# A THEORETICAL STUDY ON DI-METHYL ETHER: AN ALTERNATIVE FUEL FOR FUTURE GENERATIONS

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## Abstract:
Dimethyl ether (DME) has been considered a potential and promising energy alternative for petroleum subproducts due to its good burning characteristics, and to its high cetana content which is superior to that of diesel. Furthermore, DME can be considered a cleaner fuel than diesel. DME can be produced by dehydration reaction of methanol by using solid catalysts in catalytic reactions. This report consists of a pre-preliminary study of dimethyl ether which is alternative fuel. Dmethyl ether is used in different applications. The important features of dimethyl ether, applications, methods of preparation, the factors should be consider at the time of plant construction and the safety methods are discussed here. This study shows dimethyl ether is a future energy source.

**Key Words: Dimethyl Ether, Alternative Fuel, Cetane Number, Process Technology and Safety&Health**.

## 1. Introduction
The general formula of the Ethers is $C_nH_{2n+2}O$ and its general structures is R-O-R (dimethly ether has a chemical formula, $C_2H_6O$ or $CH_3OCH_3$). Ethers of the individuals are named according to the alkyl groups attached to the Oxygen atom. Historically, dimethyl ether derived from, methyl ethers of halogenated phenols have been identified in marine air samples from the north and south hemispheres. The components are tribromoanisole, pentachloroanisole, tetrachlorohydroquinone dimethylether. It has historically been used as a propellant in consumer products. It can be used in a wide variety of consumer applications, namely personal care (e.g., hairspray, shaving creams, foams, and antiperspirants), household products, automotive, paints and finishes, food products, insect control, animal products, and other related applications. It is commonly used in organic synthesis as a reaction solvent for systems requiring volatile polar solvents. A new and potentially large volume application of it is as a fuel Promising fuel applications include, LPG Blending and Substitute, Diesel Blending and Substitute, Power Generation, Acetylene Substitute. The structure of dimethyl ether has tetrahedral bond angle (like water with $sp^3$ hybridization) and the different names of dimethyl ether are DME, wood ether, Oxybismethane, Dimethyl oxide, Demeon, Dymel A, Prozone, Ice Blue, Blue Fuel, Holzether etc.

## 2. Properties
Appearance of dimethyl ether is a colorless gas with typical smell, chromatous gas which can be easily identified with specific smell of ether. It can be appeared in both the gaseous and liquid states having densities 1.97 gm/lit and 668 gm/lit respectively. The melting and boiling points are -138.5 ˚C and -23 ˚C; due to these low temperatures it can be stored in Spherical Tanks. It is inert, no corrosiveness and weak light when burning. Dimethyl ether reacts with sulphur trioxide to form dimethyl sulphate and also a process that converts dimethyl ether to gasoline range hydrocarbons or to lower olefins over zeolite catalysts also available.

## 3. Features (as an Alternative Fuel)
Dimethyl ether has features as a fuel. Some of them are discussed below,

### 3.1. Domestic Fuel
Domestic fuels used in large and medium cities in China are still mainly natural gas, coal gas and LPG (liquefied petroleum gas). DME is similar to LPG in property. Liquefied DME has many advantages as a domestic fuel. As DME contains oxygen, it burns completely with no residual liquid, and the tail gas conforms to the national environmental standard. As the pressure of liquefied DME can meet the requirements of LPG at normal temperature, it can be stored in LPG cylinders, share cookers with LPG and is safer than LPG in storage, transportation and use. Besides, DME can be blended with coal gas at any ratio to improve combustion properties and increase the heat value of coal gas.

### 3.2. Mixed Fuel
DME can also be used in alcohol/ether fuel (mixed fuel composed of DME, methanol and other components). Compared with alcohol-based fuel, alcohol/ether fuel has advantages. Alcohol-based fuel has a relatively low steam pressure and therefore needs preheating before use. Alcohol/ether fuel has no such defect. In addition, alcohol/ether fuel has higher heat value, moderate price and convenient application dissemination. Alcohol/ether fuel is however not as good as liquefied DME in safety and convenience.

### 3.3. Synthetic Fuel
DME is a synthetic fuel that is to diesel what LPG is to gasoline, while gaseous at ambient conditions it can be liquefied at moderate pressure. With a high cetane number, DME is clean-burning, sulfur-free, and with extremely low particulates.

### 3.4. Diesel Fuel
Use of DME as a diesel fuel replacement can reduce $NO_x$ emissions 90%. A dedicated DME vehicle might not require a particulate filter but would need a purpose-designed fuel handling and injection system as well as a lubricating additive.

### 3.5. DME for Cocking and Heating
DME can be blended with LPG (in a proportion of up to 20%) and used for domestic cooking and heating, without modifications to equipment or distribution networks. Growth in DME's use for domestic applications is expected to increase sharply as DME use and blending becomes more widespread within the large and growing LPG market – especially in developing countries where portable (bottled) fuel is providing a safer, cleaner and more environmentally benign fuel for cooking and heating.

### 3.6. Cetane Number of DME Fuel
Cetane number is the vol% of n-cetane present in the mixture of n-cetane and α-methyl naphthalien. Cetane rating is a measurement of the diesel fuel's combustion quality of during compression ignition. Cetane number of DME fuel is 55-56, compared to fossil diesel 42-48 and biodiesel 52-55. Higher cetane fuels permit an engine to be started warmed more easily.

### 3.7. Sulfur and Pollutions Content
DME is a pure substance, not the mixture of diverse hydrocarbons as fossil fuels. It is chemically free of sulfur also no other pollutions such as phosphorous and cancerous aromatic compounds-benzene and toluene. DME is almost nontoxic.

### 3.8. Vehicle Conversion
Most diesel engines are suitable for an DME conversion. We get the cost and environmental benefits of driving an DME vehicle immediately after conversion. Many service companies are specialized in convention gasoline engines to be able to run on propane –butane. Conversion diesel engines to run on DME are similar task. There may be computer tuning a little different.

## 4. Applications
DME has several industrial applications. Some of the applications are discussed below,

### 4.1. An Aerosol Propellant
Aerosol products (such as spray insecticides, styling gels, air scenting agents, spray coatings and adhesives) used great quantities of fluoro-chloro-hydro-carbons as propellants in the past. With the overall prohibition to the production and

use of fluoro-chloro-hydro-carbon, DME has gradually replaced fluoro-chloro-hydrocarbon and propane (butane) gas due to its features of easy volatility, no toxicity, no carcinogenicity and good water/alcohol solubility and become the fourth-generation propellant for the aerosol sector.

## 4.2. Refrigerant

DME used as a refrigerant (adding a certain amount of other assistants) has the advantages of low pollution and good refrigerating effectiveness. The consumption of DME in this sector will increase with technical advances.

## 4.3. Foaming Agent

The use of DME as foaming agent for polystyrene, polyurethane and thermoplastic polyester foam has already been developed in foreign countries. Foamed products have even pore size, great flexibility and improved pressure resistance.

## 4.4. Chemical Intermediate

In the synthesis of chemical products with high added value such as Dimethyl sulfate, Dimethyl sulfide, Dimethyl carbonate and polycarbonates. With the price rise of crude oil in recent years, the use of Dimethyl ether as a substitute fuel has become a market focus.

## 4.5. Laboratory Reagent and Solvent

DME is a low-temperature solvent and extraction agent, applicable to specialised laboratory procedures. Its usefulness is limited by its low boiling point (−23 °C), but the same property facilitates its removal from reaction mixtures. DME is the precursor to the useful alkylating agent, trimethyloxonium tetrafluoroborate. DME is a promising fuel in diesel engines, petrol engines (30% DME / 70% LPG), and gas turbines owing to its high cetane number, which is greater than 55 compared to diesel, which is 40–53. Only moderate modifications are needed to convert a diesel engine to burn DME. DME is being developed as a synthetic biofuel (BioDME), which can be manufactured from lignocellulosic biomass.

## 4.6. Power Production

DME has potential applications as a chemical building block. In addition, since the characteristics of DME are similar to those of LPG and given its higher heating value, it has been speculated that DME could be used in large scale power production. DME has a performance comparable to natural gas when used for the production of electric power, and it has been approved by manufacturers as a fuel for use in the gas turbines. DME is an efficient alternative to other energy sources for medium-sized power plants, especially in isolated or remote locations where it can be difficult to transport natural gas and where the construction of liquefied natural gas (LNG) re -gasification terminals would not be viable.

## 4.7. Cleaning Material

Given that DME is miscible with many resins and solvents, it is now being used as a cleaning material for laboratory systems and some high precision, high value added cleaning applications, such as in electronics. Different pathways to petro chemicals from dimethyl ether shown in Figure 1.

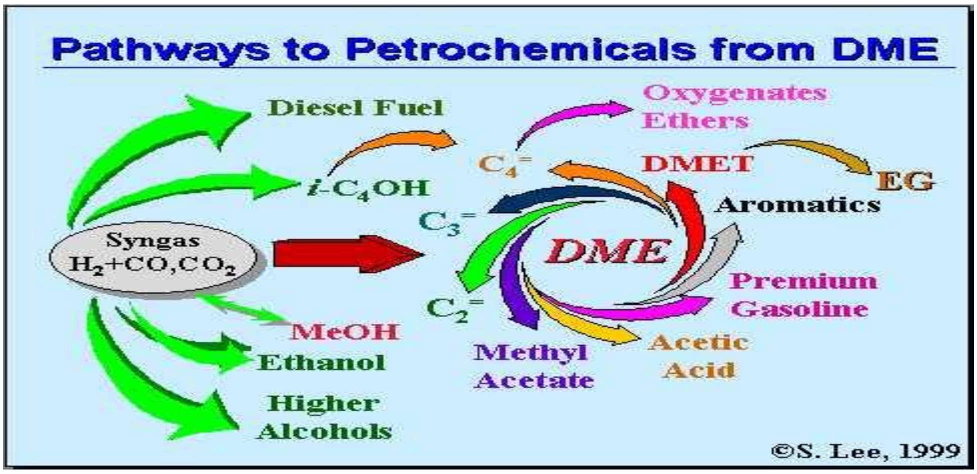


Figure 1. Pathways to petro chemicals from dimethyl ether

## 5. Manufacturing Process by Fenix Process Technology

DME can be produced by different methods. One of the methods which are used abundantly by industries is Fenix Process Technology.

### 5.1.FenixProcessTechnology

A process for production and recovery of DME by dehydration of methanol which significantly reduces the distillation duties associated to the preparation of the fresh methanol feed stock and/or the recovery of unconverted methanol for use as recycle feed stock to the DME production process while maintaining a high rate of conversion of methanol to DME.
In this method, we have two types of processes. They are

- Two-Step Process
- One-Step (Direct) Process.

### 5.1.1. Two-Step Processes

The only current commercial two step technology process in use for the production of DME is via fixed bed catalytic dehydration of methanol. Because the process is relatively simple, this method is commonly used because of the low capital investment required and the availability of feedstock. Currently, the production of dimethyl ether based on a two step process is offered by industries.

Methanol and shift catalysts are typically copper based. Increasing temperatures rapidly decrease catalyst activity so that isotherms need to be carefully controlled. Different types of catalysts are employed for methanol dehydration. Of these, the catalytic activity of g -alumina and silica-alumina catalysts has been investigated more thoroughly than most.

### 5.1.2. One-Step (Direct) Processes

Haldor Topsoe has developed a process technology for large scale production of DME via direct synthesis from natural gas, without having to first produce and purify methanol.

The direct synthesis of DME (or single step) process requires a dual catalyst system that acts as a methanol synthesis catalyst and a methanol dehydration catalyst in a single unit. In the 1990s, Air Products and Chemicals discussed the use of $Cu/ZnO/\ y\text{-}Al_2O_3$ shift catalysts as a single catalyst for single step processes.

### 5.2. Synthesis of DME from Methane

DME is produced in a minimum of two steps. First, hydrocarbons (predominant feedstock for DME production is natural gas) are converted into synthesis gas, a combination of carbon monoxide and hydrogen. The synthesis gas is then converted into DME, either via methanol (conventional process) or directly in one step. The predominant feedstock for DME production is natural gas. Current commercial synthesis gas technologies include steam methane reforming, partial oxidation, auto thermal reforming, and combined reforming. Technologies under development include compact reformers and ceramic membranes. The chemistry behind the formation of DME is shown in Figure 2.

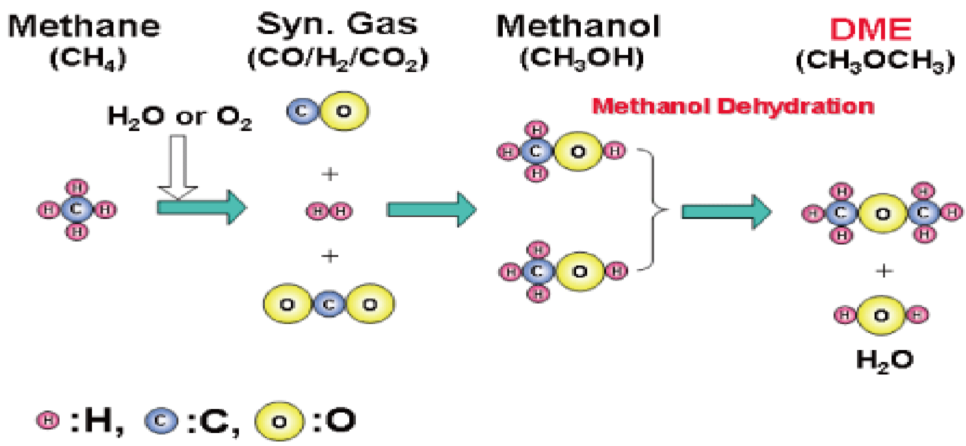


Figure 2. Chemistry behind the formation of DME

## 6. Plant Considerations

The location of the plant can have a crucial effect on the profitability of project, and the Scope for the expansion. Factors considerartion while selecting a plant site are:

- Transportation
- Source and costs of raw materials
- Prospective market for the products
- Corporation long range planning
- Water source –quality and quantity
- Special incetive
- Climate conditions
- Pollution requriements (Waste disposal)
- Utilities-cost,quantity,and realiability
- Fuel-costs,reliability,and availablity
- Amount of site preparation necessary(site condition)
- Construction costs
- Operating labor
- Taxes
- Living condition
- Corrosion
- Expansion possibilities
- Other factors

Three factors are usually considered the most important. These are the location of the markets, raw materials and the type of transportation to be used. The economic construction and efficient operation of a process depend on how well the plant and equipment specified flow sheet is laid out. The principal factors to be considered are:

- Economic consideration
- Construction and operation costs
- The process requirement
- Convenience of operation
- Convenience of maintence
- Safety
- Future expansion
- Modular construction

## 7. Safety& Health

Safety and health aspects of the personnel and equipment are important in the plant. A safe and comfortable working environment is essential for the efficient operation of the plant. Control measures are taken to prevent exposures and contacts to harmful or objectionable levels of contaminants. The organization will also have to consider loss prevention. The term Loss Prevention is an insurance term, the loss being the financial loss caused by an accident. This loss will not only be the cost of replacing damaged plant and third party claims but also the loss of earnings from lost production cost and lost sales opportunity. All manufacturing processes are to some extent hazardous, but in the chemical processes there are additional, special hazards, associated with the chemicals used and the process conditions.
The awareness of these hazards and their application of sound engineering practices to keep the risks associated to a minimum is an engineer’s job. As a consequence we will have to consider the characteristics like toxicity, flammability, chemical instability, reactivity, operating conditions, corrosive properties etc. in order to analyze the hazards and provide safe and healthy working conditions. Fire accidents, exposure to chemicals, explosions are some of the major hazards in the operation of the plant. The presence of various chemicals and there handling is very important and the relevant precautions to be followed in storage are mentioned subsequently in the material safety data sheets.

## 8. Conclusions

Use of DME has a major role in future due to decreasing of non renewable energy sources like petrol, diesel etc. The preparation, storage of DME is easier and which have more applications. Future world is based on the energy, so the use of DME is one of the options to regain energy sources.

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