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Status and Prospects for the Development of Synthetic Liquid Fuels

— Liquid Fuels Produced from Natural Gas and Biomass —

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1 Introduction

The latest forecasts suggest that oil will continue to be a major source of energy, with demand expected to increase at an average annual rate of 1.9% until 2020[1]. With the markets in China and India growing dramatically, the world's demand for petroleum products including LPG (Liquefied Petroleum Gas) is likely to outpace supply between 2010 and 2020, which will probably result in a surge in oil prices and disruptions in supply[2]. To prepare for such a tight oil market and help alleviate global warming and air pollution, it is therefore paramount that technologies be developed to convert natural gas, biomass and coal - each of which is more abundant than oil - into relatively environmentally friendly liquid fuels.

In some European countries, government initiatives are underway to produce environmentally friendly liquid fuels from natural gas, biomass and coal. These programs are designed to reduce greenhouse gas emissions, tighten regulations on vehicle emissions and improve fuel economy. Capitalizing on abundant biomass resources, the U.S. and Brazil are producing and promoting liquid fuels as a means to ensure energy security and promote domestic agriculture. South Africa, meanwhile, is converting natural gas and coal into liquid fuels for domestic consumption and exports to Europe and the U.S.

Likewise, efforts are underway in Japan to develop technologies to convert natural gas, coal and biomass into synthetic liquid fuels in accordance with the "Energy Basic Plan" (a plan announced in October 2003 that sets out priority technologies for oil, natural gas and coal) and the "Biomass Nippon Strategy" (a strategy announced in December 2002 that sets out key technologies for high-efficiency energy conversion). However, several problems have yet to be solved, e.g., high production costs, and a lack of fuel standards and demonstration projects for the infrastructures needed. The diversification of fuel sources improves compatibility among fuels and reduces geopolitical risks associated with energy supply. Such an approach is critical in diversifying primary energy supply sources and reducing the environmental burden associated with commercial fuels.

This report addresses five promising liquid fuels that could substitute for oil - i.e., dimethyl ether (DME), gas-to-liquid fuel (GTL fuel), methanol, bioethanol and biodiesel fuel (BDF) - examining the status of their development, consumption and challenges. Chapter 2 reviews the characteristics and development status of synthetic fuels, focusing on its security of supply, cost-effectiveness and environmental friendliness. Chapter 3 outlines technologies for using synthetic liquid fuels, focusing on the power generation, transportation, industrial, and consumer sectors. Chapter 4 describes the status in Europe, North America, Asia and other parts of the world. Chapter 5 summarizes challenges in developing and introducing synthetic liquid fuels. And, Chapter 6 presents policy recommendations for diversifying Japan's fuel mix.

2 Status of synthetic liquid fuels

This chapter discusses medium- to long-term trends in fuel demand, expected needs for oil alternatives, and the characteristics and development status of new types of synthetic liquid fuels.

2-1 Trends in fuel demand

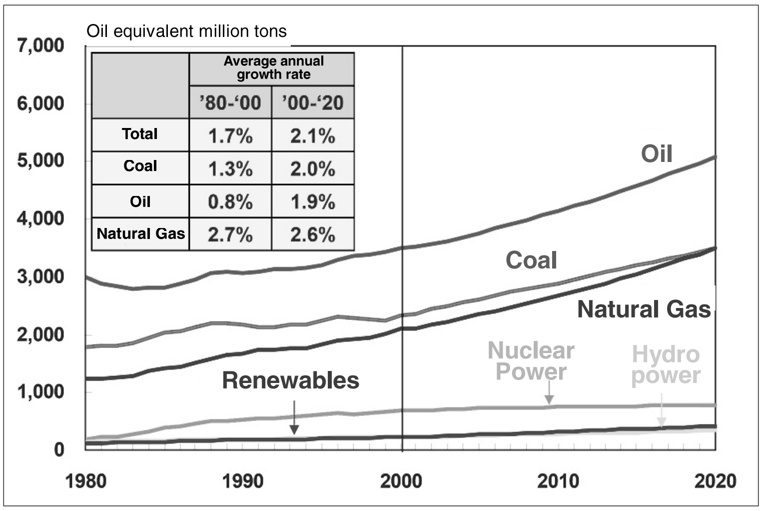
As shown in Figure 1, the world's fuel (primary energy) consumption is likely to increase at an average annual rate of 2.1% until 2020, far outpacing the average of 1.7% between 1980 and 2000. Oil continues to be a major source of energy, with consumption expected to increase by 1.9% annually until 2020[1].

2-2 Needs for oil alternatives

According to the “BP Statistical Review of World Energy (2003)”, the world’s proven oil reserves can sustain oil production for 41 years at current consumption rates. However, forecasts made by IEA, OECD, oil majors, etc. suggest that oil demand will outstrip supply by around 2015 due to growing demand in China and India, resulting in a surge in oil prices. As shown in Figure 2, the point of time when demand begins to outstrip supply (coupled with a decrease in supply and a surge in prices) is referred to as the “Roll-Over Point”[2]. A surge in oil prices and disruptions to supply are expected to take place.

It is therefore paramount that technologies be developed for converting natural gas, biomass and coal - each of which is more plentiful than oil - into liquid fuels.

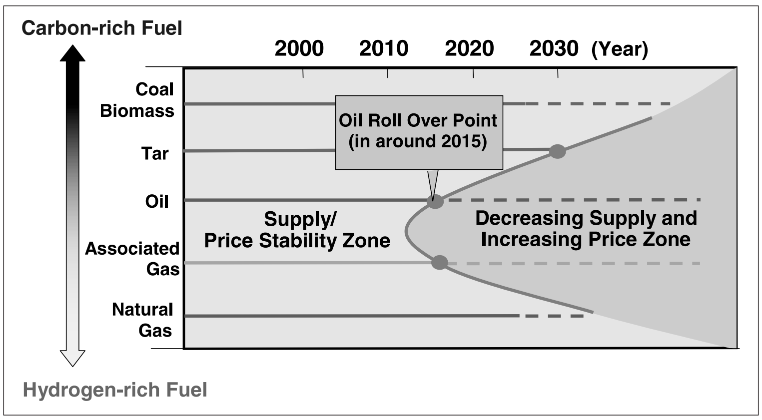
Figure 1 : Trends in world fuel demand



	Average annual growth rate	
	’80-‘00	’00-‘20
Total	1.7%	2.1%
Coal	1.3%	2.0%
Oil	0.8%	1.9%
Natural Gas	2.7%	2.6%

Source: Reference [1]

Figure 2 : Fuel supply-demand inversion curve



Source: Reference [2]

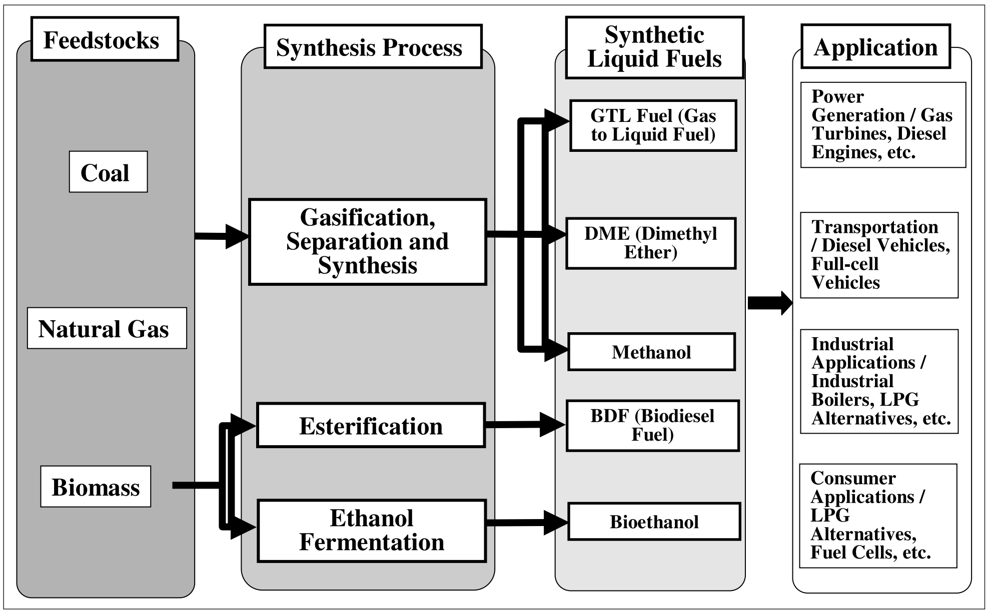
2-3 Characteristics and development status

Promising alternatives to oil include: (1) dimethyl ether (DME), (2) gas-to-liquid fuel (GTL fuel), (3) methanol, (4) bioethanol, and (5) biodiesel fuel (BDF). Figure 3 shows the processes of converting natural gas, biomass and coal into liquid fuels. Table 1 summarizes the advantages, disadvantages and handling characteristics of each oil alternative, their overall characteristics (production technology, supply stability, cost-effectiveness and environmental friendliness) and development status, all of which are described below:

(1) Dimethyl ether (DME)

Dimethyl ether (DME) is a clean fuel produced from a variety of resources such as natural gas, biomass and coal. It is a sulfur-free, highly ignitable and non-toxic gas at atmospheric temperatures and pressures, and can be readily liquefied through direct and indirect liquefaction processes*1. However, its calorific value and lubricity are lower than those of conventional light oil. Domestic consumption is estimated at 10,000 tons a year, mainly for use as a propellant. About 150,000 tons is consumed annually, worldwide. As for prospects for its future supply, projects led by Japanese companies (see Table 2)

Figure 3 : Synthesis process of liquid fuels and their applications



Source: Prepared by STFC based on references [3, 4, 5]

Table 1 : Characteristics of synthetic liquid fuels

Synthetic Liquid Fuels	Advantage	Disadvantage	Handling
DME	Ignitable, combustible and environmentally friendly	Adaptation needed for equipment, low in lubricity	Pressurized and liquefied for transportation and storage
GTL Fuel	Ignitable, combustible and can be distributed through existing facilities	Pegged to oil prices, low in lubricity	Can be handled like kerosene and light oil
Methanol	Stays in the liquid phase under normal temperature and pressure conditions	Toxic, low in calorific value	Can be handled like kerosene and light oil
Bioethanol	Carbon-neutral, renewable, environmentally friendly	Competes against food, highly water-absorptive, corrosive, degradable, low in calorific value	Measures needed to prevent water absorption
BDF	Carbon-neutral, renewable and can be distributed through existing facilities	Competes against food, component fluctuations low in calorific value	Can be handled like diesel fuel

Source: Prepared by STFC based on references [2, 6]

Table 2 : Commercialization plan for DME production (Excerpts)

Developer	Technology	Commercialization Plan
DME International (led by JFE)	Direct synthesis (slurry bed reactor), 250 degrees Celsius, 4-8 atm	37,000 t/y (planning phase), 910,000 t/y (market research phase)
Japan DME (led by Mitsubishi Gas Chemical)	Indirect synthesis (methanol dehydration)	1,830,000 t/y (planning phase), Australia
The Mitsui & Co. Group	Indirect synthesis	2,500,000 t/y (planning phase), Iran, etc.
Topsoe (Denmark)	Direct synthesis (fixed bed reactor)	Benchmark tests underway
Lu Tian Chemical Group Co., Ltd. (China)	Indirect synthesis (methanol dehydration)	50,000 t/y (commercialized), 1,000,000 t/y (planning phase)

Source: Prepared by STFC based on reference [5] and http://www.meti.go.jp/committee/summary/0002068/0001.html

are expected to produce a total of 4.7-6.4 million tons a year, using natural gas as a feedstock. However, this amount accounts for a mere 20% of domestic LPG consumption, which stood at 19 million tons in 2002 (equivalent to some 30 million tons of DME on a calorie basis); there is a long way to go before DME will substitute for LPG[6]. In the medium- to long-term, demand for DME could increase in response to growing demand for power generation fuels in certain parts of the world, particularly Asia.

The standard import price of DME for commercial power generation is set at ¥1.5-2.0 per 1,000 kcal, which is cheaper than light oil and LPG, or on a par with liquefied natural gas (about ¥2.0 per 1,000 kcal; an average of the actual costs over the past three years). However, the cost of DME may exceed that of LPG because of the need to build receiving terminals and renovate users' facilities, together with higher distribution/storage costs attributable to the low calorific value of DME. The production cost of DME should be reduced further.

On the environmental front, production of DME generates more carbon dioxide per unit calorie than do LPG and LNG, although the combustion gases of these fuels appear to contain a similar percentage of carbon dioxide*2. However, taking combustion efficiency into account, DME has an advantage over oil for power generation purposes, and is more efficient than diesel fuel and LPG for use in diesel vehicles. Moreover, unlike diesel fuel, it does not produce particulate matter, and hence can contribute to reducing air pollution caused by vehicle emissions.

(2) Gas-to-liquid fuel

Gas-to-liquid fuel is a highly ignitable synthetic hydrocarbon containing no sulfur or aromatics; it is produced from natural gas and coal, with light oil, kerosene, naphtha, etc. as byproducts. GTL light oil is expected to substitute for light oil as it can be distributed via existing light oil infrastructures. GTL fuel production is composed primarily of three processes: synthesis gas production, Fischer-Tropsch synthesis*3, and hydrocracking. The bulk of GTL fuel is produced by foreign oil majors*4 and various production technologies are in the pipeline, some of which are close to commercialization. In Japan, Japan Oil, Gas and Metals National Corporation (JOGMEC) set up a pilot plant (7 barrels/day) in September 2003 in cooperation with Chiyoda Corporation and Nippon Steel Corporation, while other projects have yet to take shape.

The world's total production currently stands at 147,000 barrels/day (Shell, Sasol, etc.), which is likely to increase when projects in the Middle East, etc. are completed in a few years' time. The dependence on Middle Eastern products may not decrease in the short term as they are produced from low-cost feedstocks. However, in the long term small- to medium-sized oil fields in Southeast Asia will likely start producing GTL fuel.

The supply price of GTL light oil is estimated a ¥10/liter higher than conventional light oil if low-cost Middle Eastern natural gas is imported. However, further cost reductions could be possible through economies of scale.

GTL light oil, when burned, releases less CO_2

than conventional light oil, but its production involves high emission levels, resulting in more CO_2 emissions overall. However, lower emissions of NOx and particulate matter may contribute to reducing vehicle emissions.

(3) Methanol

Methanol is produced through catalytic methanol synthesis, a process that converts synthesis gas into methanol. Demand for methanol as a chemical feedstock, remains strong. Methanol, when burned, does not produce SOx and particulate matter, but it is not in widespread use in Japan for liquid fuel because of its toxicity and low calorific value. About 700,000 tons of methanol (blended with gasoline) is consumed annually, worldwide (particularly in Brazil, the U.S. and EU). Although some 200 methanol-powered vehicles are on the road in the Kanto and other areas, the government's "Eco 2000 Initiative", which was designed to set up 2,000 methanol stations across the country by 2000, has yet to be accomplished.

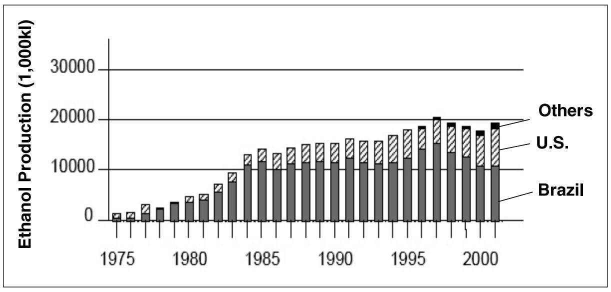
Because of its poor cost competitiveness and regulatory constraints, the chances are slim that methanol will be used widely as automotive fuel. However, it holds promise as a fuel for fuel cells for mobile information devices and motorcycles as it can readily be reformed [7]. Research is now underway to develop direct methanol fuel cells for mobile information devices.

(4) Bioethanol

Bioethanol is produced from energy crops such as sugar cane and corn through biochemical conversion. It is one of the renewable energy sources that do not increase the atmospheric CO_2 concentration (i.e., it is carbon-neutral), while it has some drawbacks such as corrosiveness to metals and rubber, and degradation due to moisture absorption.

Standards have been in place in Japan since August 2003 for the ethanol-gasoline blend ratio; up to 3% of the total. While use of this type of blended fuel has yet to become widespread in Japan, some 1.8 million kiloliters/year of ethanol

Figure 4 : Ethanol production in Brazil, the U.S. and others



Source: Prepared by STFC based on reference [6]

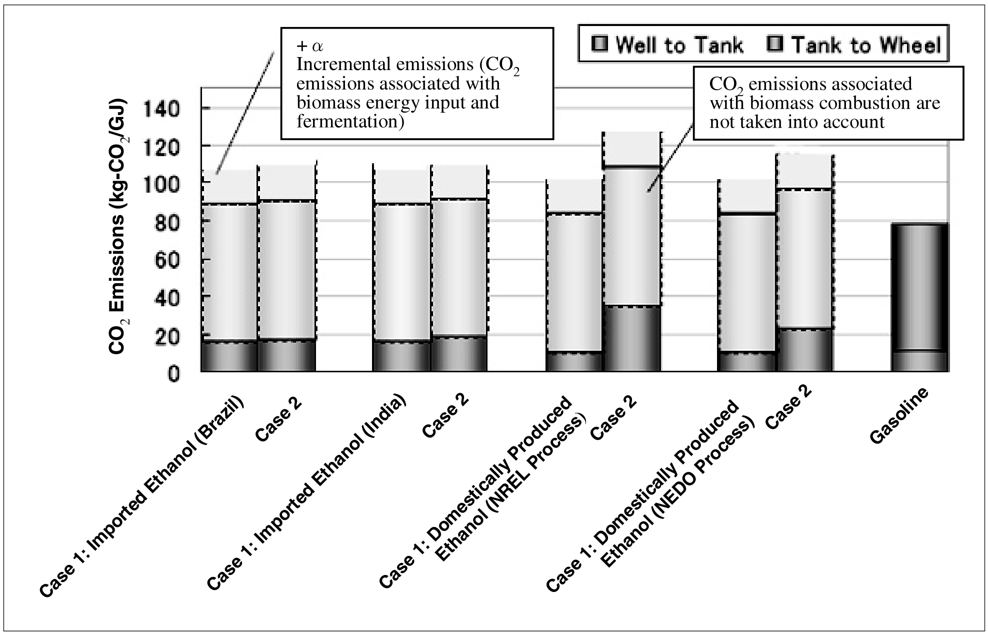
will be needed if three percent of gasoline is to be replaced with it (hereinafter referred to as "E3"). As is obvious from Figure 4 (Ethanol Production in Brazil and the U.S.), Brazil will most likely be the only country to have surplus export capacity for bioethanol. Domestic production of bioethanol is not commercially viable since its raw materials (sugar, starch, etc.) are used primarily for food production. Its current import price is somewhere between ¥40 and ¥50 per liter as against a wholesale gasoline price of ¥27 per liter. Moreover, bioethanol prices are susceptible to fluctuations in the raw materials market. For these reasons, arrangements such as long-term contracts with exporting countries are needed to ensure the supply of bioethanol at stable prices - a prerequisite to converting all gasoline into E3.

From the viewpoint of LCA (Life Cycle Assessment), as shown in Figure 5, CO_2 emissions of ethanol are estimated at 13-45% of those of gasoline since the emissions associated with biomass combustion are not taken into account[6]. However, gasoline, when blended with oxygen-containing organic compounds such as ethanol, produces various effects, both positive and negative: its combustion gases contain less carbon monoxide and hydrocarbon, but more NOx, aldehyde and fuel evaporation emissions. The ethanol-gasoline blend ratio is thus capped at 3% in Japan.

(5) Biodiesel fuel (BDF)

Biodiesel fuel (BDF) is comprised of fatty acid methyl esters, which are produced from fats

Figure 5 : Life cycle assessment of ethanol for its CO_2 emissions



"Well to tank" refers to CO_2 emissions associated with production (mining), transportation, and production (refinement); "tank to wheel" refers to those associated with combustion. Case 1 uses average values for variables such as feedstock yields and waste material occurrence density; Case 2 assumes that feedstock yields and waste material occurrence density are 15 and 50% lower, respectively, than the averages. The NREL and NEDO processes (homegrown ethanol production technologies) are both ethanol fermentation processes using wood biomass, research on which is underway at NREL (National Renewable Energy Laboratory) and NEDO (New Energy Development Organization). Assumptions for the calculation are based on the targets. LCA of gasoline represents accurate figures based on actual data on operating plants; that of biofuels involves scores of assumptions, showing rough figures. Of the figures discussed above, fossil fuel consumption outside Japan (including marine transportation fuel) is not included in Japan's greenhouse gas emission inventory. "Incremental emissions" in the chart cannot be quantified.

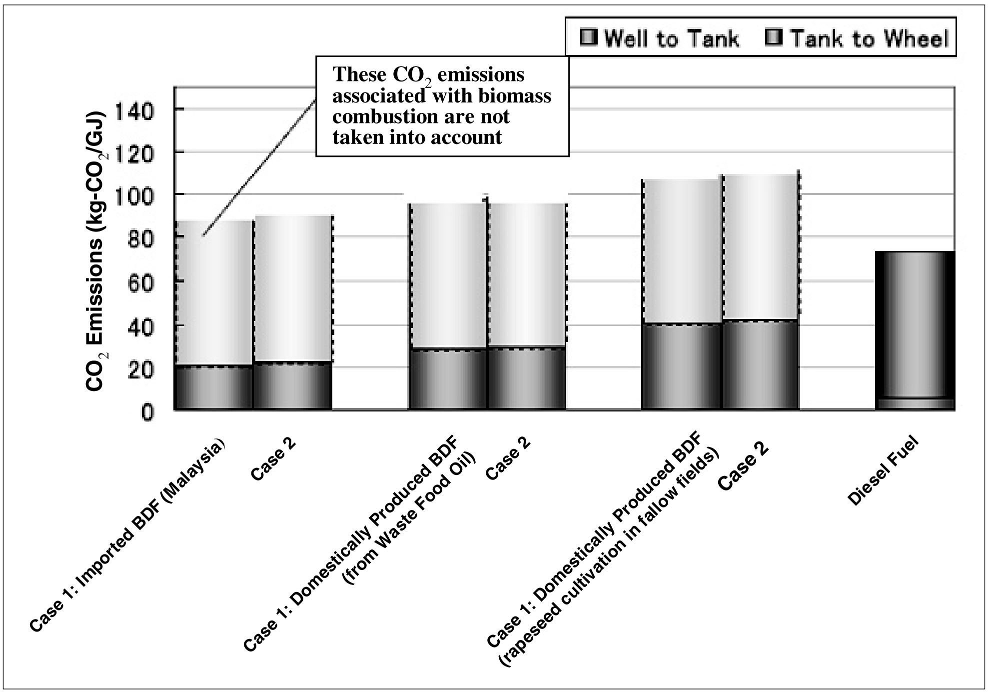
Source: Prepared by STFC based on reference [8]

and oils of biomass origin (palm oil, rapeseed oil, etc.) through thermochemical conversion (methyl esterification reaction). It is used, either undiluted or blended with light oil, as automotive fuel. Some municipalities in Japan have fleets of BDF-powered official vehicles.

In consideration of the export capacity of each raw material exporting country, palm oil produced in Southeast Asia is most promising as a feedstock for BDF, though its import price is estimated at ¥38-91 per liter as against a wholesale light oil price of ¥30 per liter[6]. Its cost, when produced domestically from waste food oil, is still high, hovering between ¥72-87 per liter.

From the viewpoint of LCA (Life Cycle Assessment), as shown in Figure 6, CO_2 emissions of BDF are estimated at 28-57% of those of light oil since the emissions associated with biomass combustion are not taken into account[6]. BDF has another advantage: CO_2 emissions associated with the combustion of imported BDF are not counted as Japan's emissions. As for the effects of "light oil blended with BDF" on vehicle emissions, an experiment conducted by the Ministry of the Environment in 2002 showed that the fuel produces more carbon monoxide and NOx than light oil; particulate matter such as soot decreases, while unburned components of light oil and lubricant increase. Further research should be conducted to analyze how the various properties of BDF affect fuel tanks, engines and emissions.

Figure 6 : Life cycle assessment of BDF for its CO_2 emissions



"Well to tank" refers to CO_2 emissions associated with production (mining), transportation and production (refinement); "tank to wheel" refers to those associated with combustion. Case 1 uses average values for variables such as feedstock yields; Case 2 assumes that feedstock yields and waste material occurrence density are 15 and 50% lower, respectively, than the averages. LCA of diesel fuel represents accurate figures based on actual data on operating plants; that of biofuels involves scores of assumptions, showing rough figures. Of the figures discussed above, fossil fuel consumption outside Japan (including marine transportation fuel) is not included in Japan's greenhouse gas emission inventory. The combustion of BDF produces CO_2, the amount of which cannot be quantified as BDF varies in its composition. Source: Prepared by STFC based on reference [8]

3 Technologies to use synthetic liquid fuels

This chapter outlines technologies for using synthetic liquid fuels, focusing on the power generation, transportation, industrial, and consumer sectors. Table 3 shows applications for each fuel.

3-1 Power generation sector

DME - a clean fuel whose combustion gases contain less NOx, carbon monoxide and soot - can be used in gas turbines, diesel engines, boilers, fuel cells, etc. (see Figure 7). However, because it is a new type of synthetic fuel, technologies to accommodate its chemical and physical properties should be developed and demonstrated for the purposes of commercialization.

3-2 Transportation sector

DME is a highly ignitable gas that produces no particulate matter, and hence is a promising alternative fuel for diesel vehicles. Regulations on particulate matter do not apply to DME, and NOx regulations - or new, long-term regulations on NOx emissions - can be complied with by using catalytic converters. However, for use of DME as automotive fuel, minor conversions such as large-capacity fuel pumps and fuel optimization are required. DME and methanol are both suitable as fuels for fuel cells as they can produce hydrogen at low temperatures.

Meanwhile, GTL fuel can be used as transportation fuel without extensive renovation of existing infrastructures. Conventional light oil containing 10-30% of GTL light oil is considered acceptable for use as automobile fuel. In the future, it is expected to substitute for jet fuel.

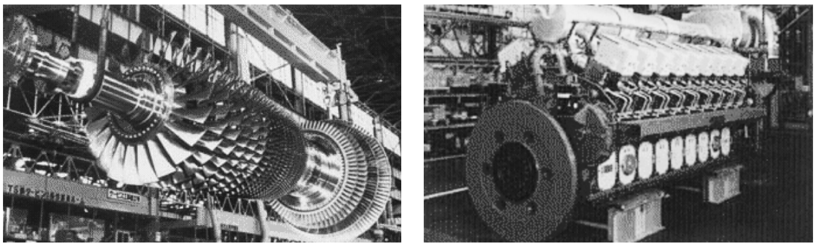
As mentioned in Chapter 2, methanol is already used as automotive fuel, but its use has yet to become widespread because of its toxicity and low calorific value.

Bioethanol is blended with gasoline to be used as automotive fuel. Likewise, BDF is blended with

Table 3 : Applications of synthetic liquid fuels

Applications		DME	GTL Fuel	Methanol	Bioethanol	BDF
Power generation	Thermal power generation	○				
Transp ortation	Gasoline alternative				○	
	Diesel fuel alternative	○	○			○
	LPG alternative					
	Fuel-cell vehicles	○		○		
Industry	Kerosene/heavy-oil alternative	○				
Consumer	Household LPG alternative	○				
	Town gas feedstock	○				
	Kerosene/heavy-oil alternative	○			○	
	Fuel cells	○		○		

Figure 7 : DME-powered generators



(a) Gas turbine generation (b) Diesel engine generation

Source: Reference [9]

light oil for use in diesel vehicles, although such use requires some conversions and more frequent maintenance.

3-3 Industry sector

DME could substitute for LPG as a fuel for simple combustion equipment such as boilers[10]. For relatively complex equipment like glass burners and textile dryers, however, the burners need to be modified to control the flame.

3-4 Consumer sector

DME is a promising LPG alternative fuel for use in household gas appliances. It is recommended that gas appliances designed for LPG, DME and other types of mixed gases be developed to provide users with options and ensure security of fuel supply. Development and selection of relevant technologies hold the key to promoting the use of DME in the consumer sector.

The consumer sector is about 60% dependent on oil fuel (kerosene, heavy oil, etc.) to meet its heating demands (air conditioning, hot-water supply, etc.). Oil fuel blended with bioethanol is currently under review for use in household boilers, which would help reduce CO_2 emissions[10].

4 World trends

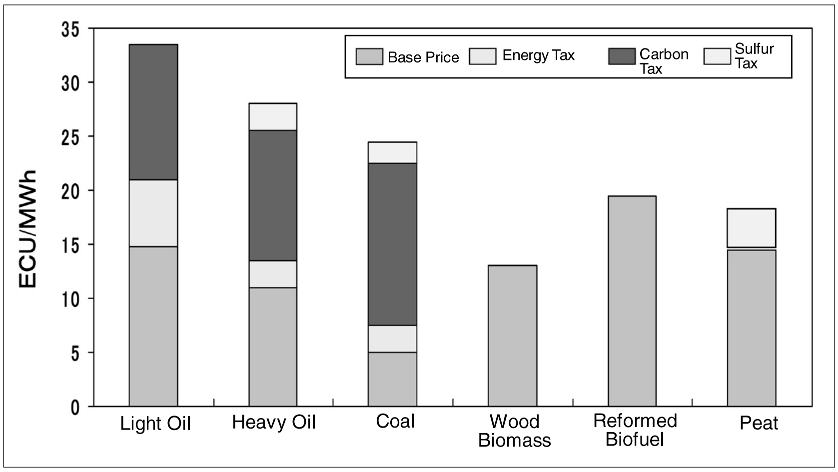
World trends in the development and use of synthetic liquid fuels are summarized below.

4-1 Europe

As part of its measures against global warming, the EU in October 2001 issued the “Renewables Directive”, which aims to double renewables' share of the EU's total primary energy supply, from 6% in 1998 to 12% in 2010[12]. A particularly promising renewable energy source is biomass, whose share for 2010 is set at 5.75%, according to the plan. Unlike in the U.S. and Japan, diesel vehicles are popular in Europe, which is why European carmakers are striving to develop biomass fuels.

In line with the directive, the German

Figure 8 : Fuel costs in Sweden



Data of 1996 (ECU is the former name of EURO) Source: Reference [14]

government is promoting BDF, applying a reduced mineral oil tax rate to biofuels (0.47 euro/liter or ¥63.9/liter based on an exchange rate of ¥136 to the euro). With this abatement in place, BDF is cheaper in Germany than conventional diesel fuel, by 0.12 euro/liter.

Three types of fuel taxes are in place in Sweden, on energy, carbon and sulfur. The energy tax is imposed on fossil fuels and electricity, while the carbon and sulfur taxes are levied on the basis of the amount of CO_2 emissions and the sulfur content of fuels, respectively[13]. These taxes, as shown in Figure 8, are not applied to biofuels - an arrangement to reduce the costs and promote the introduction of such fuels. In the field of alternative automotive fuels, three large-scale facilities (including plants for ethanol and DME production) are in operation, subsidized by the EU and the Swedish Energy Agency. In addition to these, small-scale facilities are located across the country, each of which is engaged in the development of oil alternatives[12].

4-2 North America

The U.S. government is pushing ahead with the development of biofuels as part of its policy to alleviate air pollution, ensure energy security, and promote domestic agriculture. Gasoline blended with 10% bioethanol (E10) is distributed widely in major cities, accounting for some 13% of the total market. Federal subsidies are available for bioethanol (US$0.14/liter or ¥14.7/liter based on an exchange rate of ¥105 to the dollar, to be reduced gradually) and BDF (US$0.27/liter or ¥28.3/liter). In addition, an annual budget of some ¥20 billion is earmarked for research, development, and promotion of biofuels between 2003 and 2007.

Eighty-four plants (including those under construction) located in 19 mid-western states produced a total of 14 million kiloliters of bioethanol in 2004, using cone as raw material[15]. About half of the producers are raw material producers, including farmers. Bioethanol plants in the U.S. are becoming larger in order to pursue economies of scale. As for BDF, 20 plants (of which 15 plants are under construction) produced a total of 100,000 kiloliters in 2003, using soybean oil and waste food oil as raw materials. BDF plants are also becoming larger, although production lags far behind that of bioethanol.

Both Exxon Mobil and ConocoPhillips will commercialize GTL fuel production in Qatar, sometime between 2009 and 2011, using low-cost natural gas as a feedstock to produce 80,000-150,000 barrels a day.

The Canadian government, meanwhile, has supported research and development on ethanol production since the mid-1980s, with ethanol exempted from the federal gasoline tax since 1992. As part of its measures against climate change, the government launched a C$100 million ethanol expansion program in October 2003, setting a target for 35% of the volume of gasoline currently sold in the country to be replaced with "gasoline blended with 10% ethanol" by 2010[12].

4-3 Asia

Malaysia and Indonesia are ranked first and second in global palm oil production, producing 12 million and 8 million tons/year, respectively. Being more plentiful than other vegetable oils, palm oil is cheap and can be readily produced; it is an ideal feedstock for BDF. Malaysia is expected to increase its production by 2 million tons in 2005, and Indonesia by 1-2 million tons in 2006 or 2007. While BDF use has yet to become widespread in these countries, the governments are poised to ramp-up BDF production for export purposes, using palm oil as a feedstock[16]. Japan should cooperate with both Malaysia and Indonesia, offering its BDF production expertise and development funds, to encourage exports from these two countries.

The Chinese government, in its 10th Five-Year Plan (2001-2005), designated E10 (gasoline blended with 10% ethanol) as a priority alternative fuel. In the wake of a surge in international oil prices, E10 demonstration programs were launched in 2004 in five provinces; these programs will be put into practice across the country by the end of 2005[17]. As for DME, about 50,000 tons is produced annually by indirect synthesis (methanol dehydration) for use as an LPG alternative fuel. According to some estimates, annual production is expected to reach one million tons in a few years' time, using natural gas and coal as feedstockss[3].

4-4 Other parts of the world

Using abundant sugar cane as a raw material, Brazil produced about 15 million kiloliters of bioethanol in 2004, most of which was blended with gasoline. Brazil's bioethanol production - based on a policy for stabilizing domestic sugar cane prices - dates back to the 1930s. Brazil has vehicles using three types of alternative fuel: E25 (gasoline blended with 25% ethanol), ethanol, and flex fuels (gasoline, ethanol or any mixture of the two). A total of 2.4 million kiloliters of bioethanol was exported in 2004, of which 0.5-0.8 million kiloliters was for drinks and industrial use. Exports to the U.S. and Europe for fuel use are on the rise. A Brazilian delegation visited Japan in January 2005 to survey Japan's potential as an ethanol market.

In South Africa, Sasol is producing GTL fuel from coal, and Mossgas from natural gas. Their production capacities stand at 100,000 and 30,000 barrels/day, respectively. Domestic oil wholesalers are mandated to purchase locally produced GTL fuel in proportion to their shares of the domestic market. GTL fuel is then blended with oil at tank facilities or at gas stations. The South African government has set the "floor price" of oil to protect the GTL fuel industry; subsidies are provided to Sasol and Mossgas if oil prices dip below the floor price, taking into account the balance between the two[4].

5 Challenges in developing and introducing synthetic liquid fuels

From the viewpoint of energy and fuel policies, challenges in developing and introducing the five promising oil alternatives (synthetic liquid fuels) can be summarized as below:

5-1 Dimethyl ether (DME)

DME, which can be produced from coal and biomass as well as from natural gas, is a clean fuel that is highly ignitable, produces no soot and has excellent combustion characteristics. It has a wide range of applications, and hence is expected to play a vital role in diversifying the supply of primary energy sources. As DME is still slightly more expensive than oil fuels, its cost needs to be reduced by developing applications other than automotive fuel. Specifically, DME-fired power plants should be built and applications for commercial power generation and other industrial processes should be developed to expand the DME market. There is also a need to reduce the operating costs of direct and indirect synthesis processes.

On the other hand, use of DME as automotive fuel requires demonstration and construction of distribution infrastructures dedicated to DME. As for DME vehicles, large capacity fuel pumps are needed to make up for its low calorific value, while measures should be developed to prevent fuel leakage and optimize fuel performance. Medium- to long-term approaches are required (reduced vehicle prices, etc.) and relevant laws and regulations such as DME safety standards and specifications should be improved to facilitate the use of DME.

5-2 Gas-to-liquid fuel (GTL Fuel)

As GTL fuel production projects currently underway are concentrated primarily in the Middle East, promoting this fuel in the domestic market may not necessarily reduce Japan's dependence on the Middle East in the short term. In the long term, however, there is a likelihood that small-to-medium-sized gas fields in Southeast Asia will also start producing GTL fuel in response to growing world demand for light oil, with particular emphasis on Asia. GTL fuel can be produced from biomass and coal as well as from natural gas. This means that eventually it can be produced wherever it is consumed. The development and use of GTL fuel will be essential in diversifying primary energy sources. Another great advantage of this fuel is that it can be used as a automotive fuel, without extensive renovation of existing infrastructures.

As mentioned in Chapter 2, a pilot plant using homegrown technology has succeeded in producing GTL fuel in Japan. However, in order to compete with overseas technologies and realize commercial production, a demonstration plant capable of producing several hundred barrels per day should be set up for the purpose of accumulating operational data and building confidence among all the parties concerned. It is also recommended that a large-scale demonstration project be implemented for domestic production, transportation and consumption of this type of fuel. Moreover, to encourage the private sector to commercialize GTL fuel production, a public financing system should be put in place for the construction of GTL fuel plants, which involves some degree of risk.

5-3 Methanol

With research and development underway on direct methanol fuel cells and the international standards for methanol fuel cartridges approved by the United Nations[11], demand is expected to increase for methanol to be used in fuel cells for mobile information devices. Key technologies for producing methanol from natural gas, biomass, and coal are nearing completion. The next challenge is to set up large-scale production facilities and reduce production costs.

5-4 Bioethanol

Bioethanol, when burned, produces less CO_2 emissions than gasoline. For this reason, large-scale introduction of this fuel - to the extent that all gasoline is converted into E3 - contributes to curbing global warming. However, disruptions to supply may occur because Japan is heavily dependent on imports and Brazil is the only country that has excess supply capacity. As for the infrastructures needed to refine and distribute E3 (including import infrastructures and facilities for handling hygroscopic feedstocks), the required capital investment is estimated at no less than ¥350 billion[6]. Bioethanol - as an option in Japan's energy policy - has some negatives, including its higher production cost compared to that of gasoline.

The development and use of bioethanol will be essential in diversifying primary energy sources. The government should therefore provide a series of supportive measures, e.g., improvement of the necessary infrastructures, fuel tax abatement, and development of technology for producing bioethanol from domestic biomass resources such as wood.

5-5 Biodiesel (BDF)

The use of BDF as a transportation fuel can help curb global warming as it produces less CO_2 emissions than light oil. Although BDF produced in Southeast Asia (from palm oil) and Japan (from waste food oil) poses some problems in terms of cost efficiency and stability of supply, the development and use of BDF will be essential in diversifying fuel sources.

Research should be conducted in Japan on the characteristics of "light oil blended with BDF", which can be used for conventional diesel vehicles without causing safety or environmental problems, to set fuel standards. It is also recommended that a fuel tax abatement program be adopted, following the example of Germany and Sweden; two countries in which BDF is being promoted nationwide. On the medium- to long-term basis, technologies should be developed to produce BDF from palm leaves and residues.

6 Recommendations

The world's demand for oil is expected to increase at an average annual rate of 1.9%. With oil demand on the rise in Asia, a surge in oil prices and disruptions to supply could occur at some future point. Meanwhile, development and use of oil alternatives improves compatibility between fuels and reduces geopolitical risks associated with energy supply. As a rule, market mechanisms play a central role in promoting oil alternatives and developing technologies for diversification of fuel sources, but this may not always be the case. A fixed-term national initiative should therefore be put in place to ensure energy security, curb global warming and alleviate air pollution.

In consideration of particularly important issues in promoting synthetic liquid fuels (each of which is described in the previous chapter), and to promote oil alternatives in a strategic and diversified manner, recommendations for support measures and technology development are summarized below (WTO Global Principle also taken into account *5):

(1) Support measures

(i) Infrastructure improvement and demonstration programs

DME, which has a wide range of applications as a fuel, should be promoted from the viewpoint of conserving the environment and ensuring energy security. However, as it is a new type of synthetic fuel, dedicated infrastructures (receiving terminals, storage/distribution facilities, etc.) are needed for its commercialization as automotive fuel. Meanwhile, promotion of gasoline blended with bioethanol involves renovation of existing infrastructures (oil refineries, oil tanks, gas stations, etc.) on the part of private sector in order to prevent degradation due to moisture absorption. Public awareness should be raised about these fuels, and they should simultaneously be promoted through a national initiative. While a bioethanol demonstration program is scheduled for implementation this year by the industry and government, there is a need to continue supporting such a program for the time being. To demonstrate the feasibility of DME, preliminary tests should be conducted in such places as a special economic zone in order to identify problems and pave the way for full-scale commercialization.

(ii) Fuel tax abatement and fuel standardization

Biomass fuels are being promoted in Europe, the U.S. and Brazil as part of national commitments to conserve the environment. Following the examples set by these countries, a tax abatement program should be adopted for the purpose of immediately introducing and promoting biomass fuels: DME, GTL fuel, BDF and bioethanol. Such a preferential tax system is essential in strengthening the competitiveness of these fuels.

As for light oil blended with BDF, its effects on vehicle emissions have yet to be fully assessed. Research should therefore be conducted on the characteristics of this type of blended fuel, as part of the measures to promote BDF, to set fuel standards for its safe and environmentally friendly use in conventional diesel vehicles. Likewise, specifications, quality assurance procedures, etc. for DME should be standardized.

(iii) Preferential treatment

Given the technological and market uncertainties involved, construction of demonstration plants for DME and GTL fuel would pose too great a risk for the private sector if it were to take on the whole responsibility. A fixed-term public support system should therefore be put in place to encourage such construction. Meanwhile, financing of overseas GTL fuel and DME projects should be part of the resources development funding provided by the Japan Bank of International Cooperation (JBIC), and a system should be developed to offer preferential interest rates and higher loan limits. As for projects that will contribute to reducing CO2 emissions, the Clean Development Mechanism (CDM)*6 of the Kyoto Protocol should be mobilized, and international cooperation solicited.

(2) Technology development

(i) Demonstration plants for GTL fuel

From the medium- to long-term perspective, original technologies for GTL fuel production should be developed in order to diversify transportation fuels and address environmental concerns. In 2003, a Japanese private consortium succeeded in setting up a pilot plant (7 barrels/day) for GTL fuel, incorporating homegrown technology and government support measures. The industry and government should cooperate to enhance the international competitiveness of this fuel. To this end, a demonstration plant (capable of producing several hundred barrels per day) should be set up, with the aim of accumulating a meaningful body of operational data by 2010. There is also a need to implement a large-scale demonstration project for domestic production, transportation, and consumption of this type of fuel.

(ii) DME technology

Applications for commercial power generation (thermal power generation, etc.) as well as industrial applications (LPG alternatives) should be promoted in the initial stage of introducing DME. Meanwhile, in the medium- to long-term, a series of approaches should be adopted with a view to commercialization of automotive fuels. At the same time, research and development should be conducted on the prevention of leakage, fuel optimization and large-capacity fuel pumps needed to make up for the low calorific value of DME.

(iii) Biomass fuel technology

The bulk of bioethanol and BDF is produced from plant materials such as sugar cane and palm oil. However, a variety of feedstocks should be used in order to increase supply of biomass fuels. A medium- to long-term national initiative should therefore be put in place for the purpose of developing technologies for converting domestic cellulose resources (non-food resources such as wood, plants and used paper) into bioethanol, and producing biodiesel from palm leaves and residues.

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Notes

*1 In indirect synthesis of DME, synthesis gas is converted into methanol, which is then dehydrated to produce DME. This technology, a combination of established techniques, is now in the commercialization phase. In direct synthesis of DME, synthesis gas is directly converted into DME without producing methanol, an intermediate. This technology, unique to Japan, is still in the development phase. JFE Holdings is playing a central role in running a 100 tons/day pilot plant in Kushiro that has been in operation since December 2003.

*2 As production of DME requires a significant amount of heat for reforming processes, etc., its well-to-tank (mining, transportation and production) emissions of CO_2 per unit calorie are theoretically greater than those of LNG, LPG, and oil. DME contains oxygen and its carbon content is lower than those of LPG and light oil. However, with its calorie per unit weight being some 60% of that of LPG, the amount of emissions associated with its combustion is theoretically the same as those of LPG [6].

*3 Liquid hydrocarbons are produced from CO and H_2 through catalytic reactions, a process discovered by E. Fischer and H. Tropsch (Germany) in 1923.

*4 Shell (U.K. and the Netherlands), Sasol (South Africa), ChevronTexaco (U.S.), ExxonMobil (U.S.), ConocoPhillips (U.S.), BP (U.K.), etc.

*5 The principle, which is in line with OECD guidelines, sets out that: (1) governments as well as laws and regulations should not interfere with the market; (2) research and development programs are authorized only for basic and common techniques that are far from being commercialized; (3) objectives of measures that are close to becoming marketable should be made public within the prescribed time frame so that their achievements are shared worldwide.

*6 A system where Kyoto Protocol signatory and non-signatory countries implement joint projects for reducing greenhouse gases - benefits of which can be shared between the countries concerned. This benefits non-signatory countries in that they can promote their environmental measures through investment and technology transfer from signatory countries.

References

[1] The Institute of Energy Economics, Japan. 2004. Asia/World Energy Outlook: Burgeoning Asian Economies and the Changing Energy Supply-Demand Structure. (in Japanese)

[2] Ohki Yoshionori. Trends in Energy and Global Warming Issues and Our Approaches to Them. Mitsubishi Heavy Industries Technical Review vol.40, No.1 (Jan. 2003), and Denki Shimbun. Overview of Energy Technologies in the 21st Century (4) (Feb.4, 2005): 4 (in Japanese)

[3] The Petroleum Subcommittee of the Advisory Committee for Natural Resources and Energy, Ministry of Economy, Trade and Industry. Report of the 14th meeting of the Fuel Policy Subcommittee: (in Japanese): http://www.meti.go.jp/committee/summary/0002068/0001.html

[4] The Institute of Energy Economics, Japan. Nov. 2001. Marketability of Liquid Fuels (GTL) Produced from Natural Gas. (in Japanese): http://eneken.ieej.or.jp

[5] Graphical New Energy Outlook. 2004. The Society of Chemical Engineers, Japan (SCE. Net) and Kogyo Chosakai Publishing Inc. (in Japanese)

[6] The Petroleum Subcommittee of the Advisory Committee for Natural Resources and Energy, Ministry of Economy, Trade and Industry. The 2nd Interim Report (Draft) of the Fuel Policy Subcommittee: (in Japanese) : http://www.meti.go.jp/committee/downloadfiles/g40415a51j.pdf

[7] Website of EEchance: http://www.eechance.com/mt_ecolife/archives/entry/000067.html

[8] The Petroleum Subcommittee of the Advisory Committee for Natural Resources and Energy, Ministry of Economy, Trade and Industry. Report of the 9th meeting of the Fuel Policy Subcommittee: 4-2: (in Japanese) http://www.meti.go.jp/committee/summary/0001744/0001.html

[9] Website of the Ministry of Economy, Trade and Industry: http://www.meti.go.jp/committee/downloadfiles/g40324a06j.pdf

[10] Website of the Global Environment Bureau, Ministry of the Environment: http://www.env.go.jp/earth/report/h15-02/h-08.pdf

[11] Website of ITmedia: http://www.itmedia.co.jp/mobile/articles/0412/02/news037.html

[12] NEDO Overseas Report No.879 (4.15, 2002), No.948 (1.26, 2005) and No.951 (3.9, 2005) (in Japanese)

[13] Website of Genshiryoku Toshokan (Nuclear Library): http://mext-atm.jst.go.jp/atomica/01070611_1.html

[14] N. El Bassam. 1998. Energy Plant Species. James & James Ltd: 54.

[15] Energy Economics. 2005. Vol. 31. No.1: 72

(in Japanese)
[16] The Petroleum Subcommittee of the Advisory Committee for Natural Resources and Energy, Ministry of Economy, Trade and Industry. Report of the 11th meeting of the Fuel Policy Subcommittee: (in Japanese) http://www.meti.go.jp/report/downloadfiles/g30922b41j.pdf
[17] Website of SEARCHINA: http://news.searchina.ne.jp/2004/1014/stockname_1014_024.shtml

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