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Methanol Fact Sheets

Acc027

METHANOL: REFORMULATED NATURAL GAS

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METHANOL AS A FUEL

Uses as Fuel –

Methanol is an alternate fuel for transportation and other applications. For example, M100 is being used in compression ignition engines; M85 in spark ignition engines.

The convenience of methanol transport fuel as a liquid should not be overlooked. People are familiar with the procedures for storing and refueling gasoline, and everyone is used to handling liquids. The infrastructure for distribution of methanol will be the same, essentially, as gasoline. Other alternative fuels do not enjoy these advantages.

Other applications of methanol include its use as a clean–burning fuel for the generation of electric power in turbines, boilers and fuel cells.

Methanol Manufacture –

Methanol production benefits from the ability to draw on a variety of feedstocks. Natural gas is by far the most common feedstock, accounting for about 75% of worldwide methanol capacity in 1991. Other feedstocks used today include petroleum fractions and coal. There is growing interest in producing methanol from biomass, particularly landfill and municipal waste.

Modern commercial scale methanol production is based on synthesis gas (hydrogen and the oxides of carbon). The natural gas feed is steam reformed to yield the synthesis gas mixture, which is then converted to methanol in the presence of a metallic catalyst.

Production Economics –

The major components of methanol costs are plant construction costs, which are significantly affected by location, and manufacturing costs, particularly the cost of the natural gas feedstock.

For plants located in industrially developed sites, such as the U.S. Gulf Coast, the level of capital investment is the lowest. Lesser developed industrialized sites require larger investments. Typically, the highest investments are required for locations with offshore gas.

Considering the higher capital cost for an offshore location and the cost of shipping methanol to the U.S., domestically produced methanol can be competitive with offshore facilities where gas prices are typically lower than U.S. prices.

For a large scale, U.S. Gulf Coast facility using current state–of–the–art technology and a natural gas cost of $2.00/million BTU, the total production cost of methanol fuel has been estimated at $0.35/gallon exit the plant site; of this, $0.18/gallon is natural gas cost; $0.11/gallon is capital recovery cost, with recovery at 20% of total capital investment.

Because the energy content of M100 is half that of gasoline on a liquid volume basis, the equivalent total production cost on a gasoline basis is about $0.70/gallon. However, since the combustion efficiency of methanol is about 10 percent higher than gasoline, the equivalent gasoline cost becomes about $0.63/gallon.

The energy efficiency of the conversion of natural gas to methanol is about 65% at the present time. Further improvements in the process technology are continuously being developed.

Methanol and the National Energy Strategy –

With abundant natural gas, coal and renewable resources in the U.S., using methanol as a fuel is consistent with the Natural Energy Strategy of reduced dependence on potentially unreliable energy suppliers.

The objective of the U.S. National Energy Strategy, as established by President Bush in July, 1989, is:

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"...achieving balance among our increasing need for energy at reasonable prices, our commitment to a safer, healthier environment, our determination to maintain an economy second to none, and our goal to reduce dependence by ourselves and our friends and allies on potentially unreliable energy suppliers."

Every aspect of this praiseworthy objective can be achieved through the use of methanol as an alternative fuel.

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Methanol & Human Health

What is Methanol?

Methanol or wood alcohol is the simplest alcohol. It has been used as a chemical intermediate and solvent for 100 years and is widely used in consumer products such as gas line antifreeze and windshield washer fluid.

Where is it Found?

Methanol is naturally found in many fruits and fruit juices in low levels. It is also a breakdown product of a well–known artificial sweetener used in soft drinks.

Will it Cause Blindness?

Methanol has been reported to cause blindness in man after drinking a few ounces in a short period of time without subsequent medical treatment. Blindness from exposure by inhalation of vapors or by absorption through the skin is very unlikely.

Does it Cause Other Health Effects?

At low levels, methanol is safely metabolized by humans. Its effects have been well studied in both animals and humans. Methanol is not a carcinogenic, reproductive or mutagenic hazard. It is not a hazard to the fetus. High inhalation exposure may cause headache and other reversible effects.

Is it Safe?

Methanol is a safe chemical if reasonable care is taken. Drinking of methanol must be avoided. If spilled on the skin, it should be washed off. Use in well ventilated areas and keep away from flames or sparks.

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Methanol & Safety

Fuel Use –

Pure methanol (M100) and methanol blended with 15% gasoline (M85) are both used as fuels. Both methanol and M85 have been used safely for a number of years by the racing industry and in vehicle demonstration fleets around the United States and the world.

Fire Hazard –

Methanol is a flammable liquid and, as such, represents a fire hazard. However, when compared to gasoline, hazard assessments by the U.S. EPA have confirmed that the use of methanol or M85 would result in a much lower frequency of vehicle–related fires and a lower hazard to people and property when a fire does occur. The bases for these findings are that methanol has fuel properties that make it more difficult to ignite than gasoline and, when ignited, methanol burns in a more controlled manner with less heat and smoke generated than with conventional fuels.

Fuel Tank Flammability –

Methanol vapor can form a combustible mixture with air in an enclosed fuel tank. Simple modifications to the fuel tanks or the addition of a volatile additive, such as gasoline in M85, eliminates this possible hazard.

Flame Visibility –

Methanol burns with a barely visible flame in bright sunlight, but in most situations a methanol fire would be visible. M85 produces a flame of adequate visibility under normal lighting conditions.

Detection –

Because of methanol's low odor, taste, and lack of color, detection of its presence is more difficult than with currently used fuels. Suitable additives to give methanol a distinctive color, odor and taste are being investigated. Added gasoline is currently serving this function when necessary.

Smoke Hazard –

Methanol burns with little or no smoke and M85 produces only low levels of smoke. This results in a significant safety benefit, since it reduces the risk of smoke inhalation injury and allows for increased visibility around the fire when compared to conventional fuels. Increased visibility should allow personnel to better escape the fire, for faster rescue of fire victims and for increased ease of fire fighting.

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Methanol in the Environment

Methanol is widely available and has been used on a large scale for a long time. It is produced, stored, transported, and used in a wide variety of applications throughout the world. Its use in transportation and other fuel applications does not present any unusual problems and, in fact, offers significant environmental benefits when compared with petroleum fuels.

Physical Properties –

Methanol is a clear, low viscosity (similar to water) liquid. It does not have a strong odor, taste or color and, consequently, is not readily detected in the environment. For fuel applications, methanol additives are being considered to impart odor, taste and color.

Spills –

Although disturbances to marine, fresh water, or terrestrial eco–systems can occur with a methanol spill, methanol is removed quickly from habitats by both biological and physical processes. A marine or land spill from a tanker would not incur any significant environmental damage because:

1. Methanol is completely soluble in water.
2. Methanol is readily consumed, both aerobically and anaerobically by a wide variety of marine and terrestrial microbes.

Thus, methanol is quickly rendered harmless by its rapid dilution in water and biodegradability. Unlike petroleum products, methanol's high solubility prevents its mechanical removal from aquatic systems but, in general, dispersion, dilution, degradation and the relative ease of complete evaporation will readily reduce methanol concentration to well below toxic levels. Therefore, in comparison to petroleum fuels, a methanol spill will result in minimal consequences to the environment.

Atmospheric Emissions –

Atmospheric emissions of methanol are not biologically significant. Little disruption of plant or animal physiology is expected at anticipated levels of emitted methanol during production, storage, transportation, fueling or usage. However, both acute and chronic exposures to elevated concentrations may be harmful to a number of animal species.

Clean–up Costs –

In the case of a major spill, the physical and biological properties of methanol avoid several of the costs and losses expected in a petroleum fuel spill. In a major petroleum fuel spill near a coastline, costs may include expenditures for containment of the spill, collection of the spilled material and dispersal of any chemical surfactant that is used. In addition, some components of oil last for a long time which may lead to the loss of animal and plant life. In the case of a methanol spill, dilution and rapid degradation lead to a much lower loss of animal and plant life than in a petroleum fuel spill.

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Methanol & Car Emissions

Methanol offers substantial benefits in reduced smog formation via M85 for flexibly fueled cars (FFV) or M100 for dedicated cars.

- Most major automobile manufacturers have developed flexibly fueled cars capable of running on M85, gasoline, or any mixture of the two.

- These vehicles, when operated on M85, can achieve significant overall reductions in exhaust pollutants, together with around 10% increase in performance.

- Development work is underway on M100 dedicated vehicles which offer the potential for even better air quality benefits and performance improvements.

- According to the California Air Resources Board (CARB), the ozone forming reactivity (a measure of its propensity to form smog) of methanol is only 41% that of gasoline emissions.

- Although frequent reference is made to "the M85 emission standard," this is a meaningless concept, first of all because improvements in engine technology are taking place at a rapid pace, and secondly because the composition of M85 is still subject to variation. For example, using reformulated gasoline as the gasoline component should lead to an improvement in M85 emissions.

- For the sake of both simplicity and perspective, it is useful to describe exhaust emissions with reference to the emission categories proposed by CARB.

- Formaldehyde can be produced from methanol under certain combustion conditions. Appropriate technology has been developed such that current methanol vehicles achieve satisfactory levels of formaldehyde.

- It is estimated that 180,000 transition low emission vehicles (TLEV) will be required in 1995 for Southern California to meet CARB emission requirements. A number of major car manufacturers is planning to have methanol flexibly fueled vehicles ready to meet the new standard. Ford, for example, have announced they will build 2500 methanol Taurus vehicles in 1992 that will meet the TLEV standard.

- Various approaches are being investigated to achieve even lower emission levels, which include fitting an electrically–heated catalyst to an M85 FFV and developing an M100 dedicated vehicle. Laboratory tests indicate that the ultra-low emission vehicle (ULEV) standard is achievable by either of these means.

CARB AUTO EMISSION STANDARD CRITERIA (g/mile)

	Non–Methane Hydrocarbons	Carbon Monoxide	Nitrogen Oxides	Benzene	Formaldehyde
Current	0.250	3.4	0.4	—	—
TLEV	0.125	3.4	0.4	—	0.015
LEV	0.075	3.4	0.2	0.002	0.015
ULEV	0.040	1.7	0.2	0.002	0.008

TLEV: Transition Low Emission Vehicles (Can be met easily by current M85 Flex–fuel vehcles.)

LEV: Low Emission Vehicles (Will be met by the next generation of flex–fuel and dedicated M85 vehicles.)

ULEV: Ultra Low Emission Vehicles (Can be met by M100 dedicated and M85 flex–fuel vehicles equipped with electrically heated catalysts.)

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Methanol & Diesel Emissions

Methanol has a simple molecular structure and because it contains oxygen it is extremely clean-burning as a fuel for diesel engines. Methanol results in smokeless combustion and levels of nitrogen oxides (NOx) only one-third of the 1993 EPA standard.

- A commercially available diesel engine (Detroit Diesel 6V92) achieves reductions in both particulate and NOx emissions to one-third of the 1993 EPA requirements for these emission products.
- Methanol diesel engines have demonstrated commercial reliability and service. Over 100 methanol diesel buses were in operation across North Americas in 1991, with 500 buses expected in 1993. By mid-1992, methanol diesels had accumulated more than 5 million miles in regular service.
- The Detroit Diesel 6V92 is the first clean fuel engine to be certified by the EPA for public use.
- Existing diesel engines can be modified to operate on ignition improved methanol with significantly reduced emissions over regular diesel fuel.

*TRANSIT BUS EMISSIONS (g/BHPhr) **

	NOx	Particulates	Hydrocarbons	Carbon Monoxide
1991 Diesel Fuel	4.77	0.22	0.43	1.85
1993 Federal & 1991 California Coach Standards	5.00	0.10	1.30	15.50
1992 6V92 M100	1.70	0.03	0.08	2.00
1992 6V92 M100 + 1% AVOCET	4.00 **	0.04	0.22	0.61
1996 EPA Standard	4.00	0.05	1.30	15.50

** Source: Detroit Diesel Corporation*

*** Unoptimized for low NOx*

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Ignition-Improved Methanol

In order to function as a straightforward replacement for diesel fuel without a special engine design, methanol vapor requires the use of an ignition improver. One such additive, AVOCET, has been widely tested in the U.S., and engines using AVOCET/methanol have been shown to be cost effective in achieving substantial reductions in NOx and particulate emissions. Even converted diesel engines have been found to achieve standards close to the most stringent levels required for new engines powered by alternative fuels. At the same time, energy efficiency, at least as good as diesel fuel, and equivalent reliability have been obtained. This technical versatility allows methanol to offer the option of converting all existing diesel vehicles to clean fuel, as well as new vehicles.

Emissions Results –

Test results show the use of a catalyst with AVOCET/methanol fuel can achieve emissions reductions of up to 93 % for CO, 76 % for particulates (with the total elimination of black smoke), 49% for NOx and 20% for aldehydes, compared with state-of-the-art diesel engines.

Fuel Costs –

Fuel methanol pricing is estimated at $0.45 per gallon. The use of AVOCET involves incremental costs of $0.23 per gallon methanol fuel in the development stage at 2% addition, and $0.09 per gallon methanol fuel for large-scale demand at 1% addition. This moderate added cost is compensated by gains in fuel economy and reduced maintenance cost.

Fuel Economy/Energy Efficiency –

AVOCET/methanol vehicles have achieved 43.893 BTUs/mile compared to 45.676 BTUs/mile for diesel control vehicles (1 gallon diesel = 2.2 gallons methanol).

Bus Conversion Costs

Costs associated with the conversion of urban transit buses on an assembly-line basis range from $6,000 to $10,000 per vehicle, while one-off conversions are estimated at $15,000 to $20,000 per vehicle.

Operations and Maintenance Costs

California's experience indicates the life cycle of methanol/AVOCET engines to be at least comparable to diesel. Maintenance costs (oil change intervals, tune-up, etc.) are comparable to diesel. Until low cost fuel methanol is available from large-scale facilities, the only additional cost of this clean and practicable technology is likely to arise from the current price difference between diesel and methanol.

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Formaldehyde Emissions

Formaldehyde can be produced from methanol under certain combustion conditions. Appropriate technology has been developed to the point where acceptable formaldehyde emission limits can be readily achieved by current methanol vehicles.

Passenger Cars –

The California Air Resources Board (CARB) has established a maximum level of 15 mg of formaldehyde per vehicle mile starting in 1994. Although some of the early FFVs had formaldehyde emissions 3 to 4 times this level when operating on M85, major advances have since been made in catalyst technology and emission testing of current FFVs shows that they can meet the 15 mg/mile requirement.

It is interesting to note that pre–1982 gasoline vehicles also tended to have high tailpipe emissions of formaldehyde. In addition, the EPA has stated that ambient formaldehyde levels from gasoline vehicles are derived from two sources:

- directly from tailpipe emissions
- indirectly from the action of sunlight on hydrocarbon tailpipe emissions

Formaldehyde emissions from methanol vehicle tailpipes still tend to be higher than from gasoline tailpipes, but the indirect formaldehyde emissions are far less, due to the much lower photochemical reactivity of methanol. When both these effects are taken into account, methanol vehicles at the present time produce about the same total amount of formaldehyde as gasoline vehicles.

Diesel Engines –

Experience with the Detroit Diesel 6V92 engine indicates that with an appropriate catalyst the formaldehyde tailpipe emissions can be brought down to a very low level. For example, whereas CARB has suggested a standard of 0.1 g/BHPhr, the 6V92 engine has achieved a level of 0.06 g/BHPhr, which is slightly less than the formaldehyde produced by diesel fuel.

Health Hazard Information – Cancer Risk

Formaldehyde is a component of normal human metabolism. It is also widely encountered in nature. It is rapidly metabolized to formic acid and eventually to carbon dioxide. If the body is exposed to abnormally high concentrations of formaldehyde, acute toxic effects can be experienced. Such concentrations cannot be attained via vehicle emissions.

Toxic effects occurring after formaldehyde exposure are attributed primarily to its interactions with contact tissue. The major non–cancer effects posed by formaldehyde are due to sensor irritation (i.e. of the eyes nose and throat) and to cellular changes. The irritation effects generally occur in humans at concentrations above 1ppm. Because of its high chemical reactivity and rapid rate of metabolism, inhaled formaldehyde is not transported into the body from the site of contact at least at environmental concentrations.

Formaldehyde is classified as a Group B1 (probable human carcinogen) by the EPA guidelines. Studies of cancer incidence among workers, in a wide variety of occupations, have failed to convincingly show carcinogenic activity of formaldehyde in humans.

EPA carcinogenic risk estimates for lifetime continuous exposure to 0.1, 0.5 and 1.0 ppm for formaldehyde are 3×10^{-5}, 2×10^{-4}, and 7×10^{-4}, respectively. For comparison, smoking ten cigarettes per day presents a significantly higher cancer risk of 2.5×10^{-2}.

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Global Warming

The vast majority of the world's man–made energy is based on the combustion of carbon–containing materials (coal, oil, wood, natural gas) to carbon dioxide (CO2) and water. Use of such fuels adds quantities of CO2 to the atmosphere to augment that which is already produced from respiration and other natural sources, such as volcanic eruptions and forest fires. At the same time, CO2 is being continuously withdrawn from the atmosphere via photosynthesis, dissolution in the ocean, fixation via shell–bearing organisms, and chemical combination with newly formed rocks. There is evidence that atmospheric CO2 has been increasing over the last 50 years because the rate of its production is currently greater than its rate of disappearance. It is estimated that CO2 emissions of man–made origin contribute about 5% of the planetary production of CO2.

Increasing CO2 can be linked to global warming because the sun's radiant heat to the earth is received as short wavelength infra–red rays to which CO2 is transparent. This radiation is converted by the earth's surface to long–wavelength infra–red rays to which CO2 (and the other so–called Greenhouse Gases) is opaque, i.e. they are absorbed as heat. More CO2 means less heat is radiated back into space and so the earth's atmosphere may be warming up. In this way, man–made CO2 is responsible for about half of the greenhouse effect caused by gases resulting from human activities.

Although the case for global warming is not completely proven and there is even debate concerning the benefits which higher CO2 may bring via increased crop yields, prudence suggests we should slow down CO2 production by:

- Using less fuel.
- Using fuel more efficiently.

until more knowledge of global warming is gained or new non–carbon energy sources are discovered. The clean alternative transportation fuels have been scrutinized to determine their sensitivity to CO2 emissions compared with existing technology, even though CO2 from transportation fuel is only a very small fraction of total existing man–made CO2 emissions (<5%).

The following table illustrates the greenhouse gas emissions performance of various alternative transportation fuels measured against conventional gasoline/diesel on a "cradle–to–grave" basis, i.e. considering all inputs and outputs in the fuel life cycle from production to use. Of the alternative fuels, only natural gas and methanol derived from natural gas offer any reduction of CO2 generation.

To conclude, realism dictates that carbon–based fuels will be a fact of life in the transportation sector for the medium future, and only small global warming benefits can be obtained from alternative fuel use. Long–term, the only energy sources having minimal greenhouse effects and which will be available include solar, hydroelectric, geothermal, wind and nuclear. Each of these possesses serious limitations either in quantity, cost or environmental penalties. Until these limitations are overcome, the best policy will continue to be conservation and efficiency improvements.

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Lifetime Cycle Emissions of CO_2: Alternative Transportation Fuels Compared with Gasoline

Fuel Type	Much Worse	Slightly Worse	Neutral	Slightly Better	Much Better
Diesel (1)				X	
Natural Gas (NG)				X	
Methanol from NG(2)				X	
Methanol from Coal(3)	X				
LPG(4)			X		
Ethanol(5)	X				X
Hydroelectiricity					
Coal–fired Electricity(3)	X				

(1) Diesel engines are more efficient than gasoline engines, and so emit less CO_2 per power output unit. Alternatively fueled diesel engines therefore hold great promise especially when used to replace gasoline engines.

(2) The Environmental Protection Agency has pointed out that using flared natural gas to produce methanol would reduce CO_2 levels. A further, though modest, reduction would be achieved by expanding the capacity of many existing methanol plants via CO_2 injection.

(3) Electricity or methanol derived from coal lead to substantial increases in carbon dioxide. Fortunately, only about 2% of the world supply of methanol is derived from coal.

(4) Of the alternate fuels, since LPG is neutral, only vehicles operating on natural gas or methanol made from natural gas offer any reduction in CO_2 generation.

(5) Ethanol requires considerable amounts of fossil fuel for its manufacture (see OTA Report E–364 1990).

The following report is highly recommended for further reading: "Greenhouse Gas Emissions From Alternative Fuels," by Wells et al, Resources for the Future, October 3, 1991.

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Distribution Infrastructure

Impact on Fuel Market –

Methanol is at present a world commodity chemical with the current total demand in excess of 20 million metric tons. The development of a transportation fuel market has the potential to bring about a significant increase in methanol demand. For example, one scenario that is being suggested is a 5% penetration of the U.S. gasoline and diesel market by the year 2010. To achieve this will require a tripling of the current world production of methanol. It is anticipated that a significant amount of this increase will be supplied from North America.

Quite apart from the challenge of increasing supply by this amount, such a development would make it possible to take a somewhat different approach to the transportation of methanol from plant site to the fuel market.

Methanol is currently transported overland by truck and rail and by water using barges and tankers up to about 35,000 dead weight tons (DWT). At the present time, pipelining methanol is not viable for two reasons.

- the volume of methanol is insufficient
- the level of purity required for chemical applications cannot be maintained

These considerations no longer apply to methanol as a transportation fuel since purity requirements are less severe and the increased volume will justify pipeline shipments.

Methanol by Pipeline –

Methanol pipeline shipments have been demonstrated in Canada in two quite distinct trials. In each case the quantity shipped was the same — 4,000 metric tons — and the starting point was in the vicinity of Edmonton, Alberta, but the two pipelines were quite different.

Both shipments were made in 1986, the first from Edmonton, Alberta to Bumaby, British Columbia via the Trans Mountain crude oil pipeline, a distance of 1,146 kilometers (716 miles). The second shipment was made using the Cochin Pipeline which is primarily used for natural gas liquids and is, therefore, a clean products pipeline. This second shipment went a distance of 2,928 kilometers (1,819 miles).

Both trials indicated that methanol can be shipped successfully by pipeline and that the quality of the delivered product will be satisfactory for fuel applications. This is substantiated by the following data:

	@ Edmonton	@ Burnaby
Methanol Content %	99.99	99.68
Hydrocarbon Content %	0	0.29
Water Content %	0.01	0.02
Non-Volatiles %	0	0.01

In other words, the level of impurities in the Trans Mountain shipment was only 0.32%.

Super Tankers –

As with pipeline shipments, methanol as a transportation fuel means that greater flexibility can be exercised in maritime shipments because of higher volumes and lower purity requirements. Thus, as the fuel market develops the utilization of larger vessels, 100,000 DWT or greater, will become justified and ultimately the shipment costs of methanol will become equal to those of crude oil.

Conclusions –

Pipeline shipments, larger tankers and less stringent purity requirements, will all result in significant reductions in methanol shipping costs.

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Methanol Availability

Current and Planned Plants

Most U.S. methanol plants are located near the abundant natural gas reserves found in Texas, Louisiana, and offshore in the Gulf of Mexico. Production capacity in Texas and Louisiana currently totals about 1.4 billion gallons per year, which represents 80% of the U.S. total of just about 1.6 billion gallons per year. To meet anticipated future demand for cleaner fuels, another .5 billion gallons of annual capacity will soon be added through several projects to convert existing idle hardware or build major new methanol plants. At least two major new plants and several smaller plants are undergoing serious consideration.

Imports

To supplement domestic production, the U.S. imports about 0.4 billion gallons annually, 65% of which currently comes from Canada, while about 13% originates from Trinidad. This is expected to increase when Trinidad's production capacity doubles beginning in 1993.

Future Plants and Suppliers

With the prospect of increasing future demand for methanol as a fuel, it is likely that new U.S. capacity will continue to be added based on ample supplies of reasonably–priced domestic natural gas.

As a freely traded international commodity, methanol is obtainable at any port or terminal, or can be supplied via rail or road tanker to any destination in North America. Since it may also be pipelined, there is an assurance of competitively available future supplies to the contiguous United States.

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