking and then for other needs such as lighting, refrigeration and the production of electrical energy by small fuel cell power packages or internal combustion engines. In some cases, even when natural gas is available, the use of methanol is preferable, as in the case of methanol fuel cells. Eventually, methanol will become the hydrogen carrier used in package methanol reforming plants installed in service stations to produce compressed hydrogen for use in later generation passenger vehicles designed to run on hydrogen rather than methanol.

As we move forward to convert ever lower-grade fossil fuels and biomass in clean processes to liquid fuels and hydrogen, the extreme flexibility of carbon monoxide–hydrogen chemistry will become increasingly apparent. If hydrogen is some day low enough in cost to be produced from non-carbon sources, then we can employ the reaction:

$$CO_2 + 3H_2 = \underset{\text{Methanol}}{CH_3OH} + H_2O \qquad \text{Reaction [6]}$$

This reaction can use the small amount of CO_2 rejected when fossil fuels or biomass are converted to methanol. Or, it can be operated by recovering CO_2 from the air, just as plants do.

If we wish to make conventional hydrocarbon fuels, these can be made directly from CO and H_2 or indirectly by converting methanol to gasoline. This has been done on a commercial scale in New Zealand. (This plant was eventually converted to the production of methanol when the price of crude oil dropped and remained down; however, it could be reversed again to produce gasoline if the price of crude oil were to stay above $30 per barrel.)

When Nature gave us the wonders of organic chemistry, we were extraordinarily fortunate to have CO/H_2 chemistry with its 99% selectivity to methanol included in that gift. It remains to be seen how wisely we will use that gift. Our challenge is to convert raw energy into usable forms. One cannot put a lump of coal, a gallon of crude oil, a canister full of natural gas or a half day of sunshine into a gasoline tank or an electric generator. The challenge, once we develop a raw energy resource base that is reliable, is in the conversion step. Such conversion processes must be clean, efficient, use as little capital as possible, and make a product we can distribute and use conveniently and safely without harm to our environment. This is no small challenge. Our options are limited. Methanol is one of our very best options.

We dream of the day when our single option can be hydrogen. When that day comes, each methanol plant we build can readily be converted to a hydrogen plant. This is just one more indication of the tremendous flexibility provided to us by methanol as an energy carrier.

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