EAS-ERIA
Biodiesel Fuel Trade Handbook: 2010


Palm


Jatropha


Coconut


Rapeseed


Soybean

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Prepared by ERIA Research Project Working Group on

"Benchmarking of Biodiesel Fuel Standardization in East Asia"

Working Group Members/Authors

This handbook was edited by ERIA Research Project Working Group on "Benchmarking of Biodiesel Fuel Standardization in East Asia" with result of the studies.

The followings are members of the WG and authors of this handbook (listed in an alphabetical order of the member countries.

WG Leader

Dr. Shinichi Goto

Director, Research Center for New Fuels and Vehicle Technology (NFV), National Institute of Advanced Industrial Science and Technology (AIST), Japan

WG Sub Leader

Dr. Mitsuharu Oguma

Senior Research Scientist, Combustion and Engine Research Team, NFV, AIST, Japan

Dr. Nuwong Chollacoop

Bioenergy Laboratory, National Metal and Materials Technology Center (MTEC), National Science and Technology Development Agency (NSTDA), Thailand

Dr. Lesley Dowling and Dr. Daniel Sheedy

Fuel and Used Oil Policy Section, Department of the Environment, Water, Heritage and the Arts, Australian Government, Australia

Prof. Wugao Zhang

School of Mechanical Engineering, Shanghai Jiao Tong University, China

Dr. Tatang Hernas Soerawidjaja

Chairman, Indonesian Biodiesel Forum and Head, Center for Research on Sustainable Energy, Institut Teknologi Bandung, Indonesia

Dr. Soni Solistia Wirawan

Head of Institute for Engineering and Technology System Design, Agency for the Assessment and Application of Technology, Indonesia

Dr. Yuji Yoshimura

Prime Senior Researcher, NFV, AIST, Japan

Mr. Shoichi Ichikawa

Representative of Japan Automobile Manufactures Association (JAMA), Toyota Motor Corporation, Japan

Dr. Takashi Hoshino

Representative of Japan Automobile Manufactures Association (JAMA), Isuzu Motors Limited, Japan

Prof. Koji Yamane

Representative of Academia, Dept. of Mechanical Systems Engineering, School of Engineering, University of Shiga Prefecture, Japan

Mr. Akio Imai

Representative of Petroleum Association of Japan (PAJ), Showa Shell Sekiyu K.K., Japan

Mr. Takao Ikeda

New and Renewable Energy Group, Strategy and Industry Research Unit, Institute of Energy Economics, Japan

Prof. Mitsuru Konno

Representative of Academia, Mechanical Engineering, Ibaraki University, Japan

Dr. Harrison Lau Lik Nang

Group Leader, Biodiesel Technology, Engineering and Processing Research Division, Malaysia Palm Oil Board (MPOB), Malaysia

Mr. Andrew Saunders and Ms. Philippa Blunden

Policy Analyst, Fuels & Crown Resources Group, Ministry of Economic Development, New Zealand

Ms. Zenaida Ygnacio Monsada

Director, Oil Industry Management Bureau, Department of Energy, Philippines

Dr. Rong Yan

Centre Director, Institute of Environmental Science and Engineering, Nanyang Technological University, Singapore

Dr. Young Jae Lee

Leader, Transportation Energy Research Center, Korea Institute of Energy Research, South Korea

Ms. Peesamai Jenvanitpanjakul[†]

Deputy Governor (R&D), Thailand Institute of Scientific and Technological Research (TISTR), Thailand

Ms. Hoang Thi Tinh[‡]

Vietnam Standards and Quality Center, Directorate for Standards and Quality (STAMEQ), Vietnam

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[†] Presently as Senior Energy Expert, National Science and Technology Development Agency (NSTDA), Thailand

[‡] Presently retired

Contributing Authors

In addition to ERIA Research Project Working Group Member, many energy experts have contributed to this handbook as follows, listed by an alphabetical order of the authors' lastname.

Dr. Aparat Mahakhant

Researcher, Bioscience Department, Thailand Institute of Scientific and Technological Research (TISTR), Thailand

Dr. Xunpeng Shi

Associate Researcher, Economic Research Institute for ASEAN and East Asia, Indonesia

Dr. Makoto Toba

Team Leader, Hydrotreating Catalysis Team,, NFV, AIST, Japan

Dr. Taku Tsujimura

Research Scientist, Combustion and Engine Research Team, NFV, AIST, Japan

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List of Abbreviations and Acronyms

AAM	Alliance of Automobile Manufacturers
AAMA	American Automobile Manufacturers Association
ACEA	European Automobile Manufacturers Association
AGQM	Arbeitsgemeinschaft Qualitätsmanagement Biodiesel e.V.
AOCS	American Organization of Chemical Scientists
APEC	Asia-Pacific Economic Cooperation
APROBI	Indonesian Biofuel Producer Association
ASA	American Soybean Association
ATM	Armed forces, Malaysia
bbl	Blue barrel (42 gallon)
BDF	Biodiesel fuel
BSN	Indonesian National Standardization Agency
BTL	Biomass-to-liquid
CAPEX	Capital expenditure
CARB	California Air Resources Board, USA
CCMC	Former name of ACEA (European Automobile Manufacturers Association)
CFAR	Certificate of Fuel Additive Registration, The Philippines
CFPP	cold filter plugging point
CJCO	crude Jatropha curcas oil
CME	Coconut methyl ester
CRBOME	Crude rice bran oil methyl ester
CSIRO	Australian Commonwealth Scientific and Research Organization
CTL	Coal-to-liquid
COP	Conference Of The Parties
DA	Department of Agriculture, The Philippines
DAR	Department of Agrarian Reform, The Philippines
DBKL	Kuala Lumpur City Hall
DC	Department Circular, The Philippines
DEDE	Department of Alternative Energy Development and Efficiency, Thailand
DENR	Department of Environment and Natural Resources, The Philippines

DME	Dimethyl Ether
DMSO	Dimethyl Sulfoxide
DOE	Department of Energy
DOEB	Department of Energy Business, Thailand
DOF	Department of Finance, The Philippines
DOLE	Department of Labor and Employment, The Philippines
DOST	Department of Science and Technology, The Philippines
DOTC	Department of Transportation and Communication, The Philippines
DTI	Department of Trade and Industry, The Philippines
EAS	East Asia Summit
ECTF	Energy Cooperation Task Force
EDB	Economic Development Board, Singapore
EE&C	Energy Efficiency and Conservation
EEBS	EAS-ERIA Biodiesel fuel Standard
EGCS	Energy Grants Credit Scheme, Australia
EMA	Engine Manufacturers Association
EMA	Energy Market Authority, Singapore
EMI	Energy Market Integration
EPA	US. Environmental Protection Agency
EPBC Act	Environment Protection and Biodiversity Conservation Act, Australia
ERIA	Economic Research Institute for ASEAN and East Asia
ESCO	Energy Service Company
ERTLS	Energy Research and Testing Laboratory Service, The Philippines
ETBE	Ethyl Tertiary Butyl Ether
etc	et cetera
EUMB	Energy Utilization Management Bureau, The Philippines
FAME	Fatty Acid Methyl Ester
FIE	Fuel Injection Equipment
FT	Fischer-Tropsch
GTL	Gas-To-Liquid
HDO	Hydrodeoxygenated
HTS	high-throughput screening
ICECRD	Indonesian Center for Estate Crops Research and Development
IEA	International Energy Agency
IEC	Information, Education and Communication

IOC	International Oil Companies
IP	Induction period
IPP	Investment Priority Projects, The Philippines
IPCC	Intergovernmental Panel on Climate Change
ITH	Income Tax Holiday, The Philippines
JAMA	Japan Automobile Manufacturers Association
JAO	Joint Administrative Order, The Philippines
KIER	Korea Institute of Energy Research
LCA	Life cycle assessment
LCFS	Low Carbon Fuel Standard, USA
LGUs	Local Government Units
LNP	Liquefied natural gas
LP	Liquefied Petroleum
LPG	Liquefied Petroleum Gas
MAA	Malaysian Automotive Association
MAFF	Ministry of Agriculture, Fishery and Forest, Japan
MC	Memorandum Circular, The Philippines
ME	Methyl ester
METI	Ministry of Economy, Trade and Industry, Japan
MOCIE	Ministry of Commerce, Industry and Economy, South Korea
MOE	Ministry of Environment, Japan
MOEN	Ministry of Energy, Thailand
MPOB	Malaysian Palm Oil Board
Mu	Chinese unit for area (1 Chinese Mu equals 0.0667 hectare)
NBB	National Biodiesel Board, US
NBB	National Biofuels Board, The Philippines
NCCC	National Climate Change Committee, Singapore
NCIP	National Commission on Indigenous People, The Philippines
NEA	National Environment Agency, Singapore
NEPC	National Energy Policy Council, Thailand
NPRM	Notice of Proposed Rule Making, USA
NPTL	National Petroleum Testing Laboratory, The Philippines
NRDC	National Development and Reform Commission, China
NT	Northern Territory, Australia
NZES	New Zealand Energy Strategy

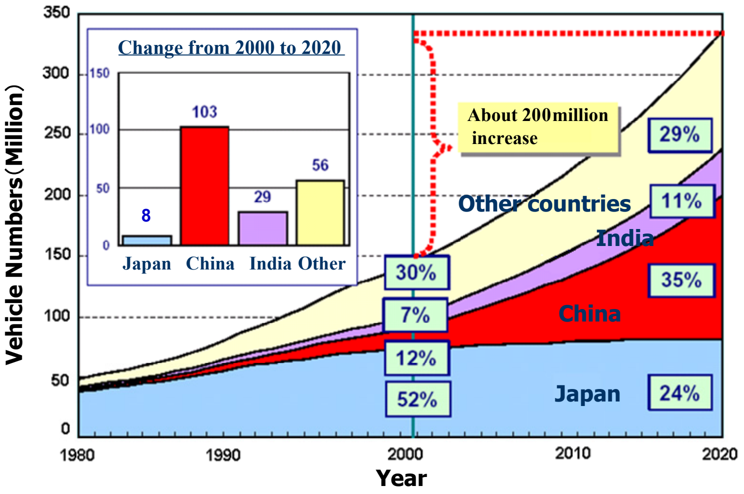
OECD	Organization for Economic Cooperation and Development
OIMB	Oil Industry Management Bureau, The Philippines
OPEC	Organization of the Petroleum Exporting Countries
PAFC	Philippine Alternative Fuels Corporation
PAJ	Petroleum Association of Japan
PCA	Philippine Coconut Authority
PM	Particulate matter
PME	Palm oil methyl ester
PNS	Philippine National Standards
PORIM	Palm Oil Research Institute of Malaysia
R&D	Research and development
RD&E	Research, Development and Extension
RE	Renewable energy
RED	Renewable energy Directive, EU
REMB	Renewables Energy Management Bureau, The Philippines
RFS	Renewable fuel Standard, USA
RM	Malaysian currency Ringgit
RMB	Chinese currency Renminbi
RRBOME	Refined rice bran oil methyl ester
RSB	Roundtable on Sustainable Biofuels
RV	Residential vehicle
SME	Soybean oil methyl ester
SRA	Sugar Regulatory Administration, The Philippines
TAN	total acid number
TC	Technical Committee
TCPPA	Technical Committee on Petroleum Products and Additives, The Philippines
TME	Tallow Methyl Ester
TOE	Tonne of oil equivalent
UNFCC	United Nations Framework Convention on Climate Change
VAT	Value Added Tax
WG	Working group
WTO	World Trade Organization
WWFC	World Wide Fuel Charter

1. INTRODUCTION

1.1 Aim and Target of the Handbook

Recently, crude oil prices have increased significantly, and on July 11, 2008 the price reached $147.27 per barrel, the highest value the world had ever seen. Speculation and increased consumption of crude oil by China and India are considered to be the causes; however it seems that a chronic high price condition will continue from this point.

Demand for oil can be indicated by total vehicle numbers. Figure 1 shows an estimate of vehicle numbers in Asia by the Japan Institute of Energy Economics. In Japan the number of vehicles is expected to increase from about 70 million in 2000 to about 80 million in 2020. A more remarkable increase is expected for other Asian countries, particularly China and India. It can be seen that the number of vehicles in the Asian region reached 150 million in 2000, but will increase by another 200 million in the following 20 years to reach a total of 350 million in 2020. That is, it is estimated that the required volume of automotive fuel will also necessarily double. Moreover, the 2008 edition of the "World Energy Prospective" published on November 12, 2008 by the IEA (International Energy Agency) states that the current sharp decline in crude oil prices is a temporal phenomena, stating clearly that in the middle-to-long term there is a high possibility of a price increase. It predicts that prices will break through $200 per barrel by 2030. It is a warning that the end of a so-called cheap crude oil era is approaching. Conversely, from a CO_2 control viewpoint, it can be expected that an era will come when biomass fuels have to be used.



(Source: The Institute of Energy Economics, Japan)

Figure 1 Estimate of vehicle numbers in Asia

Figure 2 shows a diagram of how we obtain fuels from various resources. Crude oil and natural gas are energy paths that are quite heavily traveled. Production of fuel from biomass to ethanol and Biodiesel fuel (Fatty Acid Methyl Ester, indicated “FAME” in the figure) has come into play more recently. Coal and oil sands have been coming onto the market as crude oil prices rise. However, an interesting energy pathway also exists which results in production of methanol, DME, and Gas to liquid (GTL) via synthesized gas. This gas can be derived from natural gas, coal, oil sand, and/or biomass. Since it can be produced from a variety of ingredients, it is drawing attention as a seamless fuel that can gradually increase usage of biomass fuels, while utilizing existing fossil fuels.

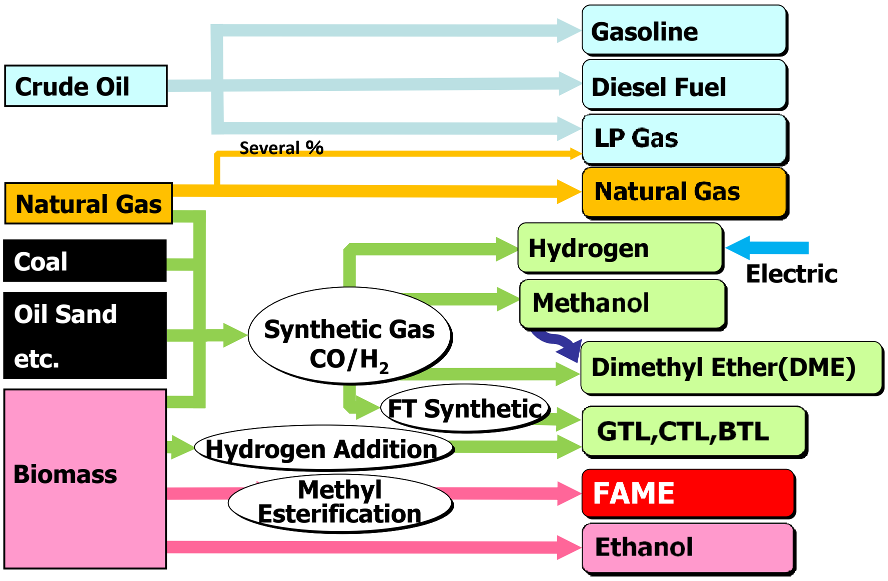


Figure 2 Resources and fuels

The Kyoto Protocol emphasized the concept of “carbon neutral” – that vehicle emissions of carbon dioxide (CO_2) are offset by using biofuels produced from plant materials absorbing CO_2. The use of biofuels contributes to the prevention of global warming.

Asian countries are actively promoting the introduction of biofuels due to soaring oil prices and increased energy consumption. The utilization of biofuels is also important from the viewpoint of energy security and alternative fuels. Especially, Southeast Asian countries are actively promoted to introduce biodiesel fuel as Fatty Acid Methyl Ester (FAME) because these countries have a lot of feedstocks for biodiesel fuel such as palm, coconuts, Jatropha and so on.

However, the low-quality biodiesel fuel raises serious concerns regarding the effect on engine performance caused by fuel impurities and the oxidation. Therefore, quality control/management of biodiesel fuel in the actual market is very important. On achieving this objective, it is expected production of high-quality biodiesel fuel, its smooth distribution, and stabilization of economic infrastructure.

In 2007, A Working Group (WG) on “Benchmarking of Biodiesel Fuel Standardization in East Asia” was established in Economic Research Institute for ASEAN and East Asia (ERIA). The WG started to discuss how to control the biodiesel fuel quality in the actual market. Starting 2007, the WG established EAS-ERIA Biodiesel Fuel Standard: 2008 for B100 fatty acid methyl ether (FAME) aimed for low level blending with diesel fuel. the next two year, 2008 and 2009, discussions were held on last year’s adjustments, potentials of inedible feedstocks, quality control/management method of biodiesl fuel in the market.

In this handbook, the three yeas discussions, the results and the findings are summarized as well. For those listed above achievements were consistently aimed at the “secure use” of the first generation of biodiesel fuel (FAME). Further, the authors would like to consider a wide view point that especially takes into consideration the biomass fuel situation to obtain the optimum energy pathway in each country.

1.2 Introduction of ERIA and Energy Studies

ERIA is an international organization based on the agreement of national leaders of 16 East Asia Summit (EAS) member countries. ERIA was established on June 3, 2008, and its status as an International Organization was accorded by the Exchange of Notes between ASEAN Secretariat and the Government of Indonesia December 30, 2008.

ERIA’s role is to do research and provide practical policy recommendations to leaders and ministers in ASEAN, EAS and so forth, in strong partnership with the ASEAN Secretariat and existing research institutes. It is expected intellectually to contribute to the regional efforts for ASEAN Community building and East Asian Economic Integration in wide-ranging policy areas from trade/investment to SMEs, human resource development, infrastructure, energy and environmental issues, etc. Capacity Building aimed at strengthening policy research capacities especially in the less developed countries is another important activity of ERIA.

As shown in Figure 3, ERIA is currently conducting research centering around three pillars of “Deepening Economic Integration”, “Narrowing Development Gaps” and “Sustainable Development”. The Joint Press Statement of the East Asia Summit on the Global Economic and Financial Crisis issued on June 3rd, 2009 stated that “ they

(EAS leaders) encouraged the Economic Research Institute for ASEAN and East Asia (ERIA), ADB and ASEAN Secretariat to work together to prepare as soon as possible a coherent master plan, which is named as "Comprehensive Asian Development Plan" by ERIA. In addition, they called upon ERIA to provide policy recommendation to stimulate economic growth in the region, deepen regional integration and strengthen partnership in East Asia.

Responding to the request of three points above from EAS leaders to stimulate economic growth in the region, ERIA is embarking on research activities toward a building the East Asian community.

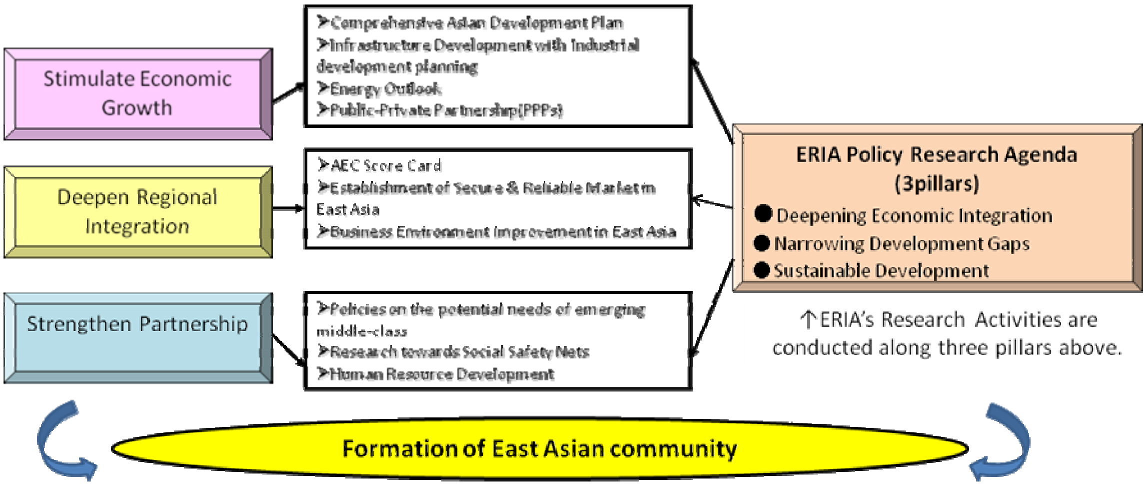


Figure 3 ERIA's research projects and its relationship to Leaders' requests

ERIA's energy projects are the key component of the "Sustainable Development" pillar. Three projects, Energy Saving, Biodiesel Standardization and Biomass Energy Sustainability, have been running for three years and have got high appreciations from EAS energy and economics ministers.

ERIA's energy research projects are servicing the energy policy-makers very well. Currently, ERIA's energy research projects cover all the three work streams under East Asia Summit Energy Cooperation Taskforce (EAS ECTF), namely, energy efficiency and conservation (EE&C), energy market integration, and bio-fuels for transport and other purposes.

For the EE&C work stream: ERIA's ongoing study, "Analysis on Energy Saving Potentials in East Asia", has estimated energy saving potentials (30%) and related CO_2 reduction (18%) by 2030. Currently, the study focuses on revision of the estimation with new information and helps some countries quantifying their energy action plans and nuclear energy development plans.

For the Energy Market Integration work stream, in 2009, ERIA started to work for this work stream. The two chair governments (Singapore and Australia) have agreed on the Terms of Reference and requested ERIA to estimate the economic impacts of EMI in 2010.

For the bio-fuels work stream, ERIA has been running two projects since 2007. The Study on Biomass Sustainability has produced “Asian Biomass Principles” and methodology for assessing sustainability of biomass energy development in the EAS region. Study on Biodiesel Standardization has produced “EAS-ERIA BDF Standard in 2008”, and the work has evolved to “Biodiesel Fuel Trade Handbook”, which will be presented hereafter.

2. ENERGY SITUATION IN THE WORLD

2.1 Introduction

With the present situation of increasing energy demand, rising energy prices, and reinforcement of countermeasures for global warming, renewable energy sources have taken the spotlight. Bio-fuels are one form of renewable energy that has become more widespread. Also, bio-fuels have been introduced and expanded as alternative fuel for the transportation sector and as a form of liquid renewable energy that can be blended with petroleum. However, since the source material of bio-fuels is sometimes the same as for food, an increase in grocery prices has drawn attention to the next generation of bio-fuels being non-food sourced. This report will discuss the demand perspective derived from the IEA (International Energy Agency) world energy forecast, basic energy price trends, and bio-fuel trends.

2.2 Increase of Energy Demand

2.2.1 Perspective of World Energy Supply and Demand

According to the IEA World Energy Outlook, the world's primary energy supply has increased by 58% in 25 years, from about 7.2 billion TOE (tonne of oil equivalent) in 1980 to about 11.4 billion TOE in 2005, as shown in Table 1. The OECD (Organization for Economic Cooperation and Development) countries used to be the center of energy demand. However, these OECD countries are lower both in economic and population growth rates than those of non-OECD countries. Further, the OECD countries' economic industrial structure has changed, therefore the increase in demand stays low. In 2005 the non-OECD countries took the lead in demand, accounting for 51% of consumption in 2006. In the future it is expected that energy demand will increase based on economic growth of emerging market countries like China, India, and the Middle East. It is estimated to increase by 48% over 25 years from about 11.43 billion TOE in 2005 to about 17.0 billion TOE in 2030. The share of petroleum demand

Table 1 Perspective of World Energy Demand

Items	Energy Demand (M_{toe})				
	1980	2000	2005	2015	2030
Total primary energy demand	7,223	10,034	11,429	14,121	17,014
Petroleum Oil	3,107	3,649	4,000	4,525	5,109
Transport	1,245	1,936	2,011	2,637	3,171
Petroleum	1,187	1,844	1,895	2,450	2,915
Biofuels	2	10	19	74	118
Other fuels	57	82	96	113	137

(Source: IEA World Energy Outlook 2007, 2008) in the world's primary energy supply will decrease from 34% to 30%, however in the absolute quantity is estimated to increase by 27.7%, from 4.0 billion TOE in 2005 to about 51 TOE in 2030.

On the other hand, it is expected that exploratory development investment of petroleum and natural gas will be more important for the future energy supply. The world average depletion rate of oil fields following production peak is 6.7 % annually at this point, and it is assumed that the depletion rate of oil fields will accelerate to 8.6% by 2030. In order to continue petroleum production to meet increasing demand in an environment of post-peak oil field production (decreasing yields), it is necessary to obtain additional petroleum by developing new oil fields. In terms of additional worldwide new production capacity, the IEA predicts that from 2007 to 2030 an additional capacity of 64 million bbl/day will be needed. This is equivalent to about six times the current production of Saudi Arabia, the biggest crude oil producing country in the world. A sufficient amount of oil deposits in the world is predicted to exist even after 2030. In order to obtain a rate of oil and gas resource development corresponding to the increase in demand, however, large-scale investment is essential. However, oil reserves are distributed unevenly throughout the world. That is, the OPEC countries account for 75.7% of confirmed oil reserves in the world, while 82% is contained within the OPEC countries and Russia [1]. Natural gas is similar. Three countries, namely Russia, Iran and Qatar hold 55% of the worlds confirmed reserves [2]. At a company level, national oil companies hold 76% of reserves, while the Russian oil companies hold 17% of the reserves. An area of improvement is in major International Oil Companies (IOC), which have access to advanced technology and funds but the amount of accessible reserves they hold is only 7%. In summary, the development of oil and natural gas at a rate to meet the future worldwide demand requires exploratory development investment, especially in a few key resource-rich countries [3]. In the IEA World Energy Outlook, it is predicted that the OPEC countries supply the majority of world petroleum increase in the future, and the OPEC share will increase from 44% in 2007 to 51% in 2030.

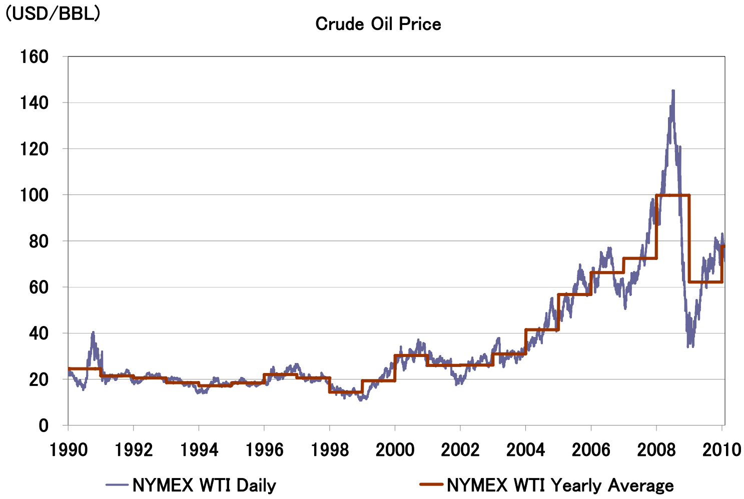
On the other hand, the worldwide amount of primary reserves in non-conventional petroleum sources like oil sand and oil shale is estimated to be about 2 trillion barrels, which is very abundant but immediately available. For example, 80% of the approximately 170.0 billion barrels of oil sand minable in Canada, must be obtained from several tens of meters deeper oil sands using vapor methods. Water and natural gas resources are utilized in vapor extraction. Development of these non-conventional petroleum reserves has environmental consequences, such as recycling of water resources, and overall CO_2 increase.

2.2.2 Transportation Sector

Energy demand in the transportation sector is estimated to increase 57% from about 2.0 billion TOE in 2005 to about 3.2 billion TOE in 2030. The ratio of petroleum in the transportation sector is estimated to consistently account for more than 90% in 2005 to 92% in 2030. The reason petroleum accounts for a large fraction of energy supply for the transportation sector is that petroleum alternatives are difficult. Petroleum fuels for airplanes, ships and automobiles have several key merits. They have a high energy density, which makes a sufficient cruising distance possible, and liquid fuels are relatively easy to handle. However, more important than that, it is not realistic to change our energy infrastructure like gas stations, storage tanks, engines, or emission characteristics, at any given point in time. Because of this, the current energy infrastructure makes it extremely important that any new alternative petroleum fuel is compatibility with the corresponding conventional petroleum fuel. Liquid alternative fuels that can be blended with petroleum fuels (like bio-fuel) are advantageous in terms of transportation fuel supply resource diversification.

2.3 Trend of International Energy Prices

Figure 4 shows the variation in crude oil prices. In the two oil crises during the 1970's and the gulf crisis of 1990, a disruption of crude oil supply was triggered by the 4th Middle East War, the Iran Revolution, and the Kuwait invasion. As a result, prices increased about 2-4 times. After that, crude oil prices in the 1990's didn't exceed $30/bbl. The WTI crude oil price (an international price index) was stable at around $20/bbl. However, after it went down to $10/bbl in December, 1998, the price started to go up around the Iraq crisis in 2003. Then the price increased as high as $147/bbl in July, 2008. After that the price decreased significantly. Although the price broke $34/bbl in December, 2008, it varied in a range of $40 to $60/bbl until April, 2009, showing a stable price trend.

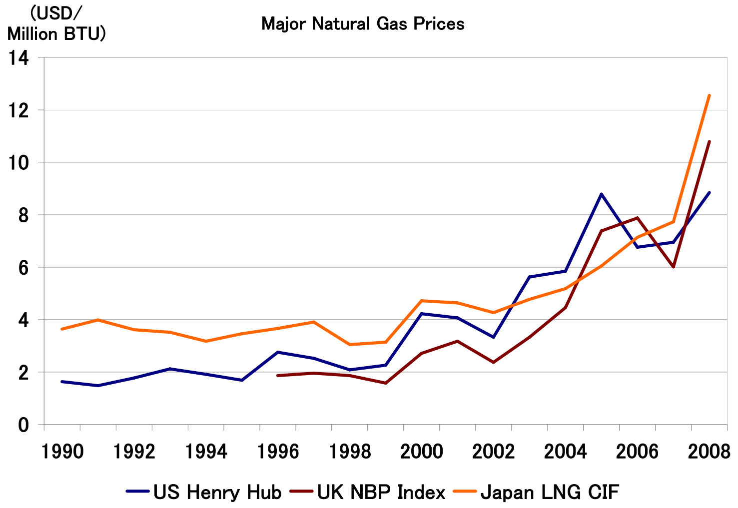


Fluctuating blue line: WTI crude oil price and Flat red line: WTI annual average price
(Source data: US Energy Information Administration)

Figure 4. NYMEX WTI Variation in Crude Oil Price（US dollar/bbl）

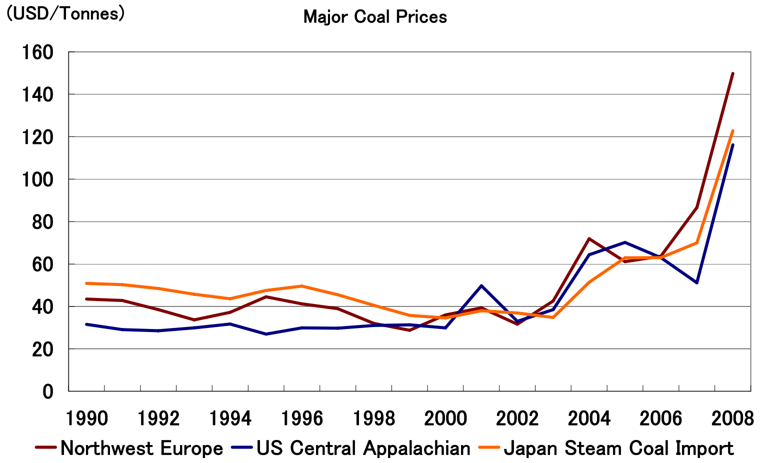
In terms of the hike in crude oil price in the 2000's, the price did not increase rapidly in a short period, as with a physical crude oil supply disruption in past oil crises, but the price increased more gradually. The price hike this time involved various factors: (1) An increase in consumption by the newly wealthy in developing countries, (2) Geopolitical risk and a decrease in stockpiles due to "resource nationalism" in supply countries, (3) The influences of speculative investors, (4) Inflation and influences of dollar depreciation and quotation in dollars, and so forth.

Figure 5(a) shows the variation of natural gas price while Figure 5(b) shows the trends in coal prices. It is expected that the demand for natural gas and coal will increase more than oil in the future. These prices are different from oil prices. Currently, there is no world index, but these prices are increasing in the 2000's similar to oil prices. There are some indirect influences of the oil price due to certain factors. For the price of natural gas, decisions are similar to crude oil buyers' prices in Japan, to heavy oil prices in Europe, and to fuel conversion users like power plants in the US. There is no direct influence of oil price on coal prices. However, there are secondary influences, such as the fuel demand increase for power plants, and higher iron and steel production, and a delay of export infrastructure maintenance due to this demand increase. Regarding coal demand, an increase is expected in China, India and the Middle East owing to their strong economic growth, while for natural gas a steady demand increase is expected in these three countries and regions, along with South America and Africa.



Blue Line: US Henry hub price; Red Line: British NBP price and Orange Line: Japan LNG CIF price
(Source data: BP Statistical Review of World Energy)

(a)



Red Line: Northwestern Europe price; Blue Line: US Appalachia price and Orange Line: Japanese general coal import price
(Source data: BP Statistical Review of World Energy)

(b)

Figure 5. Variation in Annual Average (a) Natural Gas Price (US dollar/million BTU) and (b) Coal Price (US dollar/ton)

After the summer of 2008 the world business situation declined, and crude oil prices decreased remarkably. In order to achieve the necessary petroleum development investments for the future mid-to-long range growth of oil demand, it has been said that prices like we had in the 1990's will not return. From the standpoint of attaining a stable energy supply and diversification supply sources, the importance of alternative fuels is expected to increase.

2.4 Global Environmental Problems

Discussions on environmental problems in energy policy, particularly global warming issues, have been given much attention these days. Scientific temperature observations, begun in the 19th century, have shown that the pace of temperature increase in the latter half of the 20th century has been faster. Currently, the amount of fossil fuel origin carbon dioxide discharge has been increasing, with the corresponding increase in energy demand. Due to this increase, it has been strongly claimed that the artificial greenhouse effect is the main cause. For these global warming problems, the United Nations Framework Convention on Climate Change was issued in 1994, and Kyoto Protocol was issued in February of 2005. The protocol called for efforts to reduce the amount of greenhouse type gas emissions from in advanced countries from 2008 to 2012, ultimately aiming for 1990 levels. For biomass and bio-fuels, CO_2 is absorbed during the growth process of the plants and then the same amount is ideally generated when the fuel is burned. This is considered carbon-neutral when we consider CO_2 exhaust emissions. Thus the importance of biomass and bio-fuels is evident because they not only increase diversification of energy supply sources but also aid in CO_2 reduction.

In addition, the “IPCC Fourth Assessment Report: Climate Change 2007” (Intergovernmental Panel on Climate Change, IPCC) presented by a climate change bureau of the United Nations in 2007, gives a different predicted result. This group predicts a 1.1 to 6.4 ^{o}C higher average temperature at the end of this century. This would mean it is necessary to make more efforts to reduce CO_2 emissions. It is an important task among engineers to control the amount of CO_2 emissions through significant improvements in energy efficiency, and introducing renewable energy sources. After the COP 15 negotiations in Copenhagen in December of 2009, one of the outcome was that “The Copenhagen Accord recognizes the scientific view that an increase in global temperature below 2 degrees is required to stave off the worst effects of climate change.” At this point the effort appears to be focused on CO_2 reduction in society. Considering renewable energy forms like bio-fuels, their introduction has been promoted as a core program towards a low carbon social structure.

2.5 Bio-fuels

2.5.1 Introduction and Expansion of Bio-fuels

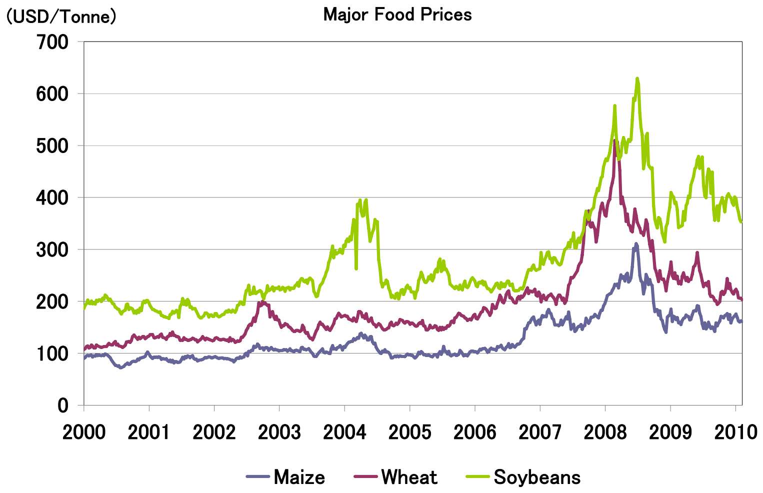
The history of bio-fuels is fairly old, since they were already investigated as automotive fuels in the latter half of the 19th century. Much later, during the first oil crisis of 1973 bio-fuels were again brought to the limelight. In the US, favorable tax treatment was given to ethanol blended with gasoline, called “gasohol”. In Brazil, at the time of the first oil crisis a national alcohol plan (PROALCOOL) was initiated in 1975. This program aimed to increase Brazil’s energy independence, and started with ethanol gasoline blending. Recently, these two countries account for about 90% of the world’s ethanol production, and Brazil attracts attention as an ethanol exporter. Finally, European countries have also embarked on a CO_2 reduction effort by introduction of bio-diesel fuel, and widespread increase in support for diesel powered passenger cars.

Bio-fuel utilization in Europe and the US has expanded after 1990 with a goal to improve automobile exhaust emission performance, to reduce CO_2 emissions, and to introduce a renewable energy source to offset the finite petroleum resource. Moreover, introduction of domestic sourced bio-fuels is an important outlet for excess supplies of corn and sugar. One should also not ignore the effect of agricultural product promotion on support prices of these agricultural products. However, as the oil price has increased in the past 5 years, the number of countries to introduce bio-fuels and the total production of bio-fuels have both accelerated, as a result competition problems with food gradually comes to the forefront.

2.5.2 Direction of Future Bio-Fuels

The bio-fuel introduction process has so far been forced to use various support measures like tax breaks and tax exemptions, but this has led to expanding levels of bio-fuel usage worldwide. If we assume a continued expansion in production, the price of grains like corn and wheat (which are sources of bio-fuel) has also increased significantly from the latter half of 2007 to the first half of 2008, as shown in Figure 6. Considering the increase in food prices, there are other factors to consider in addition to introduction and expansion of bio-fuel, namely: (1) An increase in grain consumption since developing countries like China and India have become wealthy, (2) A supply limit and a decrease of world storage of wheat due to unfavorable weather in Australia, (3) Influence of speculators, (4) Inflation effects on the US dollar and quotation in US dollars.

However, since the total amount of bio-fuels originating from grains like corn and wheat has expanded, criticism of ‘food vs fuel’ usage has grown rapidly shrill, claiming that the cause of food price increases is the bio-fuel policy, even though bio-fuel is not the only factor for the increase.



Blue Line: corn; Red Line: wheat and Green Line: soybean

(Source data: FAO Homepage)

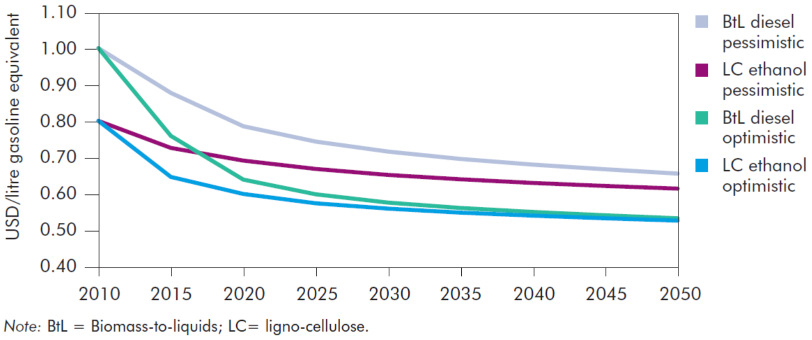
Figure 6 Variation in Grain Prices

Along with the increased criticism of the competition of food and bio-fuel source material, concerns about their actual ability to reduce a green house gas levels, and problems of deforestation to produce source material, and biological diversity, have been raised in Europe. Discussions on the long-term sustainability of bio-fuels have become more widespread. As a result, a new introduction support plan has been investigated considering the CO_2 reduction effect of various bio-fuel source materials and production methods. However, discussions are continuing on the LCA (life cycle assessment) limitations of various bio-fuels. Developing a standard for the sustainability of bio-fuels in certain parts of countries has a possibility to become a hindering factor for world free trade. Therefore, in addition to harmonization of bio-fuel quality specifications, a harmonization of sustainability standards also becomes necessary.

In this situation, expectations are rising for the second-generation bio-fuels that do not compete with food. In Europe and the US, from the middle of the 2010's, a mandatory quantity of second generation bio-fuels like cellulosic ethanol and BTL (biomass to liquid) will be increased. Commercial introduction of the second-generation biofuels in 2010s is one of the major goals of introducing biofuels especially in developed countries. On the other hand, steady increase with the first generation biofuels is also planned in many countries. As the decline in raw feedstock such as vegetable oil, further introduction of biofuels including mandatory blending is progressing steadily in many Asian countries as a measure to promote and maintain agricultural employment and mitigation of the oil import growth and so forth. With the introduction of cellulosic ethanol, the volume of potential resources will not only increase but the actual greenhouse gas reduction affect will increase significantly as well. Thus cost reduction research for commercial production has been proceeding.

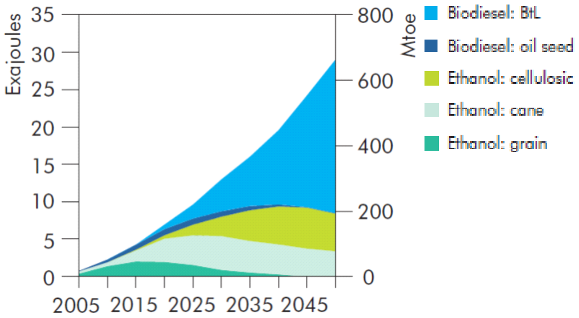
Other than energy crops for second-generation bio-fuels, other sources like micro-algae have been in the spotlight. These organisms do not require cultivated land, and can thrive on land containing high levels of salt, while still yield a large amount per unit area. This can be considered as a third generation bio-fuel ingredient. For algae-sourced bio-fuels, containing about 40% lipids overall, research on biodiesel production has been performed. However, large-scale production, cost reduction, and commercialization need to be advanced to reach current status of second-generation bio-fuels.

A cost analysis has been conducted (shown in Figure 7) on the major second generation bio-fuel sources in the IEA "Energy Technology Perspective 2008," using market-based source material prices, commercialization of plant scales, and a cost reduction trend with increased levels of total production. In an optimistic case, both cellulosic ethanol and BTL will rapidly decrease after 2010, and will reach a final cost around 2030, while in a pessimistic case the cost reduction will be slower, and the final cost will be about 0.15 dollar/L higher, compared to the optimistic case. However, the report describes a scenario that has a lower carbon dioxide exhaust emission levels in 2050, actual introduction of the third generation bio-fuel is assumed, and then an important role is expected towards a future low-carbon world, as shown in Figure 8.



(Source data: IEA "Energy Technology Perspective 2008")

Figure 7 Expected Cost of Second Generation Bio-fuels



(Source data: IEA “Energy Technology Perspective 2008”)

Figure 8. Amount of Bio-fuel Introduction in BLUE Scenario

3. BIODIESEL FUEL STANDARDIZATION ACTIVITIES

3.1 EAS-ERIA Biodiesel Fuel Standard: 2008

3.1.1 Background

The Kyoto Protocol emphasized the concept of “carbon neutral” Biofuels can have climate change benefits as they are produced from renewable sources. Asian countries are actively promoting the introduction of biofuels due to soaring oil prices and increased energy consumption. The utilization of biofuels is also important from the viewpoint of energy security and diversification of transport fuels. However, the low-quality biodiesel fuel raises serious concerns regarding the effect on engine performance caused by fuel impurities and the oxidation. Therefore, biodiesel fuel standards have been established in many countries with national standards and characterization methodologies, as shown in Table 2 and Table 3, respectively. Harmonization of standards within the East Asia region will facilitate the use and trading of good quality biodiesel**.**

At the 2nd East Asia Summit (EAS) held in January, 2007, the Cebu Declaration on East Asian Energy Security was signed. At the Energy Cooperation Task Force (ECTF) working-level meeting of persons in charge of energy policies of the EAS participating countries, it was decided that issues toward unified specification/ standardization of biodiesel would be examined. In view of this, a study group of these issues was established within the specialist meeting of the Economic Research Institute for ASEAN and East Asia (ERIA) held in May, 2007.

As part of this ERIA “Standardization of Biodiesel Fuel in East Asia” study group, a working group was established with specialist of East Asian countries as members for the commercialization of good quality biodiesel fuel in the East Asian region, and a benchmark was set on the quality of diesel fuel-mixed biodiesel fuel with harmonized specification as a goal.

Table 2 Comparison of existing biodiesel fuel standards

Items	Units	U.S.	EU	Australia	Japan	Rep. of Korea	Thailand	Vietnam
		ASTM D6751-07b	EN14214:2003		JIS K2390:2008	PPAFB Act	DOEB: 2009	TCVN 7717:2007
Ester content	mass%	-	96.5 min.	96.5 min.	96.5 min.	96.5 min.	96.5	96.5 min.
Density	kg/m3	-	860-900	860-900	860-900	860-900	860-900	860-900
Viscosity	mm2/s	1.9-6.0	3.50-5.00	3.5 - 5.0	3.50-5.00	1.9-5.0	3.5-5.0	1.90-6.00
Flashpoint	deg. C	93 min.	120 min.	120.0 min.	120 min.	120 min.	120 min	130 min.
Sulfur content	mass%	0.0015 max.	0.0010 max.	0.0010 max.	0.0010 max.	0.0010 max.	0.0010 max	0.05 max.
Distillation, T90	deg. C	360 max.	-	360 max.	-	-	-	360 max.
Carbon residue (100%) or	mass%	0.05 max.	-	-	-	-	-	0.050 max.
Carbon residue (10%)		-	0.30 max.	0.30 max.	0.3 max.	0.10 max.	0.30 max.	-
Cetane number		47 min.	51.0 min.	51.0 min.	51.0 min.	-	51.0 min	47.0 min.
Sulfated ash	mass%	0.02 max.	0.02 max.	0.02 max.	0.02 max.	0.01 max.	0.02 max	0.020 max.
Water content	mg/kg	0.05[vol%] max.	500 max.	0.050 [vol%] max.(1)	500 max.	500 max.	0.05[Wt%] max	0.05[vol%] max.
Total contamination	mg/kg	-	24 max.	24 max.	24 max.	24 max.	24 max.	-
Copper corrosion		No.3	Class-1	Class-1	Class-1	Class-1	Class-1	No.1
Acid value	mgKOH/g	0.50 max.	0.50 max.	0.80 max.	0.50 max.	0.50 max.	0.50 max.	0.50 max.
Oxidation stability	hrs.	3 min.	6.0 min.	6 min.	(**)	6.0 min.	10.0 min.	6.0 min.
Iodine value		-	120 max.	-	120 max.	-	120 max.	120 max.
Methyl Linolenate	mass%	-	12.0 max.	-	12.0 max.	-	12.0 max.	-
Polyunsaturated FAME (more than 4 double bonds)	mass%	-	1 max.	-	N.D.	-	-	-
Methanol content	mass%	0.2 max. (*)	0.20 max.	0.20 max.	0.20 max.	0.20 max.	0.20 max.	-
Monoglyceride content	mass%	-	0.80 max.	-	0.80 max.	0.80 max.	0.80 max.	-
Diglyceride content	mass%	-	0.20 max.	-	0.20 max.	0.20 max.	0.20 max.	-
Triglyceride content	mass%	-	0.20 max.	-	0.20 max.	0.20 max.	0.20 max.	-
Free glycerol content	mass%	0.020 max.	0.02 max.	0.020 max.	0.02 max.	0.02 max.	0.02 max.	0.020 max.
Total glycerol content	mass%	0.240 max.	0.25 max.	0.250 max.	0.25 max.	0.24 max.	0.25 max.	0.240 max.
Na+K	mg/kg	5 max.	5.0 max.	5 max.	5.0 max.	5.0 max.	5.0 max.	5.0 max.
Ca+Mg	mg/kg	5 max.	5.0 max.	5 max.	5.0 max.	5.0 max.	5.0 max.	-
Phosphorous content	mg/kg	10 max.	10.0 max.	10 max.	10.0 max.	10.0 max.	10.0 max.	10.0 max.

(*) 130 deg.C of flashpoint is available instead of measuring methanol content (**) Meet diesel oil specification

Table 3 Comparison of existing methods for biodiesel fuel characterization

Item	Test methods								
	Japan JIS K2390:2008	Australia	Indonesia SNI-04-7182-2006	Malaysia MS 2007:2007	New Zealand NZS 7500 (2005)	Philippines PNS/DOE QS 002:2007	South Korea PPAFB Act	Thailand DOEB-2007	Vietnam TCVN 7717
Ester content	EN 14103	EN 14103		EN 14103	EN 14103	PNS EN 14103 modified	EN 14103 (KS M2413)	EN 14103	TCVN (EN 14103)
Density	JIS K2249	ASTM D1298 or EN ISO 3675	ASTM D1298	ISO 3675 ISO 12185 ASTM D4052	ASTM D1298	PNS ASTM D1298 or PNS ASTM D4052 or PNS ISO 3675	ISO 3675 (KS M2002) ISO 12185	ASTM D1298	ASTM D1298
Kinematic Viscosity	JIS K2283	ASTM D445	ASTM D445	ISO 3104 MS 1831	ASTM D445	PNS ASTM D445	ISO 3104 (KS M 2014)	ASTM D445	ASTM D445
Flash point	JIS K2265	ASTM D93	ASTM D93	ISO 3679 MS 1831	ASTM D93	PNS ASTM D93	ISO 3679 (KS M2010)	ASTM D93	ASTM D93
Cloud point			ASTM D2500			PNS ASTM D2500			
Sulfur content	JIS K2541-1, -2, -6 or -7	ASTM D5453	ASTM D5453	ISO 20846 ISO 20884 ASTM D5453	IP 497 or ASTM D5453	PNS ASTM D2622/ PNS ASTM D5453/ PNS ASTM D4294	ISO 20846, ISO 20884 (KS M2027)	ASTM D2622	ASTM D5453
10% carbon residue	JIS K2270	EN ISO 10370 ASTM D4530	ASTM D4530	ISO 10370 ASTM D4530	ASTM D4530 ISO 10370	PNS ASTM D4530 or PNS ISO 10370	KS M ISO 10370	ASTM D4530	ASTM D4530
Cetane number	JIS K2280	EN ISO5165 ASTM D613 ASTM D6890 IP 498/03	ASTM D613	ISO 5165 MS 1895	ASTM D613 ASTM D6890	PNS ASTM D613 or PNS ASTM D6890 or PNS ISO 5165 or PNS IP 498/03		ASTM D613	ASTM D613
Distillation T90		ASTM D1160	ASTM D1160			PNS ASTM D1160 or PNS ASTM D86			ASTM D1160
Sulfated ash content	JIS K 2272	ASTM D874	ASTM D874	ISO 3987 ASTM D874	ASTM D874	PNS ASTM D874	KS M ISO 6245	ASTM D874	ASTM D874
Water content	JIS K 2275	ASTM D2709	ASTM D2709	ISO 12937 ASTM E203 ASTM D1160	IP 438	PNS ASTM D6304 or PNS ISO 12937 or PNS ASTM E203	(KS M2115)	EN ISO12937	ASTM D2709
Total contamination	EN 12662	EN 12662 ASTM D5452		EN 12662 ASTM D5452	IP440			EN 12662	
Copper corrosion	JIS K 2513	EN ISO2160 ASTM D130	ASTM D130	ISO 2160 MS 787	ASTM D130	PNS ASTM D130 or PNS ISO 2160	ISO 2160 (KS M 2018)	ASTM D130	ASTM D130
Oxidation stability		EN 14112 or ASTM D2274 (as relevant for biodiesel)		EN 14112	EN 14112	PNS EN 14112	EN 14112	EN 14112	EN 14112
Acid value	JIS K 2501 or JIS K 0070	ASTM D664	AOCS Cd3-63	EN 14104 MS 2011	ASTM D664	PNS ASTM D664/ PNS ASTM D974/ PNS EN 14104	KS M ISO 6618	ASTM D664	ASTM D664
Iodine value	JIS K 0070		AOCS Cd1-25	EN 14111	EN 14111			EN 14111	EN 14111
Methyl linolenate	EN 14103			EN 14103	EN 14103	PNS EN 14331 modified or PNS EN 14103 modified		EN 14103	
Methanol content	EN 14110	EN 14110		EN 14110	EN 14110	PNS EN 14110	EN 14110	EN 14110	
Monoglyceride content	EN 14105			EN 14105 ASTM D6584	ASTM D6584	PNS EN 14105 modified or PNS ASTM D6584		EN 14105	
Diglyceride content									
Triglyceride content									
Free glycerol content	EN 14105 or EN 14106	ASTM D6584	AOCS Ca14-56	EN 14105 EN 14106 ASTM D6584	ASTM D6584	PNS AOCS Ea 6-94 (1997)/ PNS ASTM D 6584 modified or PNS EN 14105 modified		EN 14105	ASTM D6584
Total glycerol content	EN 14105	ASTM D6584	AOCS Ca14-56		ASTM D6584	PNS AOCS Ca 14-56 (1997)/ PNS ASTM D 6584 modified or PNS EN 14105 modified	EN 14105 (KS M2412)	EN 14105	ASTM D6584
Alkyl ester content			Cakculated						
Metals (Na+K)	EN 14108 EN 14109	EN 14108 EN 14109		EN 14108 EN 14109	EN 14108 EN 14109	PNS EN 14108 PNS EN 14109	EN 14108 EN 14109	EN 14108 EN 14109	EN 14108 EN 14109
Metals (Ca+Mg)	EN 14538	EN 14538		EN 14538	EN 14538	PNS EN 14538	EN 14538	EN 14538	
Phosporous	EN 14107	ASTM D4951	AOCS Ca12-55	EN 14107 ASTM D4951	ASTM D4951	PNS ASTM D4951	EN 14107	ASTM D4951	ASTM D4951
Pour point									
CFPP				EN 116			KS M2411		
Halphen test			AOCS Cb1-25						
Additives									

3.1.2 Concepts of Harmonized Specification

To harmonize the specification of biodiesel fuel, the concepts were discussed as follows.

(1) Based on European standard (EN14214)

The subject of this WG is only focused on FAME (Fatty Acid Methyl Ester) as a biodiesel fuel. EN14214 is recognized as a comprehensive specification for FAME, and so this WG discussed the harmonized specification based on EN14214.

(2) Consideration of various oils

EN14214 is set for rapeseed oil only. There is a need to consider other feedstocks used in the East region, such as:

Coconut: low viscosity and flashpoint
Soybean: Iodine number

(3) Oxidation stability

Oxidation stability has critical impact on fuel tanks made of metals. In Europe, fuel tanks of vehicle are mainly made of plastics or resin. However in Asia, metal tanks are popular for vehicles. Oxidation stability value of “10 hours”, which was recommended by Japan Automobile Manufacturers Association, Inc. (JAMA), is based to prevent metal tank corrosion.

(4) Polyunsaturated FAME

Polyunsaturated FAME was mainly included in fish oil. It accelerates oxidation degradation and sludge production, however, the measurement method has not been developed. Polyunsaturated (more than 4 double bonds) FAME need to be excluded.

3.1.3 EAS-ERIA Biodiesel Fuel Standard: 2008

WG for Standardization of Biodiesel Fuel for Vehicles in East Asia made an “EAS-ERIA Biodiesel Fuel Benchmark Standard”. Table 4 shows the specification compared to other existing standards. This is a benchmark standard suggested for member countries for the purpose of harmonizing biodiesel standards in East-Asia.

Table 4 EAS-ERIA Biodiesel Fuel Standard: 2008 compared to other existing standards

Items	Units	U.S.	EU	Japan	EAS-ERIA Biodiesel Fuel Standard:2008
		ASTM D6751-07b	EN14214:2003	JIS K2390:2008	
Ester content	mass%	-	96.5 min.	96.5 min.	96.5 min.
Density	kg/m3	-	860-900	860-900	860-900
Viscosity	mm2/s	1.9-6.0	3.50-5.00	3.50-5.00	2.00-5.00
Flashpoint	deg. C	93 min.	120 min.	120 min.	100 min.
Sulfur content	mass%	0.0015 max.	0.0010 max.	0.0010 max.	0.0010 max.
Distillation, T90	deg. C	360 max.	-	-	-
Carbon residue (100%) or Carbon residue (10%)	mass%	0.05 max. -	- 0.30 max.	- 0.3 max.	0.05 max. 0.3 max.
Cetane number		47 min.	51.0 min.	51.0 min.	51.0 min.
Sulfated ash	mass%	0.02 max.	0.02 max.	0.02 max.	0.02 max.
Water content	mg/kg	0.05[vol%] max.	500 max.	500 max.	500 max.
Total contamination	mg/kg	-	24 max.	24 max.	24 max.
Copper corrosion		No.3	Class-1	Class-1	Class-1
Acid value	mgKOH/g	0.50 max.	0.50 max.	0.50 max.	0.50 max.
Oxidation stability	hrs.	3 min.	6.0 min.	(**)	10.0 min. (****)
Iodine value		-	120 max.	120 max.	Reported (***)
Methyl Linolenate	mass%	-	12.0 max.	12.0 max.	12.0 max.
Polyunsaturated FAME (more than 4 double bonds)	mass%	-	1 max.	N.D.	N.D. (***)
Methanol content	mass%	0.2 max. (*)	0.20 max.	0.20 max.	0.20 max.
Monoglyceride content	mass%	-	0.80 max.	0.80 max.	0.80 max.
Diglyceride content	mass%	-	0.20 max.	0.20 max.	0.20 max.
Triglyceride content	mass%	-	0.20 max.	0.20 max.	0.20 max.
Free glycerol content	mass%	0.020 max.	0.02 max.	0.02 max.	0.02 max.
Total glycerol content	mass%	0.240 max.	0.25 max.	0.25 max.	0.25 max.
Na+K	mg/kg	5 max.	5.0 max.	5.0 max.	5.0 max.
Ca+Mg	mg/kg	5 max.	5.0 max.	5.0 max.	5.0 max.
Phosphorous content	mg/kg	10 max.	10.0 max.	10.0 max.	10.0 max.

(*) 130 deg.C of flashpoint is available instead of measuring methanol content (**) Meet diesel oil specification
(***) Need data check and further discussion (****) Need more data & discussion from 6 to 10 hours

This standard is for B100 aimed for low level blending with diesel fuel. In case of the use as a final fuel, further considerations are necessary, especially in regards to oxidation stability.

In the Second EAS Energy Ministers Meeting which was held on 7 August 2008 in Bangkok, this standard was welcomed from the Ministers as a valuable benchmark reference in developing respective national standards of EAS countries.

3.2 World Wide Fuel Charter - Biodiesel (B100) Guidelines

3.2.1 World Wide Fuel Charter

(1) Background

Fuel quality plays an important role in order that the latest low emission vehicles and their emission control systems may function properly. Especially in Japan, USA and Europe, nearly same levels of stringent emission regulations are scheduled to be introduced, and it is a common recognition of vehicle manufacturers that the supply of globally harmonized clean fuels is essential to achieve the target of cleaner air quality and environment protections worldwide.

On the other hand, there are large varieties of fuels in many regions of the world, especially in the developing countries and districts (most of them have insufficient quality). This situation is one of the obstacles to prevent quick introduction of the latest low emission vehicles, and it is strongly required to improve fuel quality in the corresponded markets.

(2) Its History

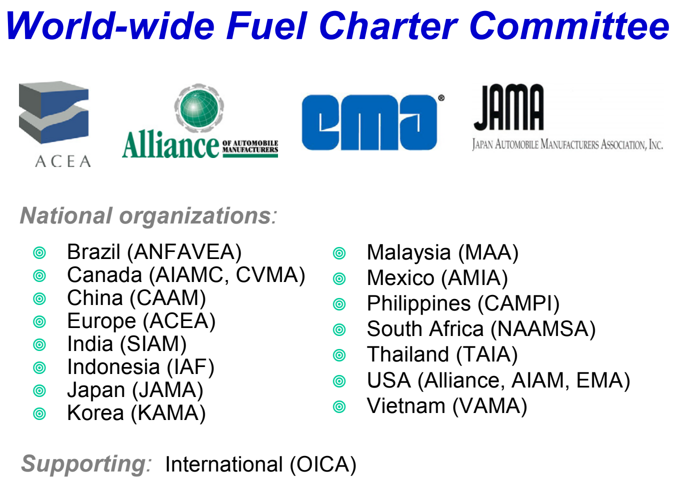
In the beginning of 1990s, former CCMC in Europe released “CCMC Fuel Charter” and established an approval system of quality fuels in the market. Even after the organization change as ACEA, this system was taken over and “The ACEA Fuel Charter” was published in 1994.

At the same period, AAMA in the USA also published “AAMA National Gasoline Specification” in 1994 and revised it in 1996. JAMA supported this activity throughout the information and opinion exchanges.

Finally, the automotive industries from Japan, USA and Europe decided to cooperate together and published the 1st edition of “World Wide Fuel Charter” in 1998. After the several times of revision, the 4th edition published in 2006 is the latest version at the moment.

(3) Contents of WWFC

The WWFC Committee consists of 4 major automotive industry organizations of Japan Automobile Manufacturers Association (JAMA), Alliance of Automobile Manufacturers (AAM), Engine Manufacturers Association (EMA) and European Automobile Manufacturers Association (ACEA), and also associates members of other country national organizations from all over the world. (see Figure 9)



World-wide Fuel Charter Committee

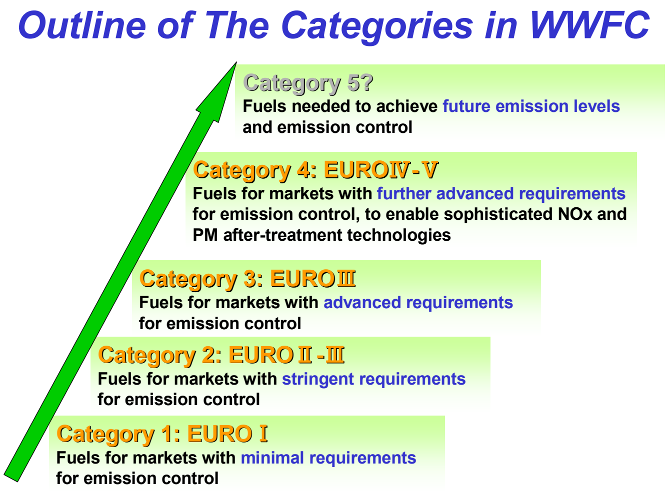
National organizations:

- Brazil (ANFAVEA)
- Canada (AIAMC, CVMA)
- China (CAAM)
- Europe (ACEA)
- India (SIAM)
- Indonesia (IAF)
- Japan (JAMA)
- Korea (KAMA)
- Malaysia (MAA)
- Mexico (AMIA)
- Philippines (CAMPI)
- South Africa (NAAMSA)
- Thailand (TAIA)
- USA (Alliance, AIAM, EMA)
- Vietnam (VAMA)

Supporting: International (OICA)

Figure 9 WWFC committee member organizations

"World Wide Fuel Charter" is an automotive industry's guiding document towards improved and harmonized market fuel quality. Gasoline and diesel fuel qualities for vehicles are classified into 4 quality levels (Category 1, 2, 3 and 4) to match emission requirements of up to Euro5/US10 or equivalent. (see Figure 10)



Outline of The Categories in WWFC

Category 5?
Fuels needed to achieve future emission levels and emission control

Category 4: EUROⅣ-Ⅴ
Fuels for markets with further advanced requirements for emission control, to enable sophisticated NOx and PM after-treatment technologies

Category 3: EUROⅢ
Fuels for markets with advanced requirements for emission control

Category 2: EUROⅡ-Ⅲ
Fuels for markets with stringent requirements for emission control

Category 1: EUROⅠ
Fuels for markets with minimal requirements for emission control

Figure 10 Outline of the fuel quality categories in WWFC

The Charter can be downloaded from each Committee member's website. Their URLs are as follows.

http://www.jama.or.jp/ or
http://www.autoalliance.org or
http://www.acea.be

3.2.2 WWFC Biofuel Guidelines

(1) Background

The use of bio-components like ethanol (and ETBE) and fatty acid methyl esters (FAME) in market fuels are increasing as from CO_2 reduction and energy security points of view. There only existed national/regional standards and specifications for bio-components so far. Their qualities were highly variable and not always fit for purpose. Bio-components can be inherently feedstock dependent (e.g. type and the nature of vegetable oils, their processing routes), and this represents additional challenges for the standardization activity.

On the other hands, as the automotive industry's activities are global, there also exists an increased need for international harmonization of market fuels including bio-components. However, bio-components are just mentioned as parts of the WWFC gasoline and diesel fuel specifications at the moment. As a consequence, the WWFC Committee concluded some 2 years ago that more uniform definition of ethanol and FAME quality is needed and decision was taken to develop "Biofuel Guidelines".

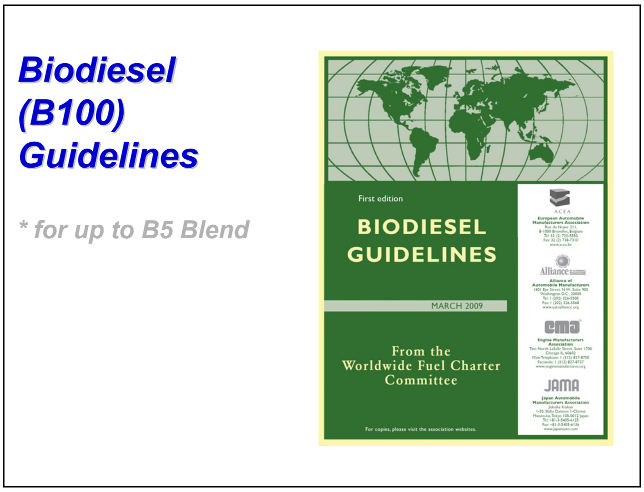
(2) Milestones of the Guideline Making

The WWFC Biofuel Guidelines drafts for comments were issued in July 2008 and the deadline for comments submission was October 1, 2008. The WWFC Committee held a meeting on October 7, 2008 in Chicago to review and discuss into details of the comments they received. After the continued work to finalize the Guidelines, the 1st editions of "World Wide Fuel Charter - Biofuel Guidelines" were published in March 2009 finally as E100 and B100 Guidelines for E10 and B5 blends. They are performance-based requirements and defined as feedstock neutral. Test methods for each property parameters are also described.

The target audiences are biofuel producers, fuel distributors, legislators and end-users. It is noted in the Guidelines that "World Wide Fuel Charter" still applies to retail gasoline and diesel fuel quality (i.e. the Guidelines supplement Category 1, 2, 3 and 4 requirements), and the fuel suppliers are responsible for final product quality. The Guidelines can be downloaded from each Committee member's website same as the Charter.

(3) The B100 Guidelines

The specification tables of the B100 Guidelines are shown in Figure 11.



Biodiesel (B100) Guidelines

* for up to B5 Blend

First edition

BIODIESEL GUIDELINES

MARCH 2009

From the Worldwide Fuel Charter Committee

For copies, please visit the association websites.

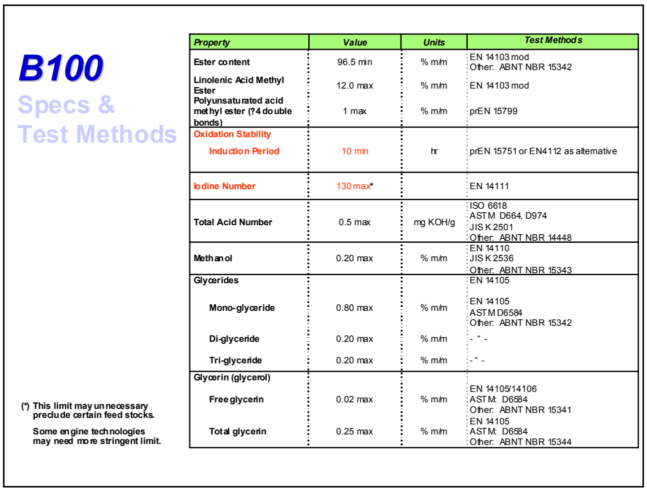
ACEA
European Automobile Manufacturers Association
Rue du Noyer 211,
B-1000 Bruxelles, Belgium
Tel: 32 (2) 732-5550
Fax: 32 (2) 738-7310
www.acea.be

Alliance of Automobile Manufacturers
1401 Eye Street, N.W., Suite 900
Washington D.C., 20005
Tel: 1 (202) 326-5500
Fax: 1 (202) 326-5568
www.autoalliance.org

Engine Manufacturers Association
Two North LaSalle Street, Suite 1700
Chicago IL, 60602
Main Telephone: 1 (312) 827-8700
Facsimile: 1 (312) 827-8737
www.enginemanufacturers.org

JAMA
Japan Automobile Manufacturers Association
Jidosha Kiakan
1-30, Shiba Daimon 1-Chome
Minato-ku, Tokyo 105-0012 Japan
Tel: +81-3-5405-6125
Fax: +81-3-5405-6136
www.japanauto.com

(a)



B100

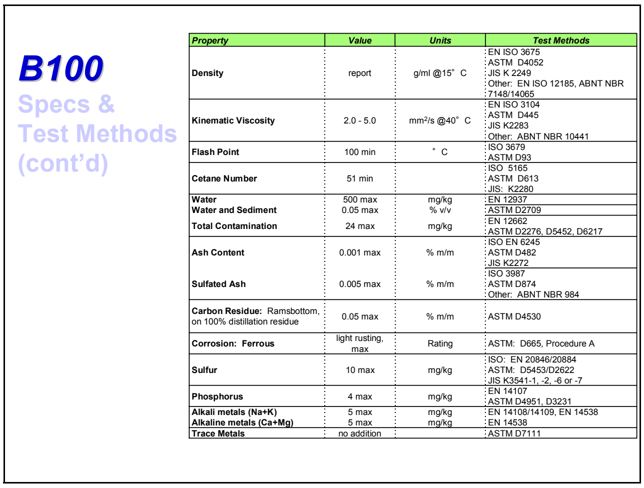
Specs & Test Methods

Property	Value	Units	Test Methods
Ester content	96.5 min	% m/m	EN 14103 mod Other: ABNT NBR 15342
Linolenic Acid Methyl Ester	12.0 max	% m/m	EN 14103 mod
Polyunsaturated acid methyl ester (?4 double bonds)	1 max	% m/m	prEN 15799
Oxidation Stability			
Induction Period	10 min	hr	prEN 15751 or EN4112 as alternative
Iodine Number	130 max*		EN 14111
Total Acid Number	0.5 max	mg KOH/g	ISO 6618 ASTM D664, D974 JIS K 2501 Other: ABNT NBR 14448
Methanol	0.20 max	% m/m	EN 14110 JIS K 2536 Other: ABNT NBR 15343
Glycerides			EN 14105
Mono-glyceride	0.80 max	% m/m	EN 14105 ASTM D6584 Other: ABNT NBR 15342
Di-glyceride	0.20 max	% m/m	- " -
Tri-glyceride	0.20 max	% m/m	- " -
Glycerin (glycerol)			
Free glycerin	0.02 max	% m/m	EN 14105/14106 ASTM: D6584 Other: ABNT NBR 15341
Total glycerin	0.25 max	% m/m	EN 14105 ASTM: D6584 Other: ABNT NBR 15344

(*) This limit may unnecessary preclude certain feed stocks.

Some engine technologies may need more stringent limit.

(b)



B100

Specs & Test Methods (cont'd)

Property	Value	Units	Test Methods
Density	report	g/ml @15° C	EN ISO 3675 ASTM D4052 JIS K 2249 Other: EN ISO 12185, ABNT NBR 7148/14065
Kinematic Viscosity	2.0 - 5.0	mm²/s @40° C	EN ISO 3104 ASTM D445 JIS K2283 Other: ABNT NBR 10441
Flash Point	100 min	° C	ISO 3679 ASTM D93
Cetane Number	51 min		ISO 5165 ASTM D613 JIS: K2280
Water	500 max	mg/kg	EN 12937
Water and Sediment	0.05 max	% v/v	ASTM D2709
Total Contamination	24 max	mg/kg	EN 12662 ASTM D2276, D5452, D6217
Ash Content	0.001 max	% m/m	ISO EN 6245 ASTM D482 JIS K2272
Sulfated Ash	0.005 max	% m/m	ISO 3987 ASTM D874 Other: ABNT NBR 984
Carbon Residue: Ramsbottom, on 100% distillation residue	0.05 max	% m/m	ASTM D4530
Corrosion: Ferrous	light rusting, max	Rating	ASTM: D665, Procedure A
Sulfur	10 max	mg/kg	ISO: EN 20846/20884 ASTM: D5453/D2622 JIS K3541-1, -2, -6 or -7
Phosphorus	4 max	mg/kg	EN 14107 ASTM D4951, D3231
Alkali metals (Na+K)	5 max	mg/kg	EN 14108/14109, EN 14538
Alkaline metals (Ca+Mg)	5 max	mg/kg	EN 14538
Trace Metals	no addition		ASTM D7111

(c)

Figure 11 B100 specifications and test methods

Comparison of the limit values for each property between the B100 Guidelines and each national FAME specification of Japan, USA and Europe are summarized in Table 5. The properties shown in red and blue letters indicate rather important properties to prevent unnecessary vehicle problems in the market. In case of limit values shown in red letters, the Guidelines require more stringent control than the other national specification (ref. the limit for iodine number was decide as a compromise with more stringent limit for oxidation stability).

Table 5 Comparison with each national FAME spec. of Japan, USA and Europe

Items	Units	Japan	USA	EU	WWFC Biofuel Guidelines B100 for up
		JIS K 2390	ASTM D6751	EN14214	
Ester content	mass%	96.5 min.	-	96.5 min.	96.5 min.
Density	kg/m3	860-900	-	860-900	Report
Viscosity	mm2/s	3.50-5.00	1.9-6.0	3.50-5.00	2.00-5.00
Flashpoint	deg C	120 min.	93 min.	120 min.	100 min.
Sulfur content	mass%	0.0010 max.	0.0015 max.	0.0010 max.	0.0010 max.
Distillation, T90	deg C	-	360 max.	-	-
Carbon residue (100%) or Carbon residue (10%)	mass%	- 0.30 max.	0.05 max. -	- 0.30 max.	0.05 max. -
Cetane number		51.0 min.	47 min.	51.0 min.	51.0 min.
Sulfated ash	mass%	0.02 max.	0.02 max.	0.02 max.	0.005 max.
Water content	mg/kg	500 max.	0.05[vol%] max.	500 max.	500 max.
Total contamination	mg/kg	24 max.	-	24 max.	24 max.
Copper corrosion		Class-1	No.3	Class-1	-
Acid value	mgKOH/g	0.50 max.	0.50 max.	0.50 max.	0.50 max.
Oxidation stability	hrs	(*)	3 min.	6.0 min.	10.0 min.
Iodine number		120 max.	-	120 max.	130 max.
Methyl Linolenate	mass%	12.0 max.	-	12.0 max.	12.0 max.
Polyunsaturated FAME (more than 4 double bonds)	mass%	N.D.	-	1 max.	1 max.
Methanol content	mass%	0.20 max.	0.2 max. (**)	0.20 max.	0.20 max.
Monoglyceride content	mass%	0.80 max.	-	0.80 max.	0.80 max.
Diglyceride content	mass%	0.20 max.	-	0.20 max.	0.20 max.
Triglyceride content	mass%	0.20 max.	-	0.20 max.	0.20 max.
Free glycerol content	mass%	0.02 max.	0.02 max.	0.02 max.	0.02 max.
Total glycerol content	mass%	0.25 max.	0.24 max.	0.25 max.	0.25 max.
Na+K	mg/kg	5.0 max.	5 max.	5.0 max.	5.0 max.
Ca+Mg	mg/kg	5.0 max.	5 max.	5.0 max.	5.0 max.
Phosphorous content	mg/kg	10.0 max.	10 max.	10.0 max.	4.0 max.

(*) Decided by both party's agreement, (**) Equivalent to diesel fuel

The points of discussion on important properties of FAME and some technical issues are as follows;

(i) Methyl ester purity: Low level of methyl ester indicates high levels of un-reacted materials or contaminations with non-FAME products. In the Guidelines, specific limits for linolenic acid methyl ester and poly-unsaturated acid methyl esters that have 4 or more double bonds are also regulated respectively because they are easily oxidized and the main cause of poor oxidation stability.

(ii) Oxidation stability is one of the most important properties. Oxidized products can disturb functioning of engine/vehicle and even create hardware damage. Poor oxidation stability increases risk of formation of gums, sludge and other insoluble compounds.

(iii) Iodine number indicates total of double bonds (level of unsaturation), and can provide information about fuel’s tendency to form sludge, also affect lubricant quality and/or cause corrosion.

(iv) Glycerides, glycerol (total and free) can cause filter plugging (especially at low temperature) and injector/engine deposits.

(v) Sulfated ash measure of amount of metals and other inorganic contaminants in the fuel. Sulfated ash content is linked to fuel injector deposits and PM filter plugging.

(vi) Phosphorus, sulfur cause catalyst poison, will cause increased exhaust emissions.

(vii) Alkali (Na, K) and alkaline earth (Ca, Mg) metals: KOH and NaOH are process chemical, which should not present in final product. Their presences can form deposits in injection systems and poison emission control systems, as well as injectors stick via soap formation.

(viii) Good house-keeping practices: In the Guidelines, good management practices are strongly recommended. CEN technical report CEN/TR 15367 gives good handling guidance.

(ix) Labeling: The Guidelines apply for up to B5 blend only. Clear labeling is also required in case of higher FAME concentration blend beyond B5.

4. BIODIESEL FUEL QUALITY

4.1 Oxidation Stability

4.1.1 Introduction of Oxidation Stability

Compared to petroleum based diesel fuel, FAME oxidizes easily and forms reaction products shown to have unfavorable effects on vehicle fuel systems. Therefore, oxidation stability is one of the most important characteristics for practical use of FAME. FAME molecules typically have several double bonds, and oxidize fairly easily. Initially, the oxidation process generates peroxides (hydrogen peroxide), which subsequently forms acids, as shown in Table 6. The acid itself also plays a role in the acceleration of oxidation. In the end, the acid reacts with sludge, deposits, or other undissolved chemical compounds and accumulate as deposits.

Table 6 Organic acids formed by heat exposure (110℃)

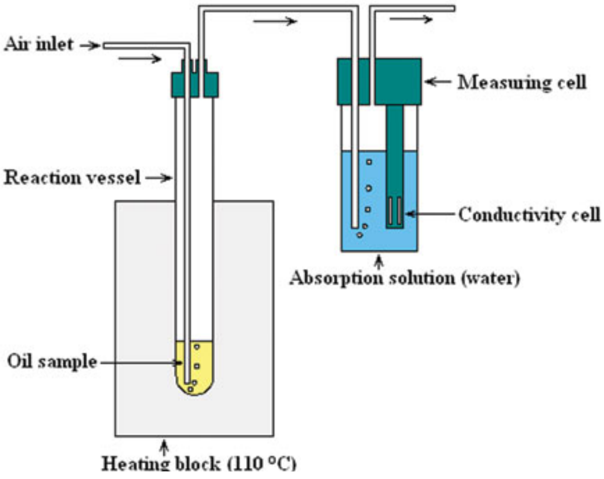
(ppm)

	FAME A B100	FAME B B5	FAME C B5	Petroleum Based Diesel
Heating Duration (h)	32	64	64	64
Formic Acid	620	180	190	120
Acetic Acid	410	190	170	170
Propionic Acid	160	89	78	43
Butyric Acid	1	38	23	36
Caproic Acid	50	316	289	47
Caprylic Acid	2	52	66	19
Capric Acid	<1	27	53	17
Lauric Acid	1	19	27	16
Myristic Acid	2	26	39	12
Palmitic Acid	95	280	374	16
Stearic Acid	27	51	253	28
Oleic Acid	354	304	388	2
Linoleic Acid	78	54	145	<1
Linolenic Acid	<1	<1	23	<1
Oxalic Acid	10	4	<1	<1
Malonic Acid	<1	<1	<1	<1
Succinic Acid	<1	6	4	5

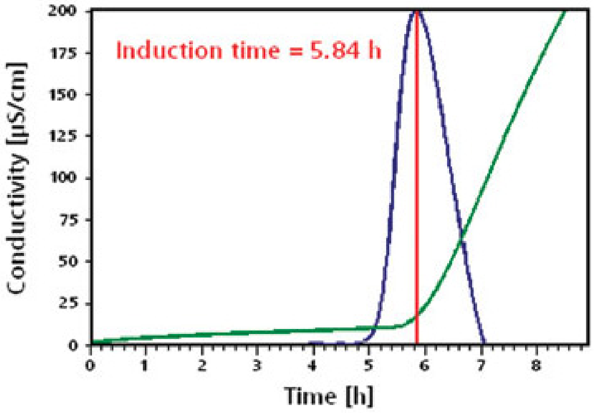
▨ : heat degradation

🟪 : hydrolysis

Rancimat method, provided in EN 14112, is the most popular test method of oxidation stability. The Rancimat method is an accelerated oxidation test that is run at elevated temperatures and exposes the sample to air. This results in auto-oxidation in a



(a)



(b)

(Source: http//www.biodieselmagazine.com)

(c)

Figure 12 (a) Principle of Rancimat method with (b) its conductivity measurement and (c) experimental setup

few hours, instead of weeks or months. Figure 12(a) shows the principle of the Rancimat method. Air is blown through the tested sample (approximately 3 g in weight) which is heated to a specified temperature (110 °C) in order to oxidize it. The stream of air then carries over the volatile oxidation products which normally formed at the end of the oxidation process to a measuring vessel containing deionized water. The readings of the conductivity measurement can be plotted as a function of the time required for the oxidation as shown in Figure 12(b). The inflection point of this oxidation curve is known as the induction time which serves as a measure of quality of the oil tested. Figure 12(c) is an example of Rancimat test equipment (743 Rancimat). With standard EN 14214 Minimum Racimat oxidation stability period of 6 hours at 110 °C is defined for biodiesel samples. In EAS-ERIA Biodiesel Fuel Standard: 2008, the oxidation stability is specified 10 hours minimum for B100 aimed for low level blending with diesel fuel.

Peroxides deteriorate plastic and elastomers, particularly at high temperatures. Acids corrode metal, which is used in vehicle fuel systems and fuel supply systems. The acids' effects on a metal fuel tank are particularly severe. Even though only light corrosion forms there, the resultant organic acid salts agglomerate and produce deposits inside the fuel pump and injector. The metallic and organic acids react again and form a metallic salt. These salts (which precipitate in fuel) pass through the fuel filter, and adhere to the fuel pump and fuel injector surfaces. These salts also form an injector deposit like sludge. Other immiscible substances formed include polymer, sludge, and oxidation products, which sometime cause fuel filter blockage, as shown in Figure 13.

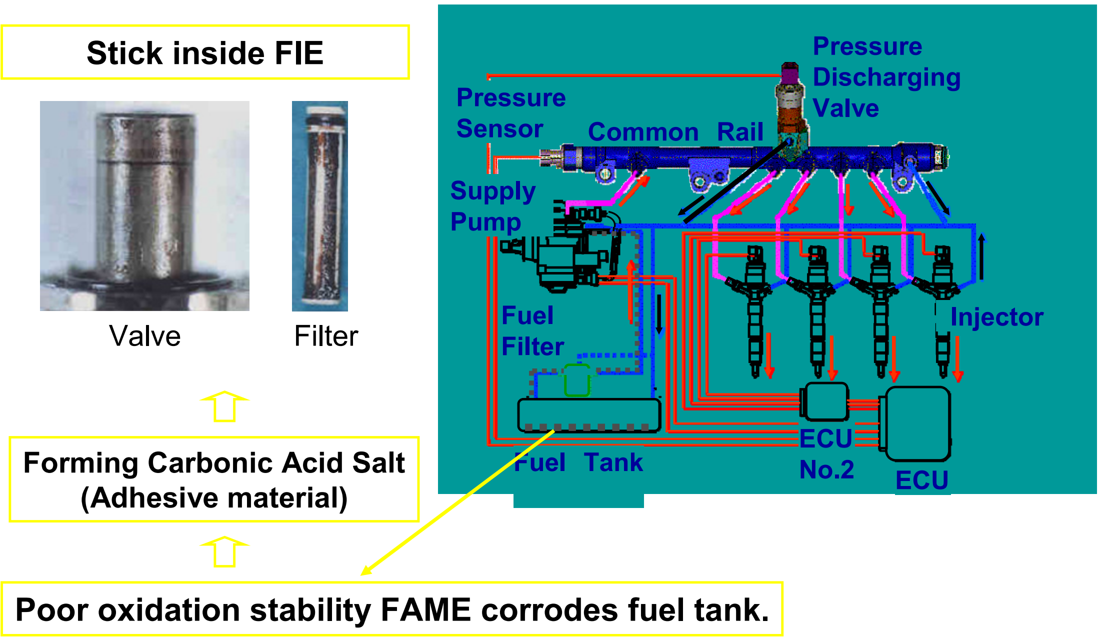


Figure 13 Example of market experience with problem from poor quality FAME

Past experience has shown that petroleum based diesel fuel can be stored without oxidation for a very long time. FAME, however, even at low blend levels, deteriorates the oxidation stability of the final FAME-diesel fuel blend. Depending on the storage condition (for example, temperature and air volume), unacceptable deterioration may occur. Thus, it is necessary to develop countermeasures to allow storage stability for a minimum of six months.

In order to prevent consumer problems, the oxidation stability of FAME must exceed a standard value. In other words, it is necessary to have more than a certain oxidation induction or delay period. Antioxidant additives can help maintain the necessary oxidation stability.

(1) Iodine Number

The iodine number indicates the total number of double bonds in a molecule (or its saturated level). In general, low oxidation stability correlates with a high iodine number, therefore the iodine number is considered as an index of oxidation stability, as shown in Figure 14. However, oxidation stability cannot be solely determined by the iodine number. Moreover, it is known that fatty acids with many double bonds are preferable to saturated fatty acids in terms of low temperature flowability.

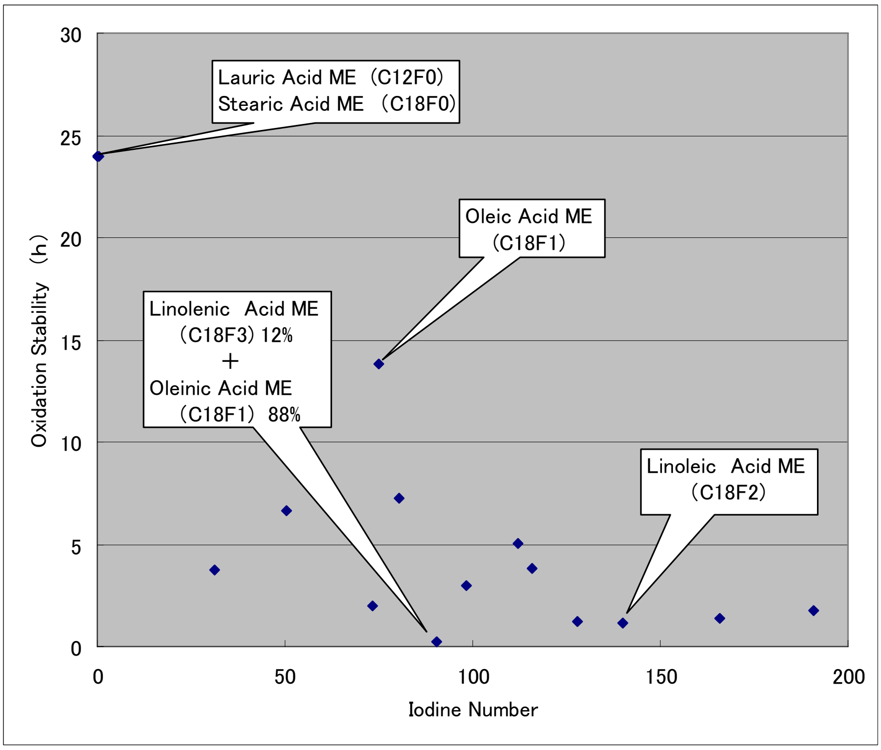
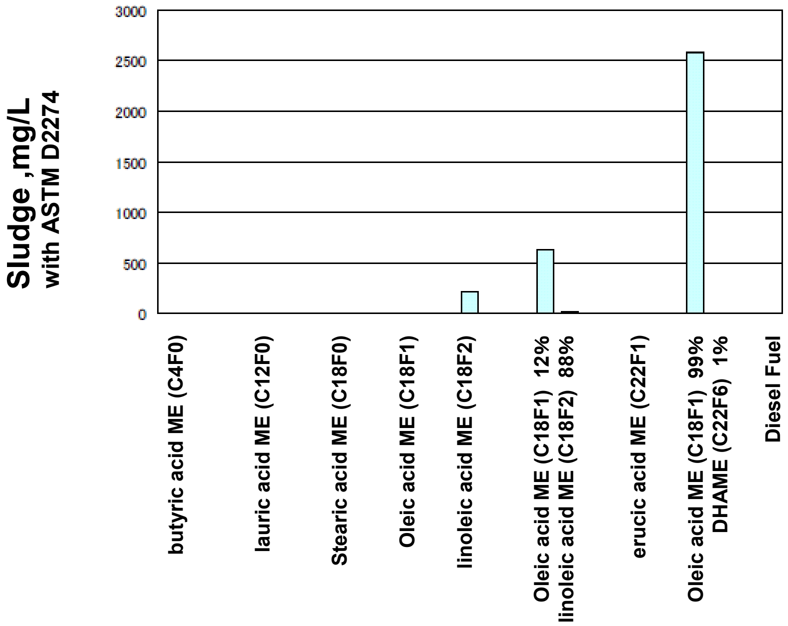


Figure 14 Relationship between oxidation stability and iodine number

In order to maintain oxidation stability, one suggestion was to establish a limit for the iodine number. In that case, it could mean elimination of FAME from raw materials which result in high iodine numbers, such as soybean, sun flower and other oils with many unsaturated bonds. If good oxidation stability can be maintained by countermeasures like the use of antioxidants, it may be not necessary to stipulate iodine numbers. A test method for oxidation stability which has been widely used at present (Rancimat Method: EN14112) can measure the induction period for acid to occur under conditions of accelerated deterioration. However, it is not fully known whether or not this method can predict sludge occurrence, or other properties. From this standpoint, and for sludge formation control, there is a thought that a certain maximum iodine number is necessary.

(2) Linoleic Acid Methyl Ester and Multi-Unsaturated Fatty Acid Methyl Esters

The linoleic acid methyl ester molecule contains three double bonds, and has very high oxidation instability. Therefore, these molecules can easily be oxidized to react, and as a result, form sludge. In addition, methyl esters with many unsaturated bonds form sludge very easily, as shown in Figure 15. It is known that fish oil contains many fatty acids which contain more than four unsaturated bonds per molecule (quite unlike plant oils). Fish oil is thus not suitable as a raw material for automobile fuels.



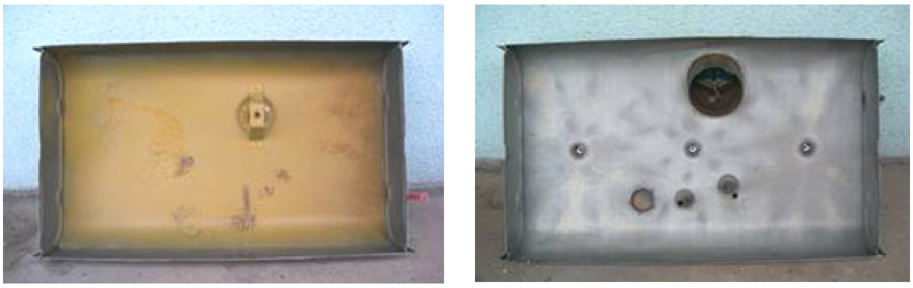
(Source: METI FAME Conformity Test)

Figure 15 Effects of poly-unsaturated methyl esters on sludge formation

(3) Metal Corrosion

When FAME thermally oxidizes, it decomposes and produces organic acids. When plant oils or fats, which are now widely used as a biofuel, thermally oxidize and decompose, formic acid, acetic acid, propionic acid, and caprionic acid are mainly formed. Metals, particularly copper, copper alloys, lead, zinc, and tin corrode easily by these organic acids. A series of tests performed by the Japan Ministry of Economy Trade and Industry, showed remarkable effects on a galvanized steel plate placed in a fuel tank. This type of metal is commonly used for automotive fuel system components. Particularly in the lead - tin galvanized steel plate (trade name: Turne sheet), lead reacts with the highly reactive organic acids present, such as formic acid and acetic acid. The products react with caprionic acid (a larger molecule), and then are deposited as a metallic salt of caprionic acid. A large quantity of this caprionic acid salt can accumulate in the fuel tank and filter, as shown in Figure 16. However, part of it goes through the fuel filter, and is accumulated as an injector deposit. As shown in Figure 17, there is widespread use of metallic fuel tanks of varying material quality in East Asian countries, thus metal corrosion is an important problem compared to other regions.

Oxy. Stab
of B100
: **6 Hrs**

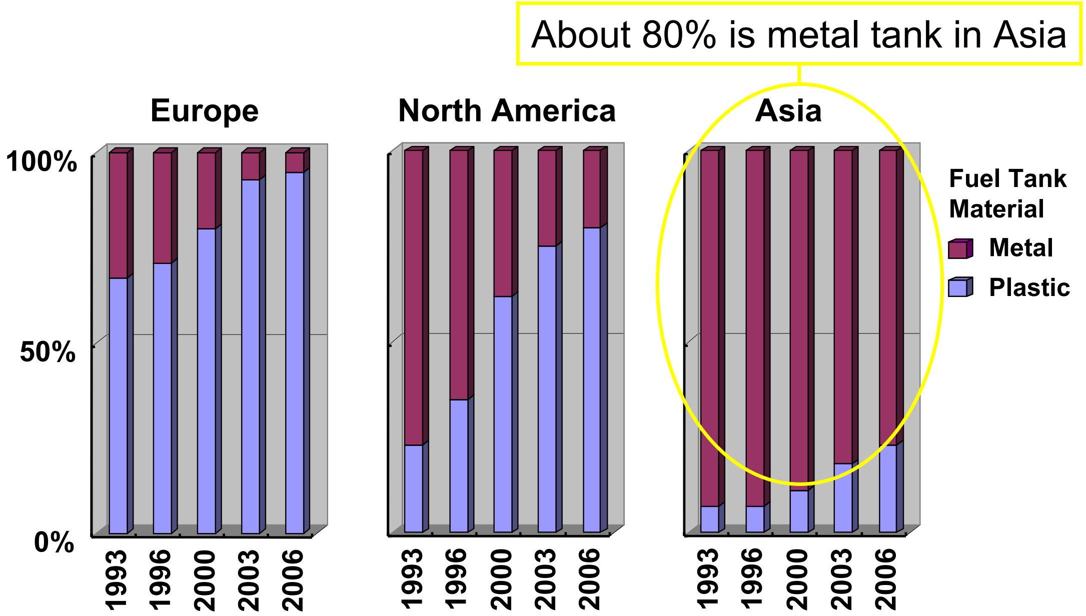


Test Fuel: Commercial diesel fuel blended the FAME meets EN14214 by 5vol%

Oxy. Stab
of B100
: **10 Hrs**

Test Fuel: Same FAME above with 400ppm of anti-oxidant (20ppm as B5)

Figure 16 Effects of oxidation stability on fuel tank corrosion



(Source: Data from Website of Plastics Fuel Systems Manufactures Association and in-house information of a material company.)

Figure 17 Fuel tank materials in Asia

(4) Storage Stability

The Japan Ministry of Economy Trade and Industry endeavored to identify problems involved with flow and storage processes of FAME blended with petroleum based diesel fuel. Several validation tests were carried out in this study, as shown in Figure 18. Two fuels were compared in the storage test. One was FAME blended with petroleum based diesel fuel, while the other was an identical blend ratio but mixed after a certain period. Both were stored for the same amount of time. Results showed that the latter case had better storage stability. Since 100% FAME has very poor storage stability, it would be desirable to add the appropriate amount of oxidation inhibitor in the production process, right after manufacturing, if possible.

Moreover, upon examination of the actual fuel transport path, it was found out that moisture typically remains inside the underground tank at a gas station. This significantly reduces FAME blend's oxidation stability. In Japan many of the underground tanks are made of steel or iron products, and do not have any surface treatment. Fuel tanks are open to the outside air for breathing. With the outside temperature changes, condensation collects at the bottom of the tank. This condensate contains oxidized metal, which works as a catalyst. It then lowers the oxidation stability of the FAME blend fuel stored in the tank.

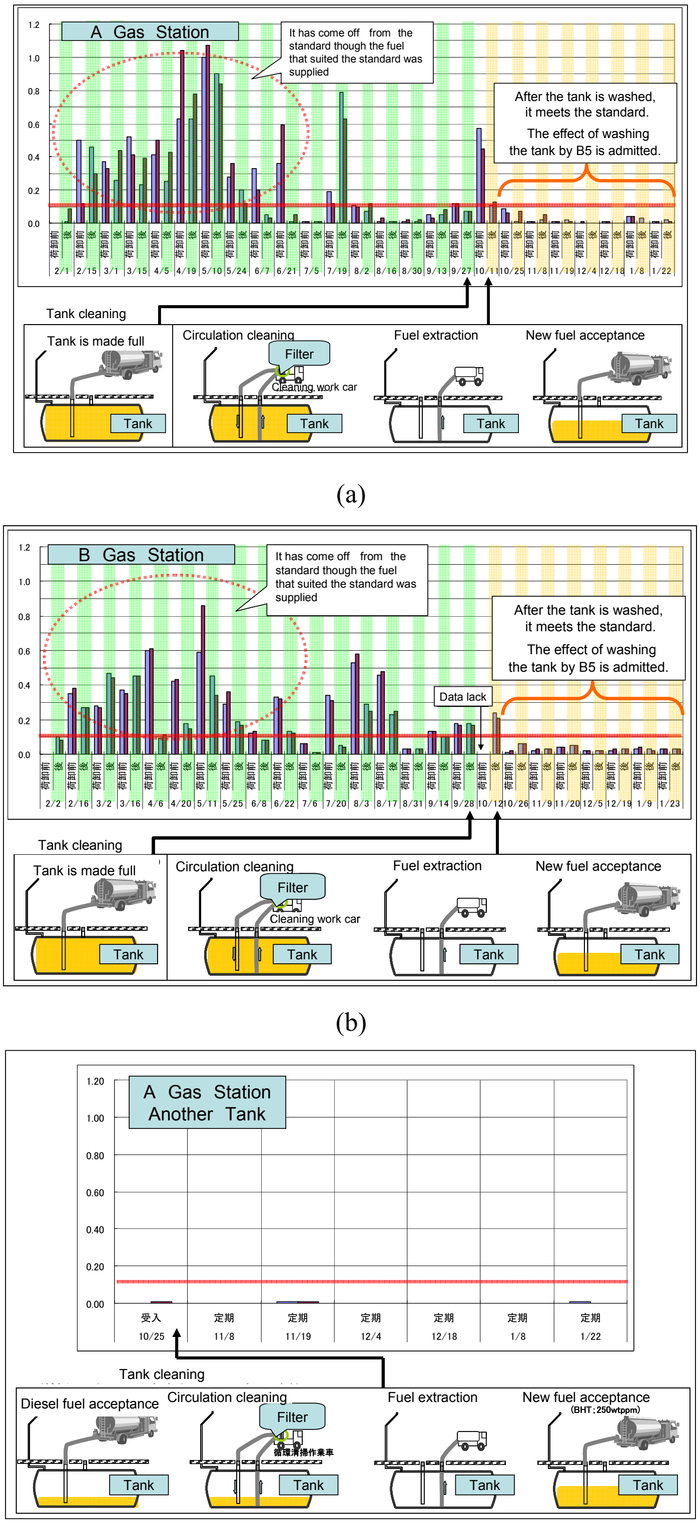


Figure 18 Oxidative stability in circulation proof examination effect confirmation by (a) transition tank washing A, (b) transition tank washing B and (c) Antioxidant Additive

As a countermeasure, before storage of a FAME blend fuel, the fuel tank should be fully washed. At this time, a conventional fuel oil or a mineral type solvent is not sufficient. It is desirable to wash with FAME blend fuel itself. Alternatively, for the initial storage period, FAME blended with petroleum based diesel fuel with more oxidation inhibitor than usual should be used. It was confirmed that after it is stored for a certain period, the condensed water is gradually removed, which helps maintain better oxidation stability.

(5) New test method of oxidation stability: PetroOXY method

The PetroOXY method is a new test method to evaluate the oxidation stability of FAME and FAME-blended diesel, which has been investigated in the EU and Japan, as shown in Figure 19(a). The principle of the test method is simple. The following gives a summary of the test method:

(1) Measure 5 ml of sample in the pressure vessel and close the lid of the vessel tightly. Pressurize the vessel with oxygen from a gas cylinder to the predefined pressure for the room temperature.

(2) Heat up the vessel rapidly to the predefined temperature and then maintain the temperature.

(3) Monitor the pressure in the vessel during the heating and at the subsequent constant temperature condition (At first, the pressure rapidly goes up with the rapid heating. Then, the pressure gradually goes down, depending on the oxidation stability of the sample. This is because bulk oxygen reacts with the sample and is consumed.)

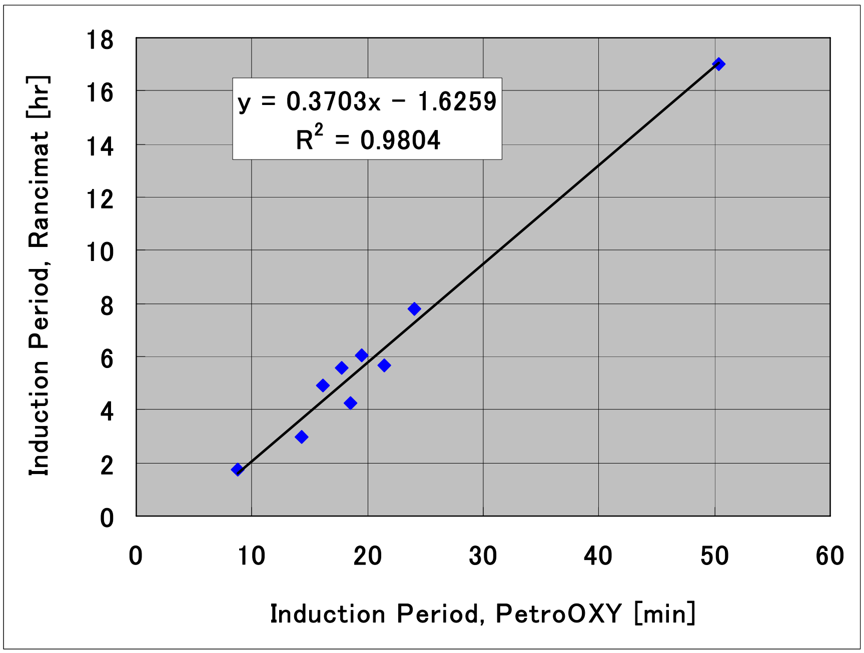
(4) The oxidation stability is expressed by the induction period, which is defined as the elapsed time from when the pressure reaches the maximum to when the pressure is decreased by 10% from the maximum. The longer the induction period, the better the oxidation stability.

Although the measurement time depends on the oxidation stability of the sample, in the case of B5, it is ca. 2-3 hrs under initial vessel pressure of 700 kPa and measurement temperature of 140 ^{o}C.

On the other hand, it is said that the EU is going to replace its existing oxidation stability test method, EN ISO 12205, with the modified Rancimat method, EN 15751. The specification with EN 15751 is min. 20 hrs, which means a much longer test duration than the PetroOXY method.

Figure 19(b) shows the relationship between results obtained using the Rancimat and PetroOXY methods [4]. Although only B100 samples were tested in this case, it can be seen that there is a good relationship between the two methods.

(a)



(b)

Figure 19 (a) PetroOXY equipment and (b) the relationship between Rancimat and PetroOXY with B100 samples

4.1.2 Antioxidant Additives

Although Fatty Acid Methyl Ester (FAME) or biodiesel has many benefits over fossil fuel including cleaner emission in terms of soot and carbon monoxide, biodiesel inherently suffers from its poor cold-flow properties and inferior oxidation stability to mineral diesel.

The cold-flow performance of biodiesel is derived from its constituent fatty acid composition, which varies among various feedstock. The superior cold-flow performance requires high fraction of unsaturated fatty acids. However, if it is inevitable to use biodiesel with inferior cold-flow properties in the cold atmosphere, the biodiesel must be treated a priori. Two approaches are available via additization and winterization process. The former is more common but is only effective for biodiesel with low saturation content. The latter is more effective for biodiesel with high saturation content because winterization process can remove high melting-point saturated esters. The remaining lower saturated fatty acids then give rise to improvement in cold-flow performance, but may reluctantly worsen oxidation stability.

It is generally known that biodiesel is more susceptible to oxidative degradation than mineral diesel. Typically, oxidation stability determined by the induction period is an indicator for the stability or shelf-life of the fuel during its storage. According to the European standard (EN 14214), an induction period of minimum 6 hours at 110°C with Rancimat test is specified for biodiesel. The oxidation stability of biodiesel depends not only on feedstock, processing condition and contaminants, but also storage condition such as storage duration, temperature, exposure to air and light and presence of metals and impurities.

Since oxidation stability of biodiesel depends on the unsaturated fraction of its fatty acid composition from the feedstock, the less stable biodiesel is most likely found in biodiesel with high polyunsaturated fatty acids. Figure 20 [5] shows the fatty acid composition of various biodiesel fuels in terms of saturated and unsaturated fatty acids of various fats and oils. Biodiesel from soybean and sunflower oils with higher fraction of polyunsaturated fatty acids are thus less stable than that from palm and coconut oils with less fraction of polyunsaturated fatty acids.

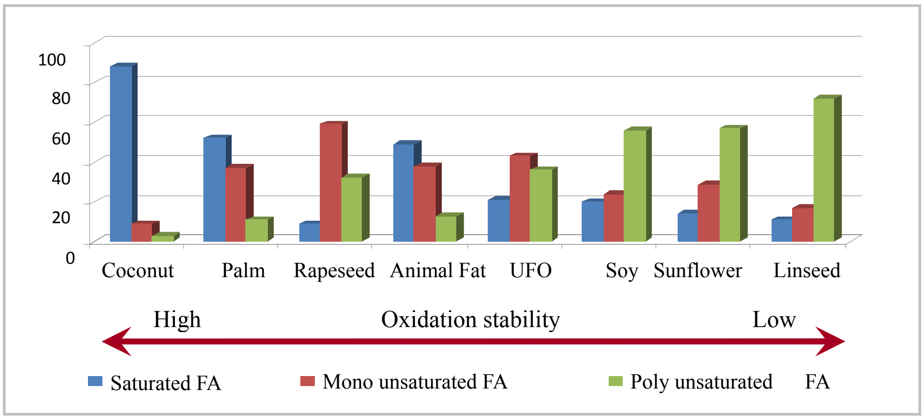


Figure 20 Fatty acid profile of various biodiesel feedstocks

The more popular countermeasure to improve oxidation stability is via natural or synthetic antioxidant additives. Hence, there is a wealth of antioxidant information in the literature from the research conducted in governmental agencies, research institute and chemical companies.

Several informative results from available literatures [6]-[13] regarding the type and effectiveness of antioxidant additives in various biodiesel were reported, as shown by various additive names in Table 7. Mittelbach [6], [7] reported that the undistilled biodiesel fuels from rapeseed oil show their induction period of 9 hours. When adding PY, PG or BHA in the amount of 250 ppm, their induction period increased to 17-22 hours. Similarly, the distilled biodiesel fuel from rapeseed oil show their induction period of 3.5 hours and increased to 6-11 hours when adding PY, PG or BHA in the amount of 250 ppm.

The biodiesel fuels from undistilled sunflower oil and soybean oil show their induction periods of lower than 6 hours. The oxidation stability can be greatly improved by various synthetic antioxidants like pyrogallol (PY), propylgallate (PG), TBHQ and BHA, but its effectiveness depends on the kind of feedstocks and biodiesel processing conditions. The palm oil methyl ester shows its good oxidation stability. Its induction period is over 10 hours without any antioxidant addition and increases to 14 and 21 hours with the addition of 50 ppm of PY and TBHQ, respectively.

The synthetic antioxidants have been continuously developed and introduced, as listed in Table 7. Several antioxidants have been experimented on the biodiesel blend in diesel oil. The recommendation of the highest amount of 500 ppm of antioxidants such as Kerobit 3627, Chimec CH 4636, IRGASTAB BD 100, Baynox plus can increase the oxidation stability of B10 to 8 hours. Nonetheless, too high dosage of antioxidant additive may deteriorate other fuel properties, such as the investigations of Baynox, DTBHQ, Vulkanox ZKF, Ionox 220, Vulkanox BKF as antioxidants in rapeseed oil methyl ester, distilled cooking oil methyl ester and tallow methyl ester as described below [14];

- With the use of 1,000 mg/kg Vulkanox ZKF antioxidant, only acid value may be affected while the viscosity, density, CFPP, carbon residue and sulphated ash content remain unaffected. However, if Vulkanox ZKF is additized into the biodiesel of high acid value, its acid value strongly increases beyond a standard limit of 0.5 mg KOH/g.
- With the use of 250 mg/kg of antioxidants, all parameters including acid value remain unchanged. All properties were within the standard specification even with the biodiesel of high acid value up to 0.42 mg KOH/g.

Table 7 List of various additives reportedly used in biodiesel

Acronyms	Explanation
BAYNOX	20% 2,6-di- *tert*-butyl-4-methylphenol (Brand of Bayer AG, Leverkusen, Germany)
Baynox plus	Product of Lanxess Deutschland GmbH
BHA	3-*tert*-Butyl-4-hydroxyanisole
BioStable ™ 403E	Product of Innospec Ltd.
Chimec CH 4636	Product of Chimec SpA
DTBHQ	2,5-Di- *tert*-butyl-hydroquinone (Brand of AECI-Aroma and Fine Chemicals_Richards Bay, South Africa)
Ionox 220	4,4'- methylene-bis-(2,6-di-*tert*-butylphenol) (Brand of Degussa Sant Celoni, S.A., Spain)
IRGASTAB BD 100	Product of Ciba Corporation
Kerobit 3627	Product of BASF SE
ppm	parts per million
PY	Pyrogallol
TBHQ	*tert* Butyl hydroquinone
UFO	Used Frying Oil
Vulkanox BKF	2,2'-methylene-bis-(4-methyl-6-*tert*-butylphenol) (Product of Bayer AG, Leverkusen, Germany)
Vulkanox ZKF	2,2'-methylene-bis-(4-methyl-6-cyclohexylphenol) (Product of Bayer AG, Leverkusen, Germany)

4.1.3 Upgrading of FAME by hydrogenation

(1) Oxidation Stability of Fatty Acid Methyl Ester (FAME) Components

Unsaturated bonds (double bonds) contained in fatty acid methyl esters influence their oxidation and thermal stability. In fact, the influence of the number of double bonds on oxidation stability is dramatic. It has been reported that as the number of double bonds increases from 1 to 2 to 3, the oxidation rate increases about 10 times each step [15]. Because of this, the oxidation stability of each type of FAME depends highly on its unsaturated fatty acid composition (see Figure 21). In fact, Figure 22 shows the Rancimat test result for B100 using a high purity "model" FAME composed of fatty acid methyl chemical compounds (Aldrich reagent, purity>99%): stearic acid methyl ester (C18:0), oleic acid methyl ester (C18:1), linoleic acid methyl ester (C18:2), linolenic acid methyl ester (18:3), all with a carbon number of 18. Stearic acid methyl ester that does not contain unsaturated bonds shows extremely high oxidation stability. On the other hand, as the number of double bonds increases, the induction time decreases rapidly. This characteristic time delay is taken as an index of oxidation stability (values inside parentheses in the figure). Note that the oxidation stability of multi-unsaturated fatty acid methyl ester is remarkably low.

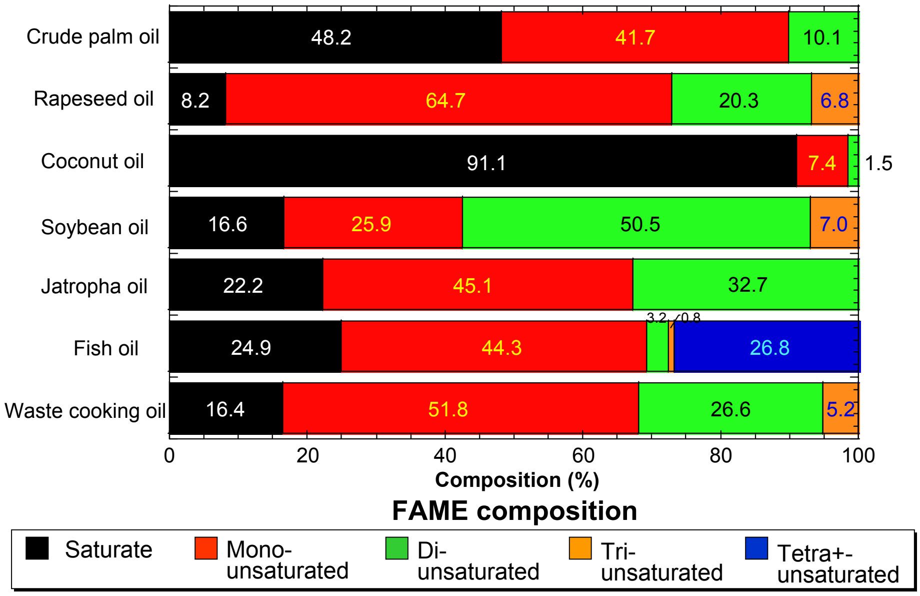


Figure 21 Composition of FAME derived from various biodiesel feedstocks

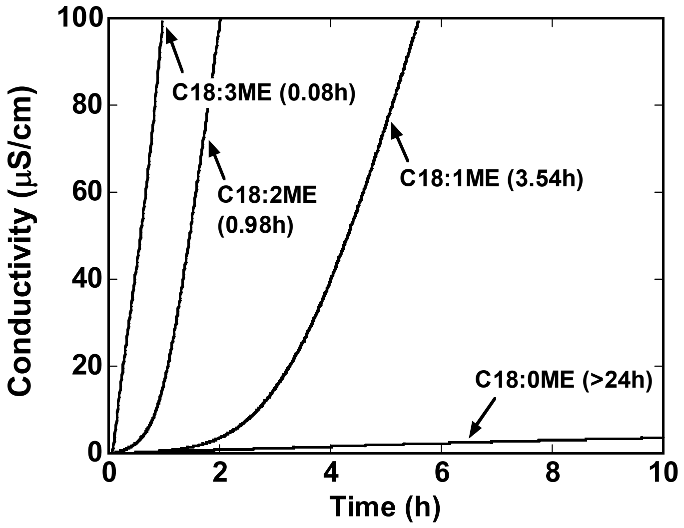


Figure 22 Oxidation stability of model FAME compounds after Rancimat tests

The oxidation stability of B100 naturally has an influence on the oxidation stability of blended diesel fuel Bx (conventional petroleum based diesel fuel blended with x% FAME) Bx supplied nationwide as a fuel. Since there is a limit when the Rancimat test method is used as the Bx oxidation stability evaluation method, the oxidation stability evaluation method in Japan for B5 blended fuel is governed by quality assurance laws. The magnitude of acid value increase (ΔAV) can be obtained from the difference between the final and initial values, when B5 is made to oxidize in a pure oxygen environment at 115ºC for 16h. It has been determined that with this amount, the oxidation stability can be evaluated, and the magnitude of increase should be below 0.12mgKOH/g. Under this assumption, a model B5 fuel was made from the pure FAME chemical compounds given above, blended with normal tetradecane (n-C14). The oxidation stability of this model FAME based biodiesel fuel was evaluated with the oxidation method underlying the above quality assurance law. As shown in Table 8, as the number of double bonds increases, the acid value increases in a similar way to the Rancimat test results for B100 mentioned above. The degree of increase for multi-unsaturated fatty acid methyl esters (e.g. C18:2 and C18:3) is significant. Moreover, for C18:3 linolenic acid methyl ester, it was observed that large amounts of acidic sludge formed after the oxidation test. It was discovered that organic acid was generated by oxidative degradation, which catalyzed the thermal oxidative polymerization in the presence of oxygen.

Table 8 Oxidation stability of a B5 blend of model FAME with tetradecane

Model FAME compounds	Increment in acid value* (mgKOH/g)
Stearic acid methyl ester (C18:0 ME)	0.07
Oleic acid methyl ester (C18:1 ME)	0.66
Linoleic acid methyl ester (C18:2 ME)	20.3
Linolenic acid methyl ester (C18:3 ME)	152.5

*Acid value difference before and after oxidation at 115°C for 16h under the blowing of pure oxygen. Increment in acid value for n-C14 was 0.10 mgKOH/g

From the oxidation stability evaluation test results using the above model FAME chemical compounds, it was determined that:

(1) The oxidation stability of multi-unsaturated FAME (containing more than two double bonds in the fatty acid part) is extremely bad.

(2) Multi-unsaturated FAMEs containing more than three double bonds in the fatty acid part easily form organic acid accompanied by oxidative deterioration and at the same time sludge due to thermal oxidation polymerization catalyzed by acids.

(3) Oxidation stability of fatty acid ME with one double bond is worse than saturated fatty acid ME. However, compared to the oxidation stability of multi-unsaturated fatty acid ME, oxidation stability is extremely high.

(2) Improvement of Oxidation Stability using Partial Hydrogenation of FAME

As the number of double bonds contained in the fatty acid part in FAME decreases, oxidation stability improves. The cold flow property of FAME, however, deteriorates because oxidation stability and cold flow property have a tradeoff relationship, as shown in Figure 23. Because of this, when improvement of FAME's oxidation stability is given a higher priority and the low temperature flowability is improved with a cold flow improver, the partial hydrogenation technology that converts multi-unsaturated FAME produced with the current method to singly unsaturated molecules is considered to be a high quality FAME technology [16]. An approach to high quality biodiesel production via partial hydrogenation of currently available FAME has merits. It is not necessary to significantly redesign or revise FAME production equipment already in place. By installing partial hydrogenation apparatus as supplementary equipment, it is possible to utilize all the current process equipment, as schematically shown in Figure 24. However, to obtain the highest bio-diesel quality from oil crops, the current petroleum products and similar hydrocarbon fuels not having double bonds or oxygen are preferable. Because of this, in environments where incoming oil crop feedstocks are fully maintained, and high pressure equipment for oil refinery processes can be utilized, an approach to produce a high quality fuels (second generation bio-diesel) [17] via hydrodeoxygenation of triglycerides would be promising. Figure 25 shows characteristics of the partial hydrogenation method of FAME and the hydrodeoxygenation method of triglyceride.

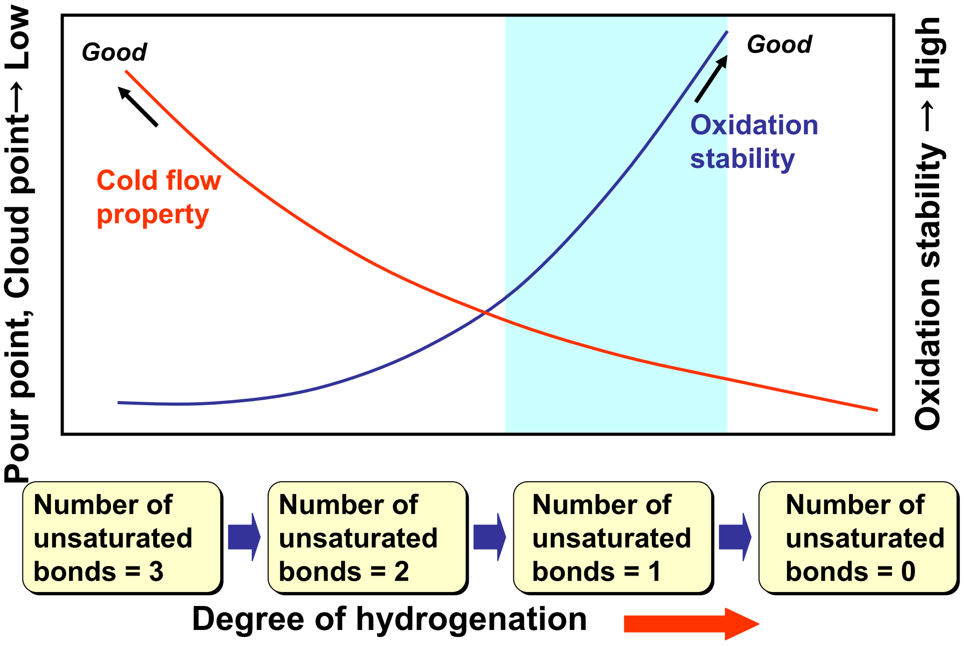


Figure 23 Concept for partial hydrogenation of FAME

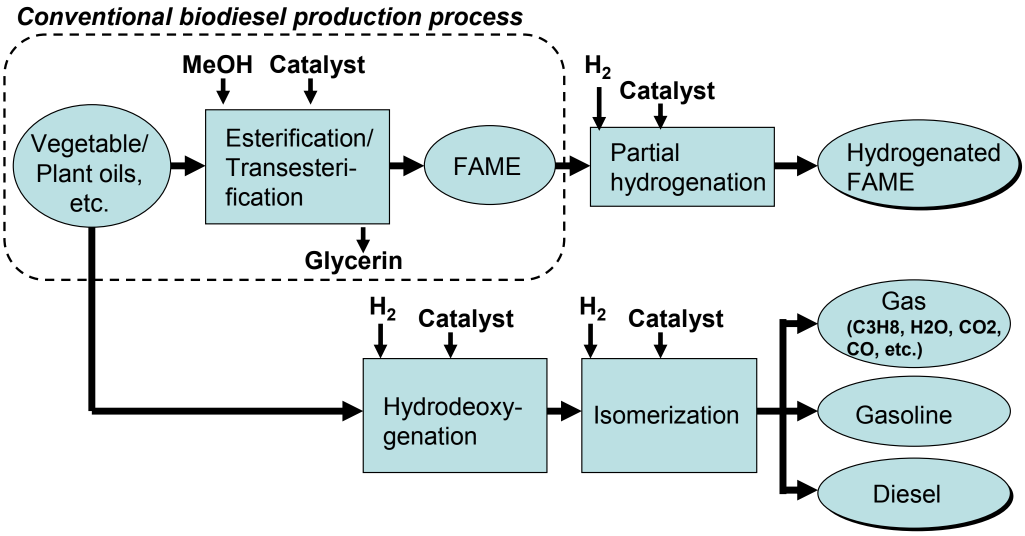


Figure 24 Partial hydrogenation for upgrading conventional FAME

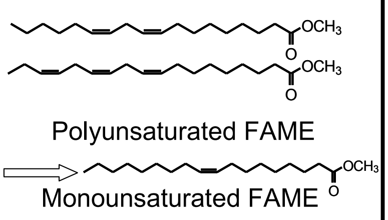
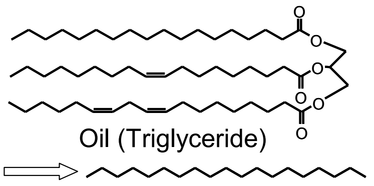
	Partial hydrogenation	Hydrodeoxygenation
Reaction	 Polyunsaturated FAME Monounsaturated FAME	 Oil (Triglyceride) Hydrocarbons
Oxidation Stability	Relatively high	High
Reaction Conditions	Low pressure (atmospheric~0.5MPa) Low temperature (80~120°C)	High pressure (>5MPa) High temperature (>300°C)
Catalysts	Ni catalysts, Noble metal catalysts, etc.	Water (steam)-tolerant NiMo catalysts, CoMo catalysts, etc.
Further processing	None	Isomerization for conditioning cold flow property and cetane number
Location of processing facility	Local Community (small ～ large plants)	Petroleum refinery (Neat ～ Coprocessing)

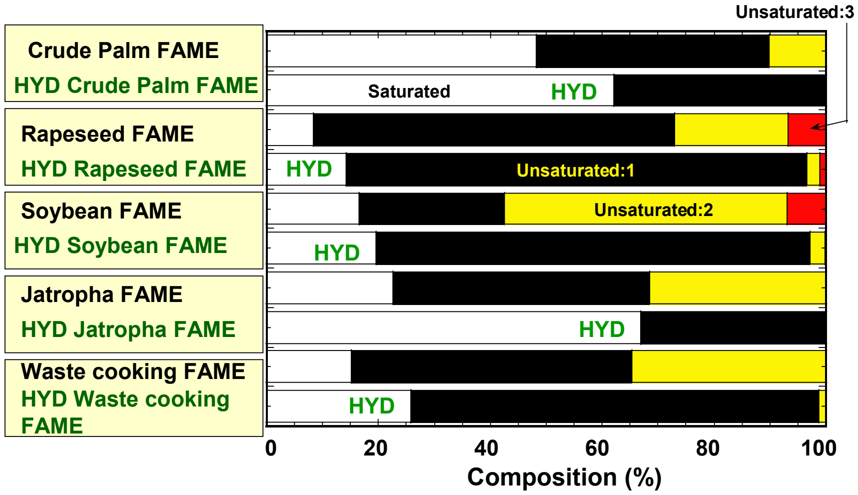
Figure 25 Comparison of partial hydrogenation for FAME upgrading and hydrodeoxydation (HDO) for second generation biodiesel production

(3) Characteristics of Partial Hydrogenation of FAME

When oxidation stability improvement via partial hydrogenation of FAME (B100) is attempted, as shown in Figure 24, the optimal hydrogenation level varies depending on the unsaturated chemical compounds present. This is because hydrogenation reactions proceed in a serial manner, for example: Trivalent unsaturated

FAME → Bivalent unsaturated FAME → Mono-unsaturated FAME → Saturated FAME. In addition, the higher the unsaturation level is, the faster the hydrogenation reaction rate is. Figure 26 shows a breakdown of saturated and unsaturated components of five types of FAME. The companion bar graph shows the corresponding composition after hydrogenation treatment. It was obtained at atmospheric pressure and 100ºC, with a 1 hour hydrogenation treatment time, in order to compare the reactivity of each type of FAME. Under the hydrogenation conditions used here, reaction selectivity to a mono unsaturated FAME is high, except for Jatropha FAME.

Crude palm oil ME and soybean oil ME (B100) that had been partial hydrogenated were blended with sulfur free diesel fuel (S = 6ppm) with 5% mass to obtain a B5 blend. Then the oxidation stability was evaluated using the accelerated oxidation method used with the Japan quality assurance law described earlier. Table 9 shows the results obtained. Antioxidants for all cases are non-additives. Oxidation stability of B5 obtained via partial hydrogenation FAME is good ($\Delta AV<0.12$mg KOH/g). Even for B10 with 10% FAME, the level of acid value increment is under 0.12mgKOH/g. When other hydrogenated FAMEs shown in Figure 26 were used as the blend material, even without an antioxidant, the amount of acid value increment after accelerated oxidation of B10 was below 0.12mg KOH/g. This means that more than one type of FAME can be fed into this partial hydrogenation method. That is, the partial hydrogenation method has the flexibility to handle not only FAME obtained from virgin raw materials, but also FAME obtained from mixtures of waste cooking oil and raw materials containing fish oil, for example. These materials can have high variability in feedstock composition and characteristics. Besides, it shows that with this quality improvement method, the Japan quality assurance levels required for B5 biodiesel can be maintained even with B10.



Hydrogenation conditions: H_2 pressure = atmospheric, Temperature= 100 °C, Reaction time = 1h

Figure 26 Changes in composition of FAME derived from crude palm oil, rapeseed oil, soybean oil, jatropha oil and waste cooking oil after partial hydrogenation

Table 9 Oxidation stability and cold flow properties of Bx

Bx[*]	blending components	Increment in acid value (mgKOH/g)	pour point (°C)
B5	CPO-ME**	0.21	-14
	Hydrogenated-CPO-ME	0.02	-13
B10	CPO-ME	1.63	-11
	Hydrogenated-CPO-ME	0.04	-8
B5	RSO-ME***	3.47	-18
	Hydrogenated-RSO-ME	0.01	-17
B10	RSO-ME	9.38	-20
	Hydrogenated-RSO-ME	0.02	-15

* X mass % of FAME blended with petrolem diesel (S=6 ppm

** Crude palm oil derived methyl ester

*** Rape-seed oil derived methyl ester

When hydrogenated crude palm oil ME was used as the blend material, the oxidation stability was good up to a FAME blended ratio 20 mass % (ΔAV=0.05mg KOH/g < 0.12mg KOH/g after accelerated oxidation). However, the pour point of B20 deteriorated to only -2°C, which means the cold flow property will be an issue in many areas. In warm regions where oxidation stability improvement receives a higher priority, it is possible to use a higher concentration of the partially hydrogenated FAME.

Table 10 shows fuel characteristics of crude palm oil ME (B100) before and after partial hydrogenation. After treatment of the raw FAME which clears the relevant EN standard (EN14214), as the density decreases and cold filter plugging point deteriorates. However, oxidation stability is greatly improved, and there was no influence on other FAME components and characteristics. The cetane value of hydrogenated FAME is still unmeasured, however it is known that the cetane value increases as the fatty acid unsaturation level decreases. Thus the cetane value is assumed to exceed 64. In other words, the FAME partial hydrogenation method negligibly changes the fuel characteristics, and it is the preferred quality improvement method to improve FAME's oxidation stability. For comparison, also shown are characteristics of triglyceride oils obtained by hydrodeoxygenation[18], which are expected to be a second generation biodiesel fuel.

Table 10 Properties of hydrogenated FAME and hydro-deoxygenated (HDO) palm oil

	FAME	Hydrogenated FAME	Hydrodeoxy-genated palm oil*
Feedstock	Crude Palm oil	Crude palm oil	Refined palm oil
Density at 15 °C (kg/m^3)	876	857	785
Viscosity at 40 °C (mm^2/s)	4.4	4.7	4.2（at 30 °C）
Flash point（°C）	168	176	132
Centan Number（-）	64	-	101
Sulfur content（massppm	＜3	＜1	＜1
Oxidation stability (h)	9.7	＞24	＞24
Acid value (mgKOH/g)	0.34	0.27	0.00
Acid value after oxidation**（mgKOH/g）	0.55	0.30	0.03
Increment in acid value（mgKOH/g）	0.21	0.03	0.03
CFPP (°C)	9	13	22

*** A. Koyama et. al., SAE 2007-01-2030.**

*** Accelerated oxidation at 115 °C for 16h under the blowing of pure oxygen.**

(4) Method of FAME Partial Hydrogenation

As shown in Figure 25, partial FAME hydrogenation is possible under reaction conditions of 0.1~2MPa hydrogen pressure and 80~120°C temperature, using a hydrogenation catalyst. A typical Ni type catalyst, which has been used for conventional oil and fat hydrogenation, has merits for catalyst cost, but it is necessary to use a hydrogen reaction pressure of several atmospheric pressure (>0.3~0.5MPa). On the other hand, noble metal catalysts like Pd and Pt are disadvantageous compared to Ni catalysts in terms of their cost. However, they have some merits in that their reaction pressure is lower – low enough that hydrogenation treatment is possible under atmospheric pressure. This means that expensive high-pressure process equipment is unnecessary. The sulfur content of the raw material FAME is less than in conventional diesel fuels. However if one takes the catalyst lifetime duration into consideration, sulfur resistance countermeasure for the selected catalysts would be necessary. FAME hydrogenation is possible using supplementary equipment along with conventional FAME production equipment. Batch type and continuous type reaction methods are possible, while slurry bed and fixed bed types of catalyst reactors can be used. The volume recovery yield of hydrogenated FAME can exceed 100% because FAME hydrogenation accompanies a volume increase.

(5) Characteristics of Triglyceride Hydrodeoxygenation

Hydrodeoxygenated (HDO) oils that are expected as the second generation bio-diesel contain negligible aromatics or sulfur. They are composed of straight-chain hydrocarbons with carbon number 15~18. As shown in Table 10, characteristics of HDO oils include a high cetane value, a lower density, and a lower viscosity, compared to FAME and partial hydrogenated FAME. The most significant difference from FAME is this: Since negligible oxygen is contained in HDO oil, the acid value is extremely low, and since unsaturated bonds are very sparse, the oxidation stability is extremely high. HDO oil has some demerits in cold flow property (Table 10Table shows the cold filter plugging point), however with current isomerization techniques used in oil refineries, it is possible to improve the low temperature flowability and optimize the cetane value.

(6) Method of Triglyceride Hydrodeoxydation

It is possible to achieve hydrodeoxydation of triglycerides, as shown in Figure 25, at high temperature conditions (>300ºC), high hydrogen pressure (>5MPa), using the appropriate hydrodeoxydation catalyst. Hydrodesulfurization reactions are similar to hydrodeoxydation reactions, therefore it is possible to use NiMo and CoMo type hydrodesulfurization catalysts for HDO reaction. However in terms of the catalyst lifetime, it has been found necessary to take countermeasures for keeping the proper sulfide conditions of supported metals and increasing the water (steam) resistance of the catalyst supports. A wide range of process methods have been reported for triglyceride hydrodeoxygenation, from a single neat treatment process, to a co-processing treatment method were triglycerides blended with petroleum fractions are hydrotreated. In addition, recalling that hydrocarbon components obtained by HDO are mainly a straight-chain hydrocarbons, the cold flow property and cetane value can be modified by secondary isomerization treatments. In the process of hydrodeoxygenation and isomerization, decomposition of straight chain hydrocarbons and over-hydrocracking reactions proceed simultaneously. Therefore, diesel fuel fraction yield improvement is one area of future work. For both hydrodeoxygenation and isomerization processing mentioned above, high-temperature high-pressure equipment is necessary. One merit is that we can use current oil refinery equipment. Moreover, methanol is not necessary for this hydroteatment method. CO_2 formation accompanying methanol production is thus not a concern. In LCA compared to the conventional FAME production technology it is said to be advantageous [17], [18].

4.2 Fluidity

4.2.1 Introduction of Fluidity

(1) Low Temperature Flowability

There are two types of fat and oil that are made into FAME: one liquid (oil) and one solid (fat) at room temperature (~ 20°C), depending on the degree of saturation as shown in Figure 27. FAME made from room-temperature solid raw materials is also solid at room temperature. When mixing these FAMEs with petroleum based diesel fuel and using them, low temperature flowability worsens. Even pure petroleum based diesel fuel has different low temperature flowability depending on the amount of wax it contains. In general, in order to use FAME during cold seasons or in a cold region, a low temperature flowability improver is added. The low temperature performance of FAME blended with petroleum based diesel fuel depends not only on the low temperature performance of FAME but also on the low temperature blend characteristics, type of improvers, and the amount of low temperature flowability additive used.

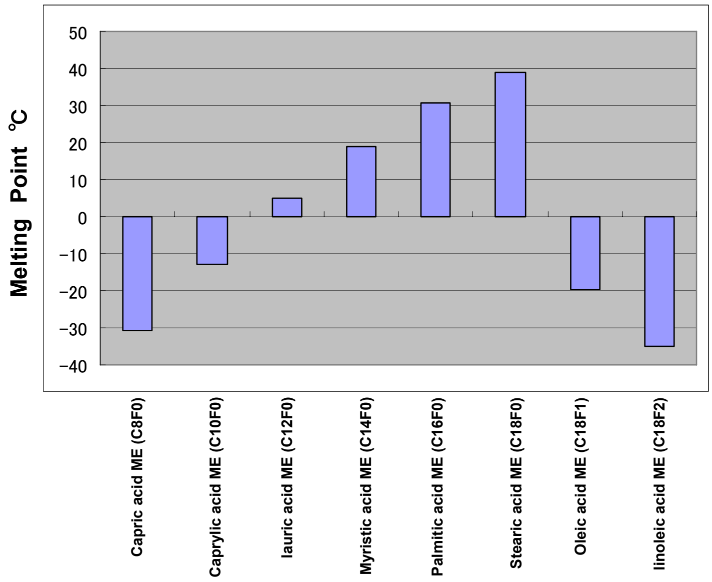


Figure 27 Melting point of FAME

(2) Low Temperature Characteristics of Fatty Acid Methyl Esters

FAME made from animal and plant oils or fats is a mixture of each kind of fatty acid methyl ester. Each component fatty acid methyl ester is a pure material, for which a solidification point exists. The bigger the FAME molecule is, the higher the solidification point is, and the more unsaturated bonds it has, the lower the solidification point is. Ordinary FAME is a mixture, therefore it does not have a solidification point but it does have a cloud point, a clogging point, and a pour point (see Figure 28). For example, palm oil methyl ester and animal oil/fat methyl ester containing many saturated bonds both have poor low temperature performance. By comparison, soybean oil methyl ester and canola seed oil methyl ester, containing a high level of unsaturated bonds, both have good low temperature performance. Moreover, compared to palm oil methyl ester, coconut methyl ester contains high levels of fatty acids with relatively low diversity of molecules and also has good low temperature performance.

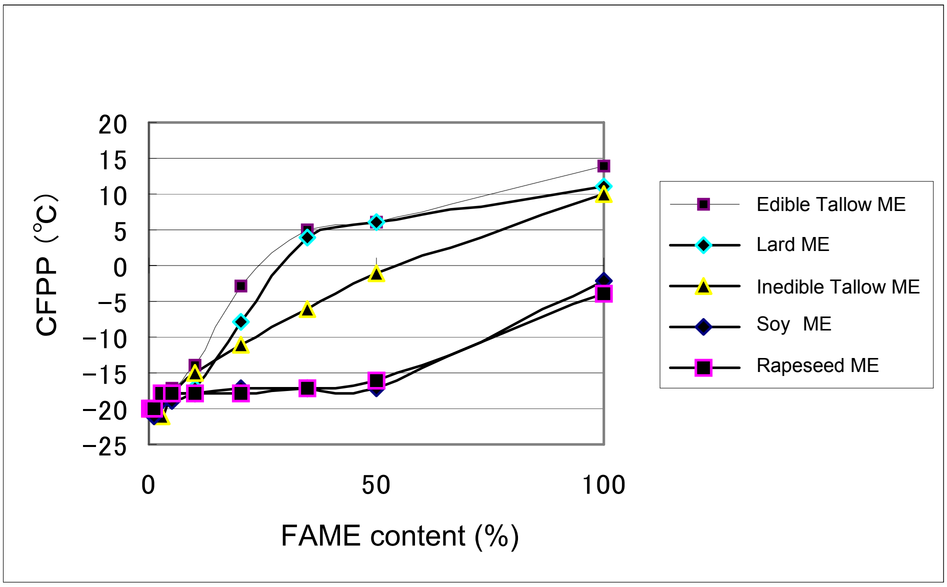


Figure 28 CFPP of Biodiesel / Diesel blend

(3) Influences of Vehicles

When using FAME blended with petroleum based diesel fuel, the low temperature performance of FAME before blending is sometimes below a certain value. However, depending on the diesel blend fuel, it does not always meet the standard for low temperature FAME characteristics that are being sought. A low temperature flowability improver, even for diesel fuel, is an effective additive, but the exact additive level depends on the composition. The specific additive and amount required do not always effectively function with FAME blended with petroleum based diesel fuel. Because of this, those who blend FAME with petroleum based diesel fuel are required to adjust the final blend such that it has the proper cloud point, clog point, and pour points.

When mixing FAME with petroleum based diesel fuel, the cloud point, clogging point and pour point generally increase with diesel fuel concentration. These sometimes change linearly, but they exhibit different characteristics depending on the FAME type. For example the effect may be large at low concentrations, or it may hardly change at low concentration but change dramatically when the concentration exceeds 50%, as shown in Figure 28.

In the past, low temperature engine starting and driving characteristics in automobiles were considered to depend on the clogging point. For current high-pressure common rail injection systems it is necessary to design the fuel filter with sufficient porosity and flow area for effective system protection. This tends to depend on the cloud point rather than the clog point. Particular attention has to be given when using palm and animal oil methyl esters, which are both prone to phase separation.

(4) Influences of Storage

Problems of low temperature flowability become apparent not only in vehicles but also in storage and flow processes as well. In storage and flow processes the temperature increases and decreases repeatedly during the daytime and night. As a result, there are several concerns:

(1) Wax separates at low temperatures, causing deposits inside the fuel tank,

(2) Wax separated at low temperatures does not melt when the temperature increases.

After the temperature repeatedly increases and decreases, the amount of separated wax gradually increases. Actually, when the test conditions are determined and tests are conducted, high pour point FAME results in wax separation, causing differences in composition between the upper and lower part of the test container, as shown in Figure 29.

From this behavior, for trouble-free flowability of FAME blended with petroleum based diesel fuel, it should be kept in mind that its possible for the composition to degrade when the temperature repeatedly fluctuates, as well as when the temperature is simply too cold.

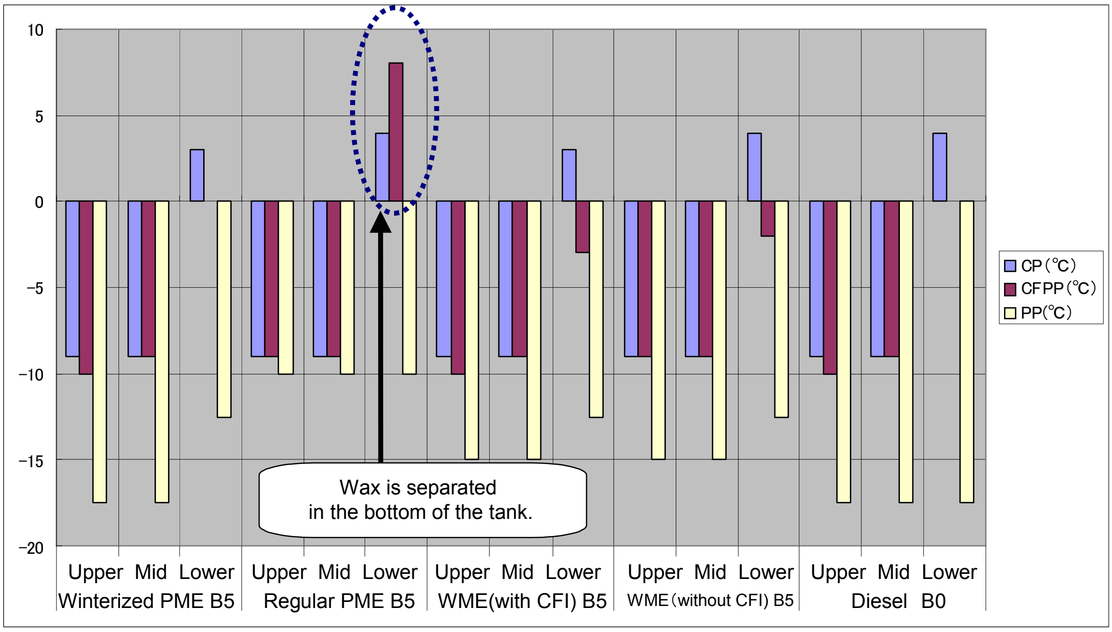


Figure 29 Wax separation of temperature circulation test

(5) Influences of Impurities

When FAME is produced, triglyceride are the raw material, and reaction intermediate products like diglycerides and monoglyceride remain as impurities. It is known that these impurities influence sludge formation, and also cause deterioration of low temperature flowability. Some saturated fatty acids like glycerides have a high pour point. For example, the pour point of stearic acid is about 40°C, while stearic acid monoglyceride, diglyceride, and triglyceride fall into the range of 50 ~ 80°C, and monoglyceride has the highest pour point of them all.

In the European FAME standard (EN14214), an upper concentration limit for these glycerides was determined. It has recently been shown that petroleum based diesel fuel blended with FAME may surpass this upper limit, and problems may occur. That is, at low to moderate temperatures the fuel filter of vehicles and also on refueling equipment can clog. When analyzing the substances plugging these filters, it was found out that monoglycerides of saturated fatty acid was the main element. Further details are still under research. It is assumed that methanol being used as a raw material acted as a co-solvent to aid dissolving these compounds, and during flow process or in the vehicle's fuel supply system, the temperature increased and methanol evaporated, resulting in decreasing dissolving performance, and phase separation. In Europe, canola oil is the most commonly investigated FAME raw material. As FAME has been widely utilized worldwide, oils and fats containing saturated fatty acids, like palm oil and beef oil, have started to be used as raw materials. When using FAME produced from these high saturated fatty acid materials in a cold region or season, it is necessary to be particularly careful and investigate further countermeasures.

4.2.2 Fluidity Improvers for Biodiesel Fuels

The low temperature fluidity of FAME is related to the specific saturated fatty acid methyl ester's (FAME) content, while the amount of saturated fatty acid methyl esters in a given FAME depends on the fat and fatty oil as the original source of the FAME. Figure 30 shows the cloud point and cold filter plugging point (CFPP) of various FAMEs in terms of the mass ratio of saturated to unsaturated fatty acid methyl esters, for each type of FAME. From Figure 30, we see that as the ratio of saturated to unsaturated fatty acid methyl esters increases, the cloud point and CFPP both increase, and for palm stearin methyl ester, with a ratio of 1.5, the cloud point and CFPP reach 15ºC and 21ºC respectively.

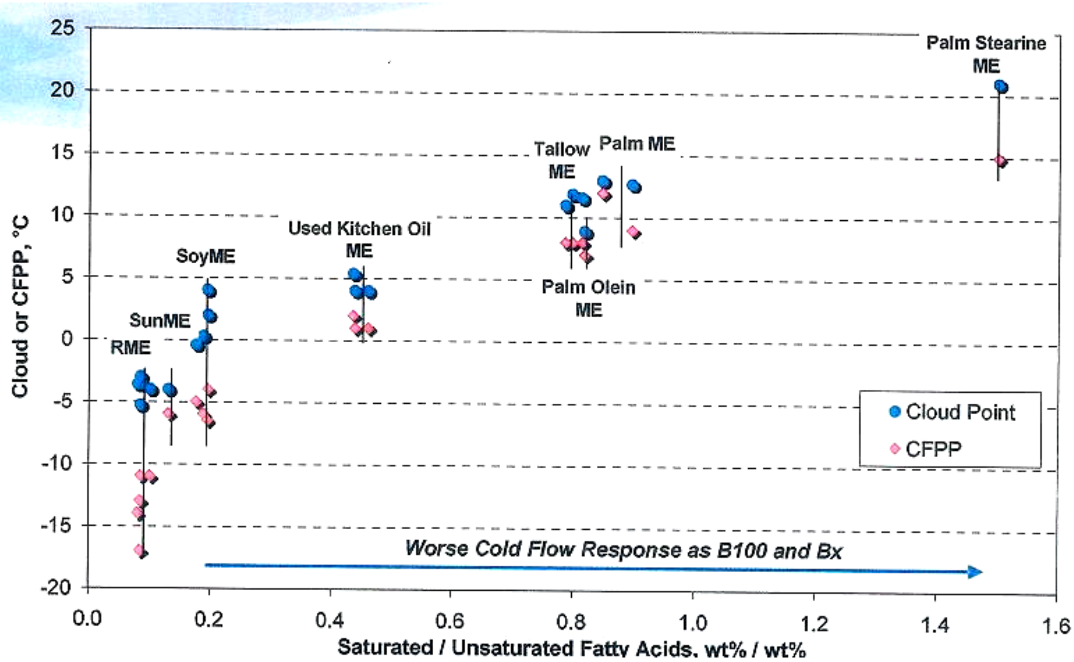


Figure 30 Cloud point and CFPP of various FAMEs

Figure 31 shows the effect of the addition of a cold flow improver for several types of FAME. The effect is indicated as the amount of the additive required to achieve a CFPP of -10ºC. For rapeseed, the addition of the cold flow improver was not necessary. However, as the amount of saturated fatty acid methyl esters in FAME increased, the required amounts of the cold flow improver were increased. Note that for palm olein and palm oil, even though a large amount of the cold flow improver was added, it was not possible to achieve the CFPP of -10ºC.

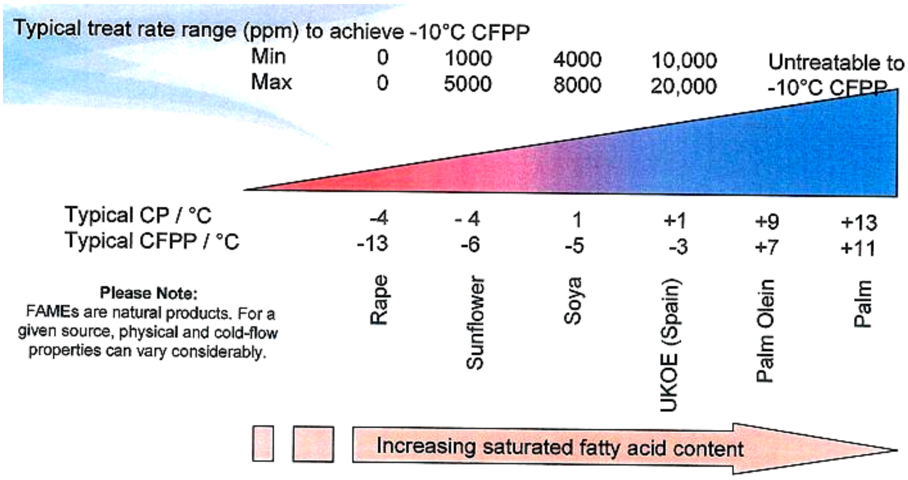


Figure 31 Treatability of FAME B100 with cold flow additives

Infineum Co. Ltd., a maker of cold flow improver additives, identifies the following four points regarding effective utilization of cold flow improvers in FAME blended petroleum diesel fuel.

- The cold flow improver should work even in base petroleum diesel fuel.
- The proper cold flow improver should be selected, depending on the kind of FAME and the amount of blending.
- FAME should be properly blended with base petroleum diesel fuel, and the blends should be in a homogenized and stable condition.
- The cold flow improver should be properly added to FAME or FAME blended petroleum diesel fuel to obtain the desired results.

Figure 32 shows an example of how a cold flow additive improves the fluidity for a range of B5, prepared by blending various FAMEs with a UK petroleum diesel fuel (B0). The effectiveness is shown as a function of the additive dosage rates to achieve CFPPs of –15 ^{o}C and –17 ^{o}C. Compared to B0, B5s was made with palm ME and tallow ME, which contain high levels of saturated fatty acid methyl esters, require twice the amount of the cold flow improver.

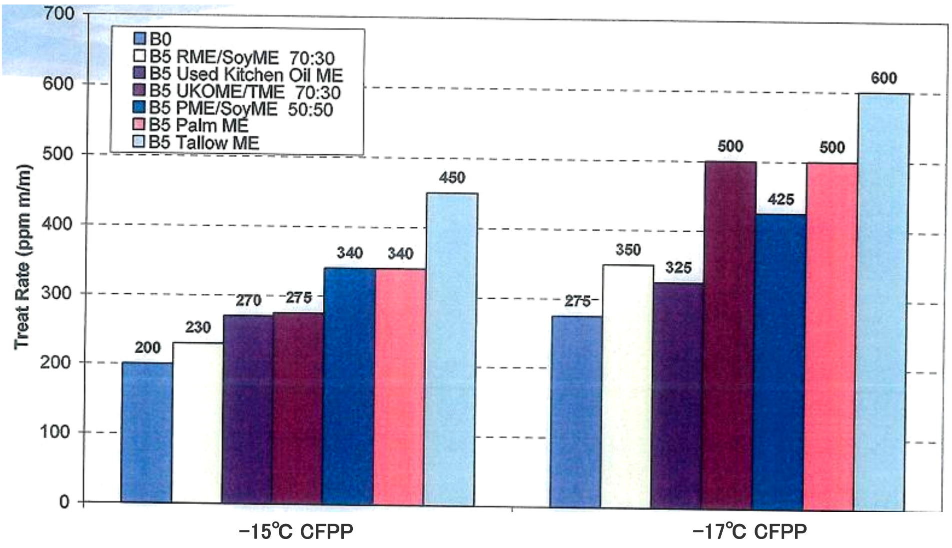
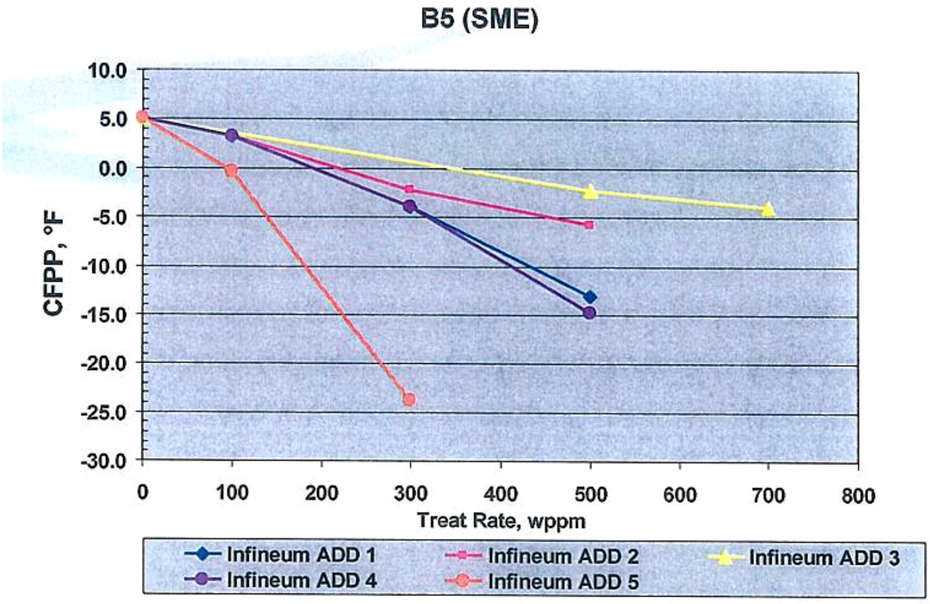


Figure 32 Impact of various FAMEs on cold flow performance

Moreover, Figure 33 shows the effects of various cold flow improvers to a common B5, made from soybean methyl ester (SME). It can be observed that the effects are remarkably different, and depend on the specific additive. Thus, proper selection of the optimal cold flow improver is important.



Additive	Rate, wppm	Cloud, °C	Cloud, °F	CFPP, °C	CFPP, °F	PP, °C	PP, °F
ULSD Base Fuel	0	-11.5	11.3	-13	8.6	-21	-5.8
B5	0	-9.1	15.6	-15	5.0	-21	-5.8

Figure 33 An example of the effectiveness of cold flow improvers for an SME blended B5

Infineum Co. Ltd. mentions the following points regarding the proper application of a cold flow improver to FAME blended petroleum based diesel fuel.

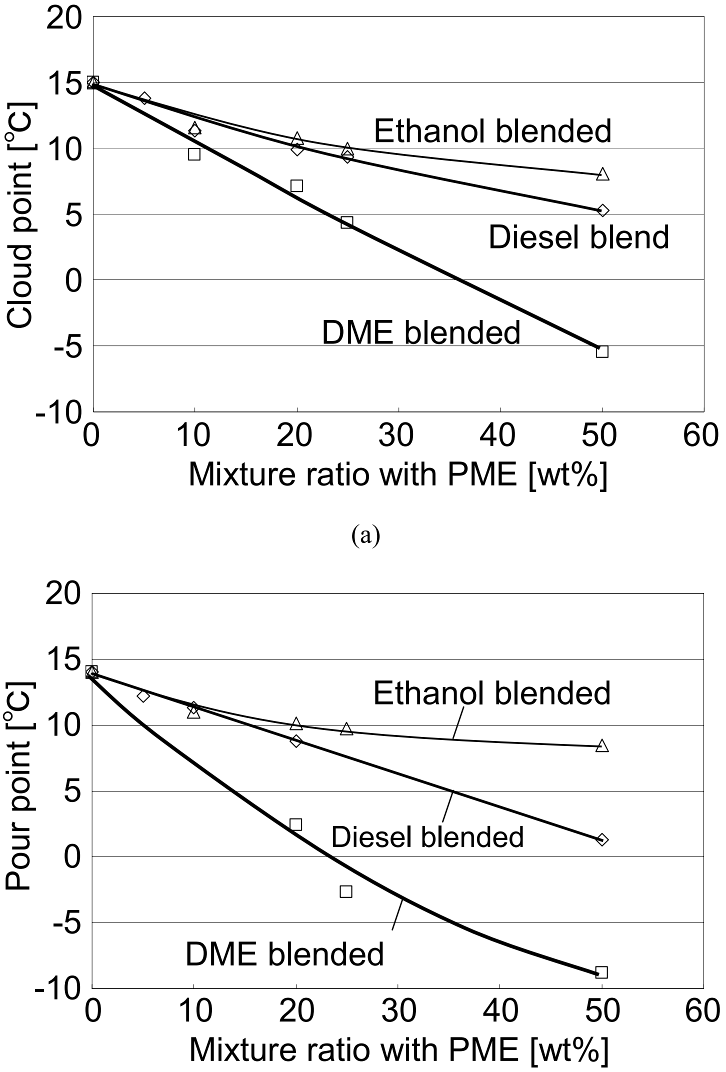
- Blending FAME with petroleum diesel fuel can result in considerable challenges for fuel suppliers and end users regarding low temperature fluidity.
- Biodiesel blends up to B5 are sometimes possible to treat with existing cold flow improvers.
- As the FAME blend ratio increases, it may be necessary to use further advanced additive technologies.
- Additive technology solutions depend on the characteristics of FAME and petroleum diesel fuel, and their combination.

4.2.3 Other Countermeasures

(1) Blending another fuels to FAME

Biodiesel fuel is a multi-component mixture of fatty acid esters, and its solidification characteristics are correspondingly complex. However, in many cases it is possible to improve the low temperature fluidity by blending with substances having a lower solidification point. Figure 34 shows the cloud point and pour point when JIS #2 diesel fuel, ethanol and dimethyl ether (DME) were blended with palm methyl ester (PME). Also, Table 11 shows the main properties of fuels used for these tests.

The cloud point and pour point of PME used in the current tests were 15ºC and 14ºC, respectively. It is understood that the solidification point of PME will decrease when blended with other fuels such as diesel fuel, ethanol and DME. For example, when 20% of diesel fuel or ethanol is blended with PME, the cloud point and the pour point is decreased by about 5ºC. When 20 % of DME blended with PME they decrease by about 10ºC. The effect of DME blending is quite large. When blended 50% of DME with PME, the pour point reaches -8.8ºC, which is equivalent to the low temperature fluidity of JIS #2 diesel fuel. It should be noted that the improvement effect is not be directly related with a solidification point of blended substances. The solidification point of ethanol is -114ºC. This is substantially lower than the pour point of diesel fuel, however diesel fuel has even better low temperature fluidity improvement effects than ethanol. When diesel fuel is blended 50/50 with PME, the pour point becomes 1.3ºC, which is equivalent to JIS #1 diesel fuel, while the low temperature fluidity improvement effects of ethanol decrease gradually with mixture ratio.



(a)

(b)

Figure 34 Effect of diesel fuel, ethanol and DME blend ratios on the (a) cloud point and (b) pour point of PME

Table 11 Fuel properties of test fuels

Fuel	PME	RME	JIS No.2 diesel fuel	Ethanol	DME
Density [kg/m^3]	873.8	880.5	822.6	789.3	667
Kinetic viscosity [cSt]	4.455	4.309	3.259	1.373	0.197
Pour point [°C]	14	-10	<−7.5	−114	−141.5
Oxygen content [wt%]	13.2	10.8	0	34.8	34.8
Low heat value [MJ/kg]	37.11	37.14	42.7	26.82	28.43

(2) Characteristics of Pressure Solidification

From a thermodynamics viewpoint, a high cloud point means that standard pressure and temperature conditions are close to the location of a solidification line at phase equilibrium diagram. Thus it is possible that wax occurs at relatively low pressures when the pressure is increased. A fuel injection pressure of current diesel engines can reach 100 to 200MPa. So even though the fuel is used at temperatures above the cloud point, it can be considered that biodiesel fuels form wax in the high-pressure fuel lines. There is thus the possibility of negative influences on the fuel injection system. The cloud point and pour point describe solidification characteristics at atmospheric pressure and have typically been used as an index of low temperature fuel fluidity. Considering the above arguments, however, it is necessary to take into consideration the solidification characteristics along with local fuel pressure.

Using a test cell, Figure 35 shows the PME solidification process when pressure was gradually increased at a constant 20°C temperature. At pressure of 56MPa, frame 2 shows that wax occurred in part of the sample. The wax that occurred first became a center for further growth of filaments. Then as the core regions became solid with filamentation, in frames 3 to 11, eventually the test cell became completely solid with wax filaments.

Figure 36(a) shows the measured solidification pressure as a function of sample temperature for PME and RME. As the temperature is increased, the solidification pressure increases quickly at first and more slowly later. The solidification point (a cloud point) of PME at standard pressure (0.1MPa) is 15°C, at 20°C the solidification pressure increases to 56MPa, at 25°C it increases to 83MPa, and then at 40°C it rises all the way to 145MPa. For diesel engines with high-pressure fuel injection systems able to reach 200MPa, PME solidification can thus occur even if the fuel temperature is kept at 40°C. With a current design common rail fuel injection system, the fuel temperature rises relatively soon after start-up, thus it is thought that problems of PME pressure solidification are limited to cold start and operating in low temperature environments.

The situation with RME is quite different. Its solidification point (cloud point) at 0.1MPa is -2.7°C. Then, at 5°C the solidification pressure increases to 115MPa, at 10°C it rises to 150MPa, and at 20°C it reaches 180MPa. So with typical fuel injection systems it is unlikely that solidification will occur. Considering temperatures from the East Asia region to the South East Asian region, RME solidification due to pressure in this area does not seem like it would be a problem.

Pressure solidification characteristics can be improved by blending with high-grade substances for improved low temperature fluidity, as at standard pressure.

Figure 36(b) shows the solidification pressure when DME is blended with PME at ratios of 10 to 25% by weight, and diesel fuel is blended with PME at ratios of 5 to 20% by weight. As the blend ratio increases, the solidification pressure increases. Looking at which substance has a more powerful improvement effect on the solidification pressure, DME appears to be stronger than diesel fuel. For example, at 20°C, when 20% diesel fuel is blended with PME, the solidification pressure increases from 56MPa to 95MPa. On the contrary, when 20% DME is blended with PME, the solidification pressure rises all the way to 140MPa.

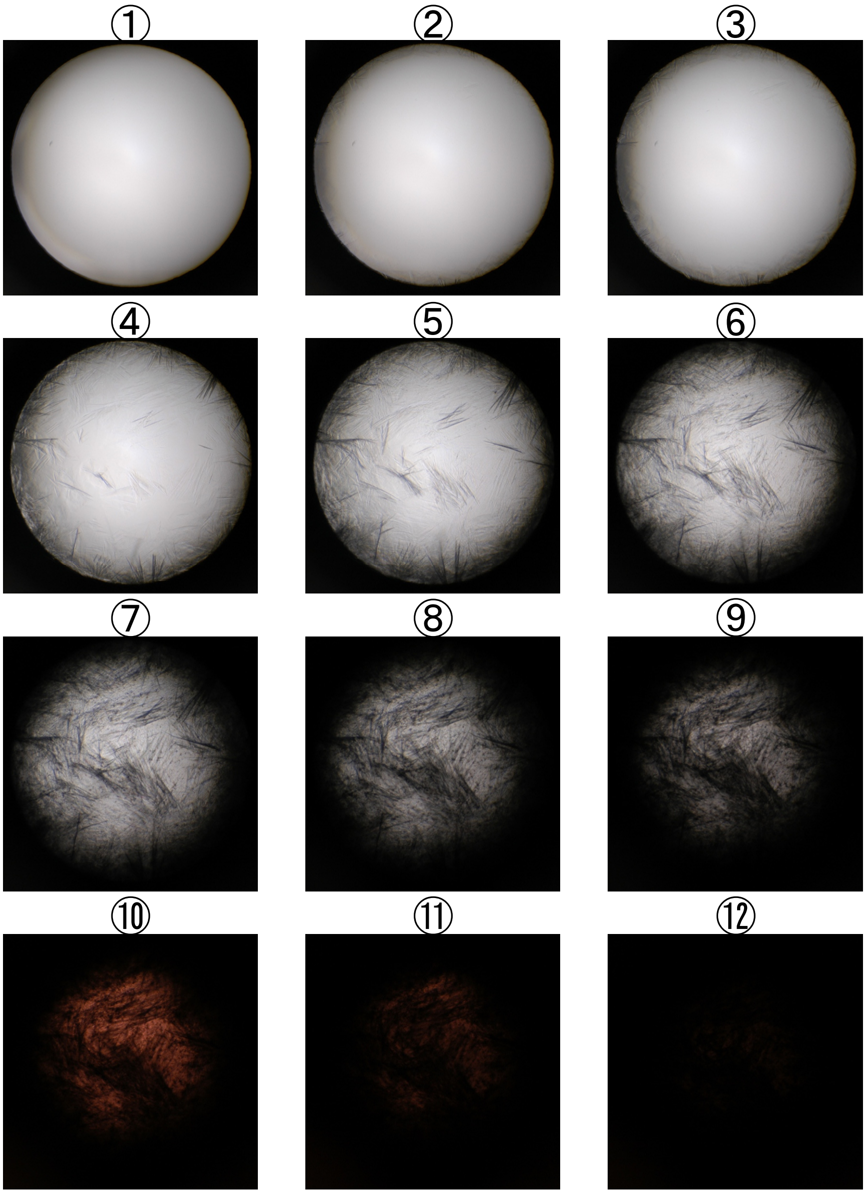
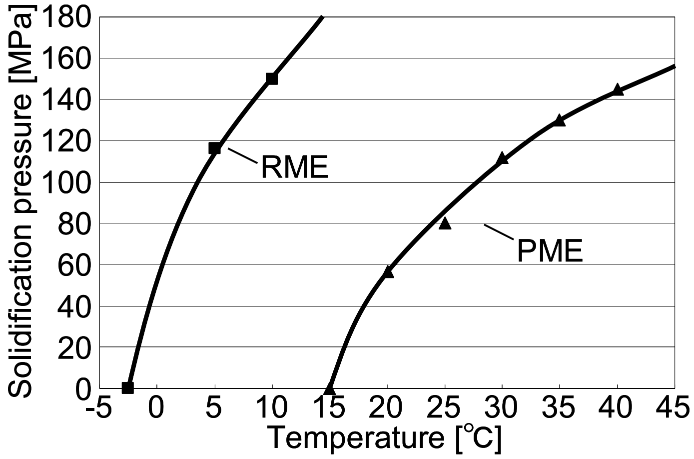
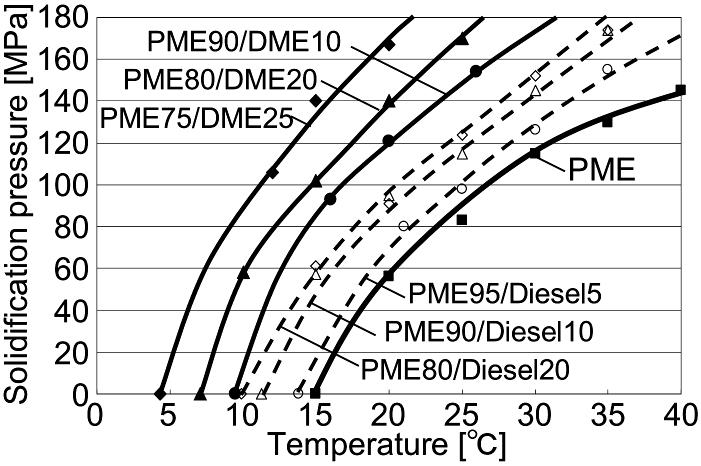


Figure 35 Pictorial solidification process of PME at 20℃



(a)



(b)

Figure 36 (a) Solidification pressure of PME and RME, and its effect by DME and diesel fuel blend ratios

(3) Winterization technology for PME

Normal grade palm biodiesel has typical pour point of about 15°C and can only be used in tropical countries. To enable palm biodiesel to be used as mineral diesel substitute in countries with cold climate, the Malaysian Palm Oil Board (MPOB) has developed a novel process to produce palm biodiesel with cold filter plugging point (CFPP) that meets the seasonal requirements of temperate countries (CFPP ranging from minus 20°C in winter to 0°C in summer). Winter-grade palm biodiesel (PME) with low CFPP and its production technology are filed under Malaysian Patent PI 20021157.

Winter-grade PME is produced by removing the high melting components from normal grade palm biodiesel. A physical separation process is used. This includes fractional distillation and/or crystallization of the esters followed by separation of the solids from the liquid fraction. Depending on the CFPP requirements, the yield of winter-grade PME is between 35 to 40% while the co-products find applications as summer grade fuel or as raw materials for the oleochemical / surfactant (α-sulphonated methyl esters) industry. The typical product specifications of winter Grade Palm Biodiesel produced by MPOB Technology is shown in Table 12

Table 12 Properties of normal and winter grades palm biodiesel

Property	Unit	EN 14214 (a)	Palm Biodiesel	
			Normal Grade	Winter Grade
Ester content	% weight	Min. 96.5	> 98.0	> 98.0
Density @ 15°C	kg/m³	860 - 900	878	870 - 890
Viscosity @ 40°C	mm²/s	3.5 – 5.0	4.4	4.0 - 5.0
Flash point	°C	Min. 120	182	150 - 200
Pour point	°C	--	15	-21 to 0
CFPP	°C	See note (b)	15	-18 to - 3
Iodine value	--	Max. 120	50 - 55	56 - 83
Cetane number	--	Min. 51	58 - 59	58 - 59
Sulphur	mg/kg	Max. 10	< 10	< 10
Phosphorous	mg/kg	Max. 10	< 10	< 10
Water	mg/kg	Max. 500	< 500	< 500
Linolenic acid methyl esters	% weight	Max. 12	< 0.5	< 0.5
Polyunsaturated methyl esters	% weight	Max. 1	< 0.1	< 0.1
Methanol	% weight	Max. 0.2	< 0.2	< 0.2
Monoglycerides	% weight	Max. 0.8	< 0.8	< 0.8
Diglycerides	% weight	Max. 0.2	< 0.2	< 0.2
Triglycerides	% weight	Max. 0.2	< 0.2	< 0.2
Free glycerol	% weight	Max. 0.02	< 0.02	< 0.02
Total glycerol	% weight	Max. 0.25	< 0.25	< 0.25

Notes :-

(a) EN 14214 : European Standard for Biodiesel

(b) CFPP (Cold Filter Plugging Point) requirements based on the German Annex to EN 14214 :-
  - Summer : Grade B (Max. 0°C)
  - Spring & Autumn : Grade D (Max. -10°C)
  - Winter : Grade F (Max. -20°C)

Oiltek Sdn. Bhd. has technology licensing agreement with MPOB to supply full scale commercial production plants for normal grade as well as winter grade palm biodiesel, as shown in Figure 37. The first three commercial winter-grade PME plants were successfully construction in Malaysia and the first plant has been in operation since September 2006 until today.

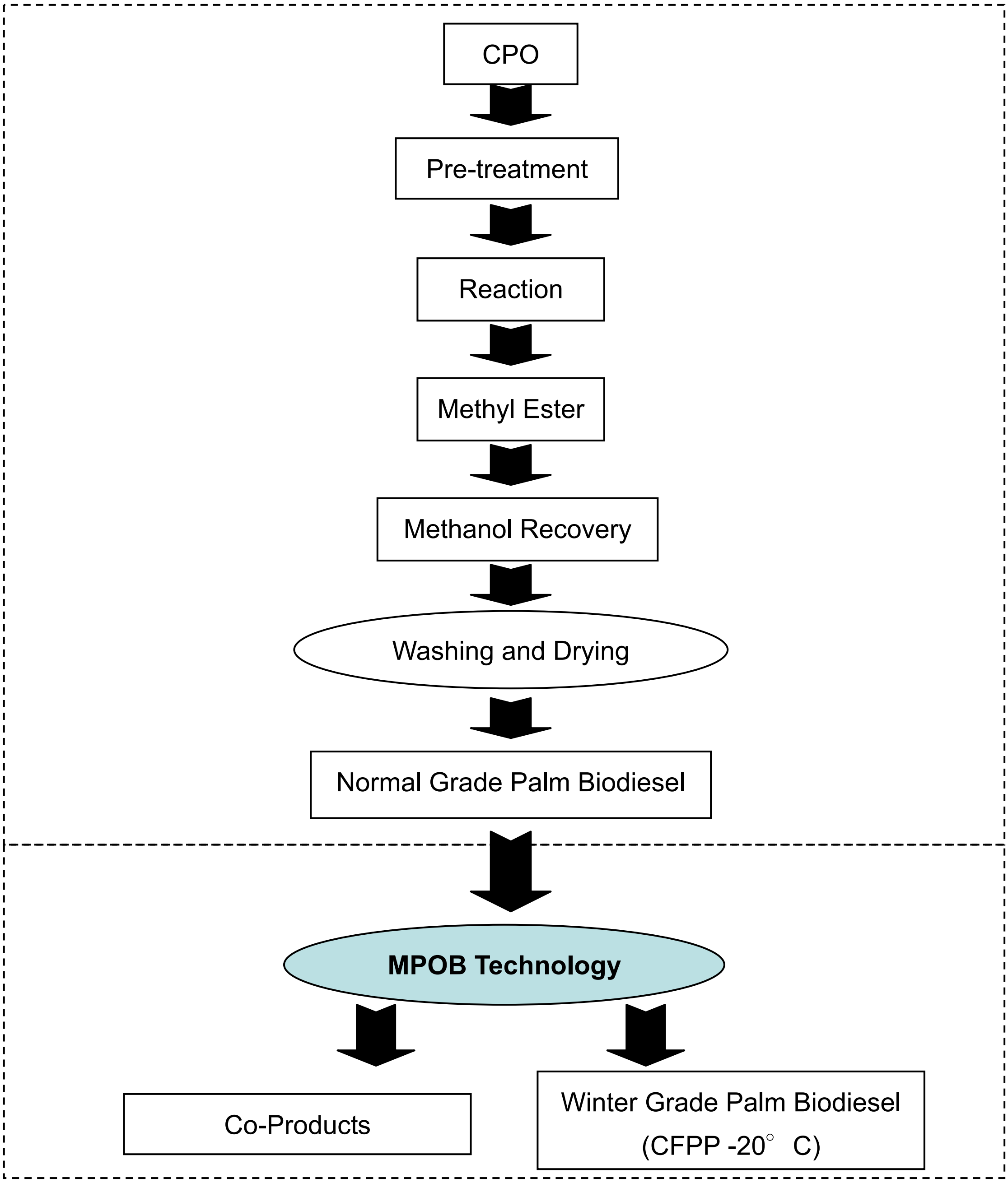


Figure 37 Process flow diagram of normal and winter grades palm biodiesel technology

Winter Grade PME has been produced and exported by Malaysia since the establishment of the commercial plant, as shown in Figure 38. Compared with other types of liquid oil derived biodiesel (e.g. rapeseed and soybean), the winter grade PME contains bulk of mono-unsaturated methyl ester (18:1) and thus, it is a premium grade biodiesel with good storage stability, low CFPP and able to decrease polymerization degree of biodiesel at high combustion temperature.

Integration of existing palm biodiesel production plant with winterization technology could provide the solution for palm biodiesel to be used in the temperate countries to suit the regional temperature requirement. MPOB is also able to provide technical know-how for helping the palm biodiesel producers to meet the cold soak filtration test specified in ASTM D6751 in 2009.

Figure 38 Palm biodiesel winterization plant at Sime Darby Biodiesel Sdn. Bhd., Malaysia.

5. POTENTIAL OF OTHER FEEDSTOCKS

5.1 Jatropha curcas L.

5.1.1 Introduction

The term biodiesel that is nowadays understood by the industries and society at large is “a diesel engine fuel composed of fatty acids methyl ester (FAME)”. It is made from vegetable oils or animal fats by a relatively simple chemical process called transesterification with methanol or methanolysis. As it is a relatively new but quite potential fuel, the industries in various regions of the world (in excitement) made biodiesel from the most readily available fat or fatty oil resource in their respective areas; understandably, most of these fats and fatty oils are edible. Thus, the current major biodiesel raw materials are :

- Soybean oil in the USA,
- Rapeseed (canola) oil in Northern Europe,
- Olive and sunflower oils in Mediterranean Europe, and
- Palm and coconut oils in Tropical Asia and the Pacific.

Recognizing the probable occurrence of food versus fuel competition, many attempts have been carried out to develop non edible raw material resources for biodiesel. Presently, physic nut (Jatropha curcas L) is undoubtedly the most popular oil-yielding tree identified for this purpose.

The initial, and rather euphoric, popularity of Jatropha curcas stems from the widespread general knowledge that it is a non-edible oil-yielding tree well adapted to marginal areas with poor soil and low rainfall, where it grows without competing with annual food crops, thus filling an ecological niche. In the last decade, therefore, extensive as well as intensive researches and developments on cultivation of Jatropha curcas, fatty-oil production from its seeds, conversion of the oil into biodiesel and engine tests of the fuel, started in many parts of the world.

Jatropha curcas (Linnaeus) is a small tree or large shrub belonging to the family of Euphorbiaceae. It grows wild in many tropical regions and is very adaptable as regards soil. It can reach a height of up to 7 m and has thick branchlets; on arid escarpments, however, its height does not exceed 2 m [19]. For planting, one can use a seedling, but the more usual practice is to use a stem cutting. Bushes begin to yield seed-containing fruits when they are 4 – 6 months old and can live up to 30 years or more. Each fruit contains 2 or 3 seeds which are separated from one another by the septums of an ellipsoidal, sparsely lobed capsule about 2 – 5 cm long. The ellipsoidal seeds are black, 13 – 19 mm long, about 10 mm thick, and each generally weighs 0.5 –

1.0 g [20]. Figure 39 shows flowers, fruits, and seeds of Jatropha curcas L. The seeds consist of 35–48% shell and 52–65% kernel [21]. The fatty oil is contained in the kernel and, on the average, the oil content is 52 % based on the kernel or 33 % based on the whole seed.

Figure 39 Various parts (i.e. flowers, fruits and seeds) of the tree Jatropha curcas L.

5.1.2 Characteristics of Jatropha curcas oil

The fixed or intrinsic empirical characteristics of crude Jatropha curcas oil (CJCO) are as follows: [22] :

- Specific gravity 15/15 ° C : 0.918 – 0.923
- Saponification value, (mg KOH)/g : 188 – 197
- Iodine value, (g I2)/(100 g) : 93 – 107
- Unsaponifiable matter content, % : 0.4 – 1.1

CJCO, which typically contains 1.45% phospholipids [23] or 290 ppm (mg/kg) phosphorus [24], has been reported with very high acid values [25], [26] and, consequently, investigated the biodiesel production processes from such acidic oils. It should be noted, however, that acid value is not a fixed or intrinsic character of a fatty oil but rather reflects the degree of correctness in seed handling prior to oil pressing. Oils obtained from properly dried seeds, and kept dry afterward, usually have low acid values, less than 1 (mg KOH)/g. Ensuring the production and delivery of low acid oils should be preferred to processing high acid ones as the former results in a much lower cost.

Table 13 shows the composition ranges of fatty acids in Jatropha curcas oil. As the table clearly indicates, Jatropha curcas oil belongs to the oleic or linoleic acid group, to which the majority of vegetable oils belong [27]. The usual method of biodiesel preparation should be applicable to this oil and many reports of its successful preparation are available in the literature (see e.g. [24]-[26]).

Table 13 Fatty acid composition of Jatropha curcas oil (%-weight)

Fatty acid	Eckey (1954) [22]	Gubitz et.al. (1999) [28]
Myristic acid, C14:0	0 – 0.5	0 – 0.1
Palmitic acid, C16:0	12 – 17	14.1 – 15.3
Stearic acid, C18:0	5 – 7	3.7 – 9.8
Arachidic acid, C20:0	0 – 0.3	0 – 0.3
Behenic acid, C22:0	-	0 – 0.2
Palmitoleic acid, C16:1	-	0 – 1.3
Oleic acid, C18:1	37 – 63	34.3 – 45.8
Linoleic acid, C18:2	19 – 40	29.0 – 44.2
Linolenic acid, C18:3	-	0 – 0.3

A potential major constraint in the widespread acceptance of Jatropha curcas as a source of biodiesel is the presence of phorbol esters, which, when consumed by human and animal, are toxic and also carcinogens [29]. Phorbol esters are defined as "polycyclic compounds in which two hydroxyl groups on neighboring carbon atoms are esterified to fatty acids" and occur naturally in many plants of the family Euphorbiaceae and Thymelaeceae. Due to the toxicity of the plant and oil, some special precautions need to be exercised during the processing of Jatropha curcas seeds and oils. The removal and degradation of phorbol esters during pretreatment and transesterification of Jatropha curcas oil has been thoroughly investigated [30]. The finding showed that during degumming, some phorbol esters were removed into the acid gums and wash water, which implies that the acid gums could not be used for animal feed and care should be taken when disposing the wash water into the environment. A silica treatment of Jatropha oil did not decrease the phorbol esters, whereas stripping/deodorization at 260 °C and 3 mbar pressure with 1% steam injection completely degraded phorbol ester. Further, phorbol esters were not detected in stripped oil, fatty acid distillate, transesterified oil (biodiesel) and glycerine. However, the presence of possibly toxic phorbol ester degradation products in these materials/products could not be ruled out [30]. The toxicity of phorbol esters has also prohibited the use of Jatropha seed meals as animal feed. Many researchers have attempted various chemical and physical treatments to extract or inactivate phorbol esters so that the protein-rich seed meals could be used as feed resources. However, not much progress has been reported so far [29].

5.1.3 R & D challenges

Contrary to the initial overly optimistic presumption that growing Jatropha curcas would, on one hand, supply non-edible raw material for biodiesel production while, on the other hand, provide employment, improve the environment, and enhance the quality of rural life. Most farmers in Indonesia (at least) are presently reluctant to grow it because, after widespread trial plantations instigated by irresponsible politicians, the farmers realized that cultivating the plant did not yield an adequate financial return. The principal problems are the relatively still low per hectare productivity of the seeds and high harvesting cost while the non existent of an established market is an extra obstacle. Although Jatropha is stated to have a potential seed productivity of up to 12 ton/ha/year, much research still has to be done to put that potential into practical reality. The non uniform (or non simultaneous) maturation of Jatropha's fruits lead to the need of frequent manual fruit/seed pickings resulting in high harvesting cost.

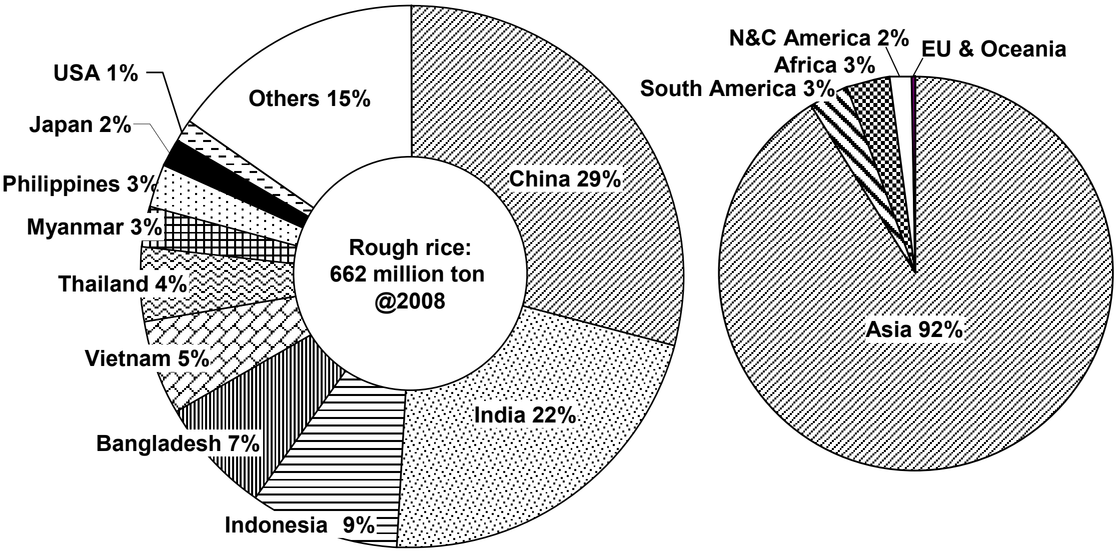
Among various institutions doing R&D on Jatropha curcas, the Pakuwon Jatropha Nursery and Experimental Plantation, which is operated by Indonesian Center for Estate Crops Research and Development (ICECRD) located between Bogor and Sukabumi in West Java, Indonesia, is presently carrying out R&D activities to solve the above problems. This Jatropha trial plantation site was established in 2005 by the Ministry of Agriculture with the purpose to improve yield of Jatropha seed production. Initially, nine Jatropha breeds were collected from all over Indonesia during the exploratory phase, and planted in a 50 ha area of the Pakuwon site. This original population yields about 25-30 capsules/shrub or average 1st year yield of 0.3-0.4 ton/. The first Improved Population (IP-1) was developed in 2006 with more than 200 capsules/shrub or average 1st year yield of 0.9-1.0 ton/ha ha (4 – 5 ton/ha/yr after the 4th year) in a 30 ha plantation area. Then, the second Improved Population (IP-2) was further developed in 2007 with more than 400 capsules/shrub or average 1st year yield of 1.9-2.2 ton/ha (6 – 8 ton/ha/yr after the 4th year) in a 25 ha plantation area. Recently (2009), they have launched the IP-3 seedlings capable of yielding 8 – 9 ton/ha/yr seeds after the 4th year. For each IP, there are varieties suitable for dry (e.g. IP-1A), medium dry (e.g. IP-1M) and wet (e.g. IP-1P) area. The Pakuwon site is also developing Jatropha breed with simultaneously maturing fruits for efficient harvesting. Other Jatropha research activities of the site include genetic control on number of seeds in Jatropha fruit, pest control, disease control, certification of distributed seed and inter-crop selection.

5.2 Rice Bran

5.2.1 Introduction

In the past, bio-diesel production has advanced with the help of price supports and an agricultural promotion policy utilizing surplus production of rapeseed in Europe and soybeans in the US. However, as biodiesel fuel demand has increased recently, the price of rapeseed oil, soybean oil, and palm oil for food has spiked, thus the competition of fuel and food has been a problem. On the other hand, from the viewpoint of national energy security, it is also important to possess the resources and/or crops that enable self-sufficiency. In Japan and the East Asian countries, rice crops are popular; however in Japan some rice fields are classified as "non-producing" and/or abandoned due to government policy. If industrial rice (not intended for food) is cultivated on the non-producing land, using low cost fertilizers and low-energy methods, it is possible to make rice into bio-ethanol and make rice-oil from the rice bran into a bio-diesel fuel feedstock.

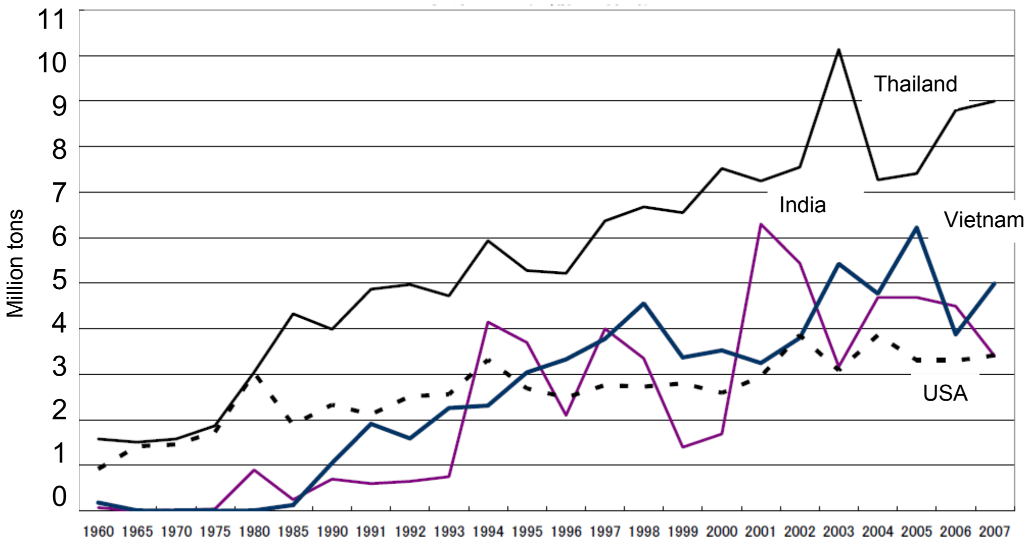
The amount of worldwide rough rice production was about 662 million tons in 2008. As shown in Figure 40, Asian countries; China, India, Indonesia, Bangladesh, Vietnam, Thailand etc., account for approximately 92% of annual production. Among the production leaders, India, China, Thailand, Vietnam, and Indonesia account for about 70%. Moreover, as shown in Figure 41(a), the main rice export countries are



(Source: USDA, PSD Online. June 10-2009 access data and International Rice Research Institute web-site "Facts and Figures-Rough Rice Production, by Country and Geographical region-USDA")

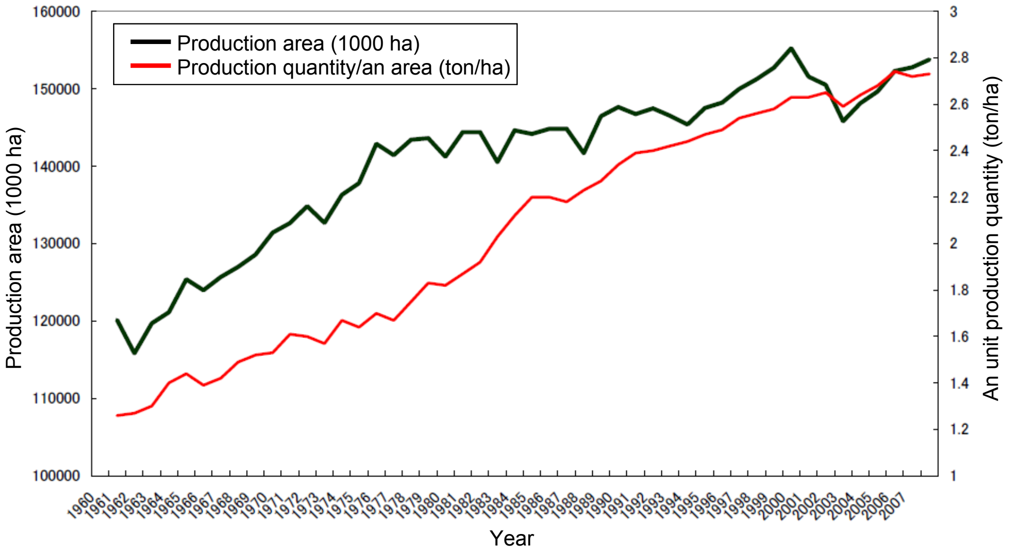
Figure 40 Estimated rice production in the world

Thailand, Vietnam, USA, and India. Although rice demand has been increasing worldwide, the production area and a unit price have been at a consistent upper limit, as shown in Figure 41(b). Thus at the present time the supply is well matched with demand, leaving negligible surplus. The largest importing countries of rice from the USA are Mexico and Japan. Japan imports about 2 million ton of rice annually, according to the World Trade Organization (WTO).



(a)

(Source: USDA, “World Agricultural Supply And Demand Estimates”, 2007)



(b)

(Source: USDA, “World Agricultural Supply And Demand Estimates”, 2007)

Figure 41 Historical plots of (a) export by main rice producing countries and (b) rice production area and an unit production quantity

5.2.2 Rice Bran Oil

Rice bran oil contains abundant unsaponificable matter that is not found in other vegetable oils. Figure 42 shows the process for which brown rice is made into milled rice, after which refined rice oil is made. Rice consists of a bran layer, the embryo, and the albumen. The albumen part of white rice is 91% of the total, while the remaining 9% is generally called the rice bran. About 18 to 20% of the rice bran is oil, and the rest is protein, fiber, carbohydrate, ash, and water. The embryo is a particularly high-quality medicinal supply ingredient, and has abundant antioxidants γ-oryzanol and tocotrienol, which are not found in other vegetable oils. Generally, oil from rice bran is extracted with a solvent (e.g. *n*-hexane) and goes through the following process.

(1) Heat up process, to make extraction easier.
(2) Solvent addition process to wash the oil from the bran.
(3) Separation process to remove the oil from the mixture of oil and hexane.
(4) Collection process to collect the solvent from defatted rice bran.

Rice bran oil that is obtained in this way is called rice crude oil.

Components of rice crude oil vary slightly, depending on the free-fatty acid. For example, about 80% is neutral oils (i.e. triglycerides), 10% is free fatty acids, 5% is unsaponificable matter, the remainder is wax, gummy matter, γ-orizanol, impurities, and water. Among these components we note that free fatty acids are created via fat and oil hydrolysis due to the lipase enzyme in rice bran, and these hydrolysis reactions vary depending on the temperature. In addition, the wax content also varies depending on the place of origin. It is known that rice produced in tropical regions has less wax, while that produced in cold regions has more wax. Purification of rice crude oil consists of degumming, de-acidification, dewaxing, wintering, bleaching, and deodorization. For good quality we point out that de-acidification, dewaxing, and wintering are important.

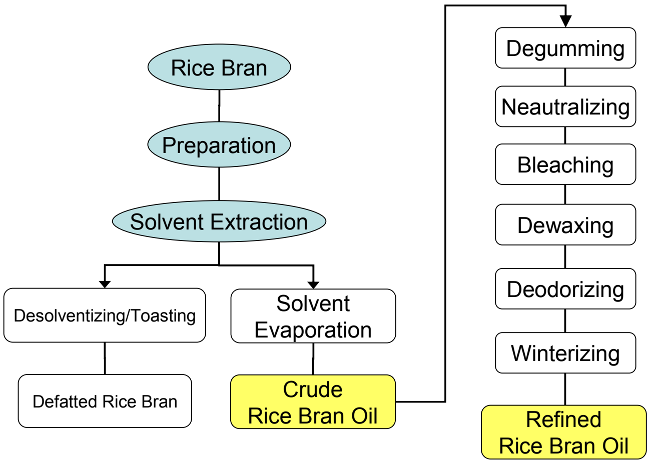


Figure 42 Process flow scheme of rice bran oil for cooking

5.2.3 Characteristics of Rice Bran Oil

Fatty acid components of rice bran oil consist mainly of oleic acid, linoleic acid, and palmitic acid. Very minor components are linolenic acid, which is an unsaturated fatty acid with three double bonds, thus rice bran oil's oxidation stability is relatively high. Moreover, compared to other vegetable oils, it contains relatively large amount of unsaponificable matter. For example, rapeseed (canola) oil has 0.87% unsaponificable matter; soybean oil has 0.46%, while rice bran oil has a relatively high 2.31% unsaponificable matter. This portion contains rice bran oil's unique components, such as the antioxidants γ-oryzanol and tocotrienol.

Rice crude oil contains 2% γ-oryzanol, and it has been reported that it aids in physiological processes like growth promotion and aging prevention, and for treatment of autonomic nerve ataxia, menopause, and for lowering blood cholesterol. It has been used as various forms of medicinal raw materials and food additives. Tocotrienol is contained only in rice bran oil and palm oil. It has been reported that it functions as an antioxidant, which helps lower blood serum cholesterol, and is effective for resistance to tumors.

Figure 43 shows the wide-ranging utilization of rice bran oil refinery byproducts. For example, the crude fatty acids generated in the deoxidation process are widely used for raw materials like soap, resins, and paints through another process of distillation and deodorization. Additionally, wax that is generated in the dewaxing and wintering processes contain behenic acid (C22), lignoceric acid (C24), ceryl alcohol (C26), octacosanol (C28), and myricyl alcohol (or triacontanol, C30). It is used for a molten type thermal printing ink ribbon, resin, and as an industrial lubricant.

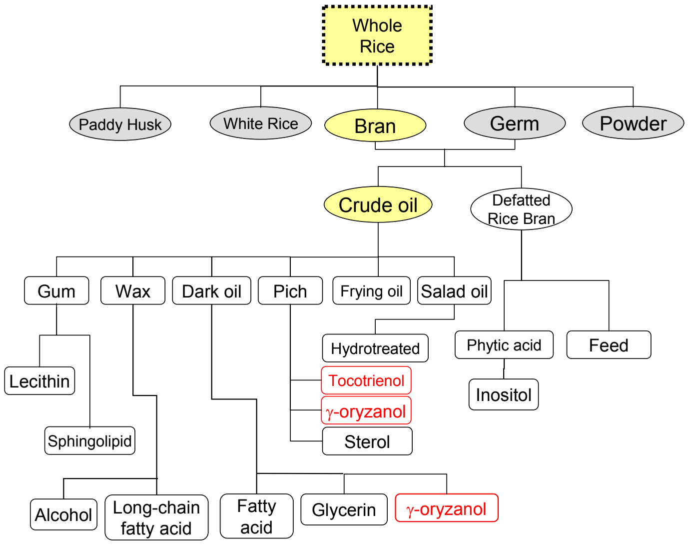


Figure 43 Utilization of rice and rice bran oil

5.2.4 Properties of Rice Bran Oil as a Biodiesel Fuel

Table 14 shows the main properties and components of RRBOME (Refined Rice Bran Oil Methyl Esters), CRBOME (Crude Rice Bran Oil Methyl Esters) that were produced with an alkaline catalyst method, as well as CJME (Crude Jatropha Oil Methyl Esters), RME (Rapeseed Oil Methyl Esters) and conventional petroleum based diesel fuel. Figure 44 shows a breakdown of the fatty acid content of these fuels. The Table and the Figure show that RRBOM and CJME have nearly identical fatty acid content, and they have a relatively high amount of saturated fatty acids (C16:0, C18:0). Because of this, both CJME and RRBOM have a slightly higher CFPP clog point, higher cloud point CP, and higher pour point, compared to RME. However, they do lack low temperature flowability. On the contrary, saturated fatty acids are relatively higher, thus compared to RME, the peroxide induction period IP is longer (with an oxidation acceleration test), and oxidation stability is excellent. Besides, since CJME and RRBOME have similar components, one may deduce that there will be no problems with mixing them together to use.

On the contrary, it is understood that CRBOME has a high acid value and low oxidation stability. This is because it contains impurities like bran in the feedstock oil, these impurities hamper reactions, and free fatty acids remain in the oil. Therefore, it is necessary to improve the refining process. For CRBOME one may add some type of preliminary treatment before doing the methyl ester exchange process.

Table 14 Biodiesel fuel specifications

		CJME	RRBOME	RME	Diesel fuel
Density	g/cm^3@15℃	0.884	0.886	0.885	0.833
Kinematic Viscosity	mm^2/s@40℃	4.8	4.7	4.4	3.5
Flash Point	℃	182.5	172.5	190	-
Pour Point	℃	0	0	-12.5	-
CFPP	℃	-1	-1	-13	-
Cloud Point	℃	5	7	-6	-
10% Carbon Residue	wt%	1.54	1.94	3.25	-
Lower Calorific Value	MJ/kg	36.1	37.7	36.7	42.7
Carbon	wt%	76.3	76.9	77.0	86.1
Hydrogen	wt%	13.1	12.8	12.0	13.7
Oxygen	wt%	10.5	10.2	10.3	<0.1
Sulfur	wtppm	<3	<3	1	<50
KF water	wt%	0.05	0.08	0.06	0
Oxidation Stability(IP)	hours	8.0	7.1	4.1	-
Peroxide Value	meq/kg	35.7	29.9	101.1	-
Acid Value	mgKOH/g	0.4	0.2	0.1	-
Iodine Value	gI/100g	93.2	101.2	111.4	-

CJME:Crude Jatropha Oil Methyl Ester, RRBOME: Refined Rice Bran Oil Methyl Ester
RME: Rapeseed Oil Methyl Ester, Gas oil(JIS 2#@2006)

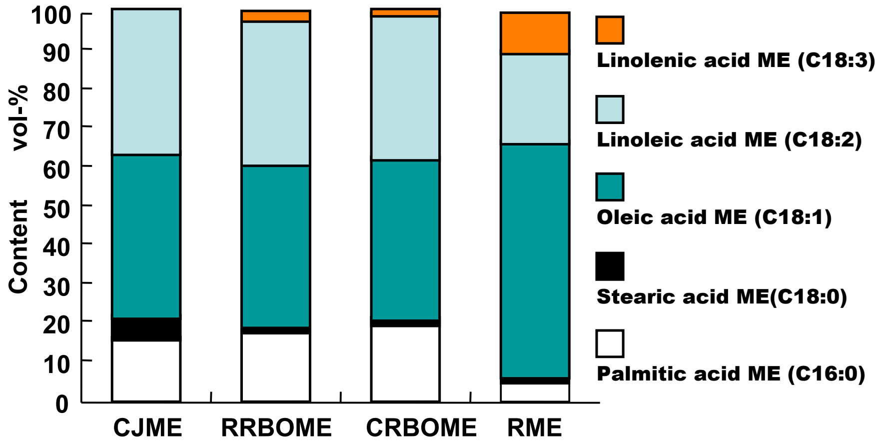


Figure 44 Fatty acid methyl ester components of raw materials

5.2.5 Potential of Rice Bran Oil

Table 15 shows the current production levels of food grade brown rice and rice bran in Japan. At present, non-cultivated land totaling about 380,000 ha exists as a result of the government production adjustment program for rice crops. Japan's annual production of brown rice for food was about 8.7 million ton in 2007. Of this amount about 870,000 ton is rice bran. Out of this total, about 20% can be obtained as oil (rice bran oil). Actually only about 63,000 ton per year is produced as edible rice oil, and about 111,000 ton is unrefined rice oil. If we could bring the non-cultivated land into production, it means that a rice oil production capacity of about 150,000 tons exists. This is equivalent to about 0.4% of the amount of light oil consumed annually in Japan. If it is assumed that from the annual 420 million ton yield of milled rice production worldwide, about 100 million ton of rice bran could be generated. From this it can be concluded that there is 20 million tons of potential rice bran oil production annually.

Table 15 Production situation of brown rice for food and rice bran in Japan

FY2007

	Crop of Rice ton/y	Planted area ha/y	Rice Bran ton/y	20% of rice bran ton/y
Total (food)	8,705,000	1,669,000	870,500	174,100
Abandoned cultivated land (Total)	1,981,965	380,000	198,196	39,639
Rice bran for food and refined rice bran oil			317,000	63,000

5.3 Microalgae

5.3.1 Introduction of Microalgae

(1) Microalgae basic characteristics and ecological functions

“Microalgae” (including blue-green algae or cyanobacteria) are group of photoautotrophic microorganisms comprising of a large, heterogeneous, and polyphyletic assemblage of relatively simple plants or thallophytes which lack differentiated roots, stems, and leaves. They have little in common except chlorophyll-a (primary photosynthetic pigment). Most microalgae usually occur in water, be it freshwater, marine, or brackish. They can also be found in almost every other environment on earth such as extreme environment e.g. snow, desert including hot springs. In most habitats, algae function as the primary producers in the food chain, producing organic materials from sunlight, CO_2, water (including nitrogen and phosphorus dissolved in water). They also produce the O_2 necessary for the other organisms, besides over 40% of atmospheric CO_2 is fixed by algae. About one third of the world plant biomass consists of algae. At present, more than 30,000 microalgal species have been reported from all parts of the world.

(2) Potential applications of microalgae

From the photoautotrophic growth of microalgae and production or accumulation of various valuable products, microalgae are potentially applied in various aspects as follows:

- Agriculture products e.g. biofertilizer, soil conditioner, plant growth regulator, pesticide and animal feed.
- Food products e.g. daily food, food supplements (neutraceutical), food colorant and thickening or binding agents.
- Medicinal products e.g. antibiotic, anticancer, antioxidant and diagnostic tag, etc.
- Environment e.g. secondary and tertiary treatment of wastewater, bioremediation of heavy metals and pesticides.
- Energy as renewable feedstock for bioenergy production (biodiesel, bioethanol and hydrogen, etc.).

(3) Advantages of biodiesel production from microalgae

Production of biodiesel from microalgae expresses advantages over “energy crops” as follows:

- No competition with food crop, therefore, no adverse effect on “food security”.

- Using smaller foot-print (production area) of non-arable land to provide higher productivity due to their rapid growth rate with short growing cycle.
- Using smaller amount of water to obtain equal biomass productivity as energy crops.
- Co-processes with various kinds of industrial wastes e.g. wastewater, flue gas (CO_2) and waste heat, hence reduce the production cost (water and nutrients) and comply with CDM together with C-credit gain.
- Co-products with various kinds of algal left-over extracts thus make biodiesel production of biodiesel from microalgae feasible.

The production of biodiesel from microalgae with co-processes and co-products is shown in Figure 45

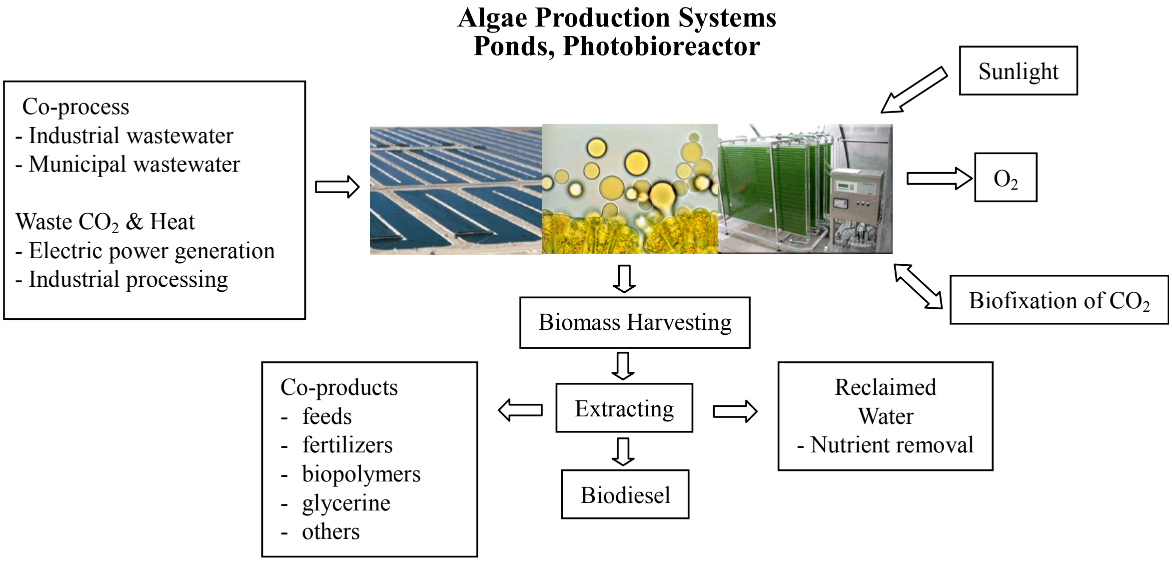


Figure 45 Production of biodiesel with co-process and co-products

5.3.2 Technology for Biodiesel Production from Microalgae

There are 5 steps in the process of biodiesel production from microalgae. The steps of which are:

(1) selection and preservation of selected oil-producing microalgal strains,
(2) preparation of inoculum for biomass production,
(3) cultivation for biomass production,
(4) harvesting of microalgal biomass, and
(5) extraction of microalgal oil.

(1) Selection and preservation of selected oil-producing microalgal strains

Currently, there are 3 microalgal groups of interest for biodiesel production. The groups of which are: (marine) diatoms (Bacillariophyceae), (freshwater and marine) green algae (Chlorophyceae) and freshwater blue-green algae (Cyanophyceae). The general criteria for strain selection are

(1) high growth rate and productivity,
(2) high oil content,
(3) suitable quality of oil (composition of fatty acids) and
(4) high (adaptation) ability to grow under the wide range of light intensity and temperature (of the cultivation location).

Apart from conventional techniques, a high-throughput screening (HTS) technique for target strains has been applied in advance laboratories. Not only had those mentioned criteria but various techniques including HTS also used for searching of other valuable substances for the production of co-products.

Besides the selection of target strains from natural sources, improvement of selected strains by genetic engineering has been done in some laboratories. However, stability of genetically modified strains is in daunted.

For the preservation of selected strains (to prevent the loss of their genotypic and phenotypic characteristics resulting from frequently sub-culturing of fresh strains), cryopreservation of strains under sub-zero temperature ($\leq$-20^{o}C in freezer to -196^{o}C in liquid nitrogen) using 5-10% dimethyl sulfoxide (DMSO) as cryoprotectant seems to be the most effective preservation technique.

(2) Preparation of inoculum for biomass production

To keep microalgal biomass production system under good condition for long cultivation period, high quality and quantity of inoculum (starter) are required. Starting the mass cultivation with suitable microalgal density can prevent the drop of microalgal growth by photooxidation and contamination. It is recommended using close-cultivation system (e.g. photobioreactor) to cultivate the strain under optimal growth condition to prepare high quality and quantity of inoculum.

(3) Cultivation for biomass production

There are 2 main microalgal production systems, so-called: (1) opened cultivation pond and (2) closed photobioreactor. The major technical challenges of these systems are how to:

(1) sustain highest photosynthesis and biomass productivity,

(2) reduce cell damage by hydrodynamic stress, photooxidation and grazer,
(3) reduce costs (fabrication, installation, maintenance), and
(4) increase the capability of the system to expand to an effective industrial scale.

Recently, various types of photobioreactors have been designed and developed e.g. hanging plastic bags and the most popular, tubular reactors (horizontal, vertical and inclined). Various types of clear plastic materials have been used to produce these reactors. The followings are advantages of closed photobioreactor over opened pond: 1) better control of algal culture, phyco-chemical culture parameters, and gas (CO_2) transfer, 2) larger surface-to-volume ratio, 3) less evaporation of water from growth medium, 4) better protection from outside contamination. (Less competition with natural microalgal species, infection by virus and bacteria as well as grazer by zooplankton), and 5) higher cell density can be obtained.

The weak point of photobioreactor is deterioration (cracking) of plastic surface (by UV) which leads to the reduction of light absorption. At present there are a few commercial microalgal products derived from photobioreactor production. The most important limiting factor to this is its high investment cost of construction and operation, especially in an indoor operation (to control light intensity and incubation temperature). In contrast to photobioreactor systems, there are many microalgal products obtained from opened cultivation pond systems located in various part of the world (Asia, Europe, America and Australia).

In the case of opened cultivation pond systems, there are 2 types of ponds designed, namely circular and race-way ponds. Race-way pond system is much more popular than circular one. Covering of race-way pond has been designed for improving of its performance. This new design does alleviate some of the disadvantages of opened pond in both quantity (biomass productivity) and quality (contamination). Semi-batch and continuous production of algal biomass can be conducted using an effective covering race-way pond system.

Apart from the selection of microalgal strains, “tailor-made design” of cultivation system suitable for the strain and growing (weather) conditions of the production area is also a vital key success factor to make the production of biodiesel from microalgae feasible. In addition, if marine phytoplankton has been used, special selection of material for constructing of the whole system should be considered to prevent the problem of corrosion.

(4) Harvesting of microalgal biomass

Harvesting method applied in the production system depends on the characteristics of selected strain. Centrifugation and microfiltration are suitable for harvesting of phytoplankton (marine diatom and green algae and freshwater green algae of unicellular with small size). Simple filtering using plankton net is suitable for filamentous blue-green algae. Flotation is suitable for gas vacuole producing strains. Auto-flocculation is suitable for colony-forming strains, filamentous strains including unicellular strain of large size or high cell density. Harvesting using flocculants can be applied with all types of strains.

Combining of harvesting methods e.g. filtration + centrifugation, floatation + centrifugation + sand bed filtration also have been applied. Development of harvesting method of an effective simple process with low cost and large-scale feasible should be “tailor-made” for each selected strain because cost of harvesting is also significant for biomass production. In addition, if de-watering or drying microalgal biomass to a certain level is required, co-process using waste heat can be done after harvesting.

(5) Extraction of microalgal oil

In general wet microalgal biomass can be directly used for oil extraction. The same as extraction of vegetable oil, mechanical expression and solvent extraction are popularly applied for microalgal oil extraction as well. To derive over 90% of the total oil present in the biomass, combing extraction method of cold press and hexane extraction has been applied. Recently, supercritical fluid/CO_2 extraction also used to obtain 100% of the oil content; nevertheless this extraction process is very expensive.

6. IMPORTANCE OF QUALITY CONTROL AND MARKET ACCEPTANCE

6.1 Fuel Quality Control

6.1.1 The fuel quality control method in Europe

In case of European diesel fuel standard (EN590), 7% of the FAME conformed to the neat FAME standard (EN14214) can be blended in diesel fuel. Therefore, it is essential to guarantee the quality of neat FAME for end user acceptance.

In Germany and Austria, Arbeitsgemeinschaft Qualitätsmanagement Biodiesel e.V. (AGQM) was established in 1999. Twenty-three FAME producers, accounting for 90 % of FAME production in both countries, and eight trading companies join the AGQM. Filling stations, which sell neat FAME or FAME-blended diesel fuel, are the AGQM's member, whose logo is shown in Figure 46. The main objectives of the AGQM are as follows;

- Observance of legal and customized requirements of the fuel properties.
- Provision of a consistently high Biodiesel quality.
- Avoidance of technical problems caused by fuel.
- Creation of all user's trust in biodiesel

Figure 46 Logo of European biodiesel fuel quality control scheme AGQM

The AGQM is operated by the membership fee, with quality management of AGQM consisted of the following measures that are not only restricted to production, but also trading.

- Definition of additional requirements
- Independent quality checks by external service providers
- Guidelines for internal quality checks and documentation
- Technical support and counselling
- Round Robin tests

6.1.2 The fuel quality control method in North America

National Biodiesel Board (NBB) has an optional certification system named BQ-9000, whose logo is shown in Figure 47. The objective of BQ-9000 is

- To promote the commercial success and public acceptance of Biodiesel.
- To help assure that Biodiesel fuel is produced to and maintained at the industry standard, ASTM D6751.Definition of additional requirements

Any FAME producers and distributors conforming to BQ-9000 regulation can be certified by NBB. Thirty-six producers and twenty-two marketers of biodiesel has passed rigorous review and inspection of their quality control processes by an independent auditor, and thus are certified as announced on the NBB website [31]. BQ-9000 greatly helps reduce any chance of producing or distributing fuel of inferior quality.

Figure 47 Logo of American biodiesel fuel quality control scheme BQ-9000

6.1.3 The fuel quality control method in Japan

In Japan, the Ministry of Economy Trade and Industry (METI) is responsible for fuel quality in the consumer market, as shown in Figure 48. In accordance with the Japan fuel standards law, METI is obligated to:

- Monitor registration of gas stations, where all gas stations are required to register with METI
- Blenders of Biofuel (ethanol and/or FAME) with petroleum based fuels are required to register with METI.
- Develop fuel quality standards (both mandatory and voluntary)
- Require gas stations to report quality sampling test of gasoline every ten days, or annually if its supply chain is approved by METI
- Monitor fuel quality at the pump, which can be outsourced to four registered testing organizations

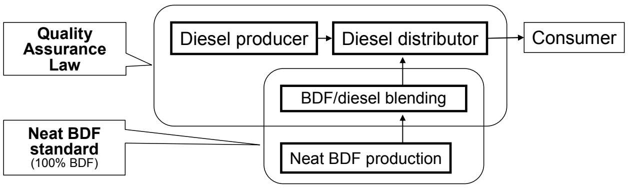


Figure 48 The fuel quality control scheme in Japan

Table 16 shows compulsory FAME blended diesel fuel standard in Japan. The regulated items of FAME blended diesel fuel are obliged to increase due to various concerns on FAME inherit fuel properties. In Japan, FAME conformed to the neat FAME standard (JIS K 2390) can be blended up to 5% in diesel fuel.

The traders, which are not only producers and importers but also distributors of FAME-blended diesel fuel, assume all responsibility by law. There are about 50,000 filling stations in Japan. METI gathers about 200,000 fuel samples/year to investigate their qualities. If METI finds any off-spec fuels, METI instructs fuel suppliers to follow fuel regulations. If they do not follow through, METI orders suspension of business up to 6 months and, in some case, fuel distributors will be charged with criminal penalties. If FAME-bended diesel fuel is made commercially available in Japan, the base fuel has to be modified so that it is fully compatible with the FAME components in the blend.

Table 16 Quality standard items for Gasoline and Diesel Fuel

Items	Level	
Lead	No detection	*
Sulfur	< 10 ppm	*
MTBE	< 7 vol%	*
Oxygen Content	< 1.3 wt%	*
Benzene	< 1 vol%	*
Kerosene	< 4 vol%	*
Methanol	No detection	*
Ethanol	< 3 vol%	*
Existent Gum	< 5 mg/100mL	*
Color	Orange	*
Octane	Regular > 89	
	Premium > 96	
Density	< 0.786 g/cm3	
Distillation Temp.	(specified)	
Copper Corrosion	< 1 max	
RVP	44 - 65 kPa (Summer)	
Oxidation Stability	> 240 min	

Items	Level	
Sulfur	< 10 ppm	*
Cetane Index	> 45	*
90% distillation temp.	< 360 deg.C	*
Flash Point	> 45 deg.C	
Pour Point	Depend on region and month	
CFPP		
10% Carbon Residue	< 0.1%	
Kinematic Viscosity	> 1.7 mm2/s	

Note: * = mandatory

6.2 Quality Control of Biodiesel-Blended Fuels at the Pump in Philippines

Standards are worthless without proper implementation and enforcement. Not all Philippine National Standards (PNS) are mandatory. Unless a regulation is issued by the appropriate government authority, the PNS is voluntary. Thus, PNS for fuels and related products, including biofuels, become mandatory only upon the issuance of a corresponding Circular issued by the Department of Energy (DOE).

The sale of petroleum products at the pump is covered by DOE Circular

DC2003-11-010 “The Rules and Regulations Governing the Business of Retailing Liquid Petroleum Products” or “Retail Rules”. Rule IV of these Circular deals with petroleum product standards, requiring compliance with the PNS. Prohibited acts include adulteration and illegal trading. Adulteration covers products not meeting the PNS. Penalties include fine per act of violation, without prejudice to criminal sanctions.

The DOE is empowered by law to stop operations of oil industry participants that do not conform to the PNS.

6.2.1 Methodology

(1) Inspection and Sampling

The Oil Industry Management Bureau (OIMB) of the DOE conducts inspection and checking of oil industry players’ compliance to DOE standards and regulations, including on fuel quality, at the various supply points, namely: refineries, import terminals, depots, and gasoline stations/retail outlets; and at times from transport vessels such as tankers, barges, tank trucks, lorries and even pipeline. Routine and spot inspections and product sampling are conducted, as well as complaint-related checks.

The OIMB inspectors, among others, take a sample of the various products at the retail outlet/petrol stations. They also check on the quantity delivered by the dispensing pumps, through a calibrating bucket, as well as the compliance of the station to the requirements under the Retail Rules.

Findings of the inspection are recorded in the numbered Inspection Report, which are signed by the inspectors. The dealer or his representative is asked to affix his/her signature on the report to certify that the statements therein are true and correct and filled up in their presence. The dealer gets a copy of the Inspection Report.

The Inspection Report sheet also includes a box wherein the dealer, by authority of the OIMB Director, is directed to institute corrective measures in conformity with the standards prescribed by law, rules and regulations governing the liquid fuels industry, and to cease and desist from selling to the public products which do not meet the prescribed PNS, and products delivered by dispensing pumps that is less than the actual quantity by more than 50 millilitres for every 10 litters. The dealer is further ordered to submit proof of compliance with the above directives and to show cause in writing under oath within 10 days from receipt thereof why no administrative and/or criminal action should be instituted against the him/her for the observed violations. This box effectively shortens the prosecution time by at least one month.

Sample Retention. Regulations require the oil companies and dealers to retain samples which may be needed for referee tests. Recommended samples for retention include those from their product receipts and from the inspection sample of DOE.

(2) Laboratory Testing and Analysis

The standard procedure is for the inspectors to gather samples and send them to the National Petroleum Testing Laboratory (NPTL) under the DOE Energy Research and Testing Laboratory Service (ERTLS) for testing. Upon completion of testing and analysis, the ERTLS then forwards the result to the OIMB.

(3) Evaluation of Inspection, Testing and Analysis

The OIMB evaluates the result from the laboratory and the ocular inspection vis-a-vis the DOE rules and prepares a report of the inspection.

(4) Prosecution

Cases of violation are forwarded to the Legal Service for due process. The Legal Service issues orders/resolutions to entities found with violations, i.e., the dealer of the off-spec or substandard product, indicating therein the violations and the corresponding penalties. Violators can file a motion for reconsideration.

(5) Feedback

Regardless of the result of the evaluation, the oil company represented by the dealer (entity owning the brand) is formally advised of the results of the inspection. If no violation is observed, the letter may be considered as a Clean Bill of Health. If there is a violation, the company is required to make the necessary corrective actions and inform the DOE-OIMB accordingly. The formal advice makes the company aware of what is going on at the retail outlets, most of which are operated by dealers who are separate entities. With the new Retail Trade Law, though, gasoline stations can now be managed and/or owned by multinational companies, subject to certain conditions.

6.2.2 Quality Control Improvement Initiatives

At present, all samples have to be brought to the single DOE testing facility – the National Petroleum Testing Laboratory (NPTL) at the Energy Center, Merritt Road, Fort Bonifacio, Taguig City, Metro Manila. It usually takes at least 2 weeks from the time the product samples are obtained up to the time the test results are determined and the gasoline station is notified, by which time the product at the subject gasoline station has been disposed of, through further distribution or sale. In this regard, the DOE-OIMB is working for possible use of the following:

(1) Product Marker

Since the 1980's the DOE has required the oil companies to use a marker as a quick-check on adulteration. Added to lower value products is an invisible chemical marker that is detectable by a few drops of extractant into a test tube with the product sample. The DOE inspectors have the portable "test kit – test tube, dropper and extractant" which they use to find out if the required product for marking is properly marked, and if there are products that are not supposed to be marked but have the marker. Such system, however, is not applicable to diesel adulteration vis-a-vis with biodiesel. Moreover, the following are the observed shortcomings of the present system:

- Marker tests are indicative and require laboratory confirmation;
- Marker tests are qualitative; and
- Extractants have short shelf life.

The DOE-OIMB is now in the process of receiving proposals of new marker systems that have the following features:

- Can determine extent of adulteration;
- Can determine source of the product (fingerprint); and
- Applicable to both biofuels and blends.

(2) Portable analytical equipment during field inspection

At the start of this century, the DOE acquired portable fuel analyzers, one each for gasoline and diesel. The infrared-technology equipment has the capability of detecting a wide range of properties in the PNS, including biofuels content. Some test methods have secured ASTM recognition. This means that while most of the tests are preliminary or indicative, some tests are final and need no further confirmatory tests. Such equipment on the field can facilitate the outright closure of pumps dispensing products that do not meet the standards of quality.

Most local oil companies now have the same equipment, correlated with the DOE's analyzer, as well as with the formal laboratory equipment. However, there is generally just one unit for each company/agency, thus the equipment is generally lab-based.

Presently, the OIMB is in the process of setting up its mobile monitoring and testing facilities to be fielded all over the country. The OIMB has received various offers of portable analyzers, which will be evaluated by the inter-agency Technical Committee on Petroleum Products and Additives (TCPPA), inasmuch as most of the TCPPA members may themselves want to have their own portable test facility.

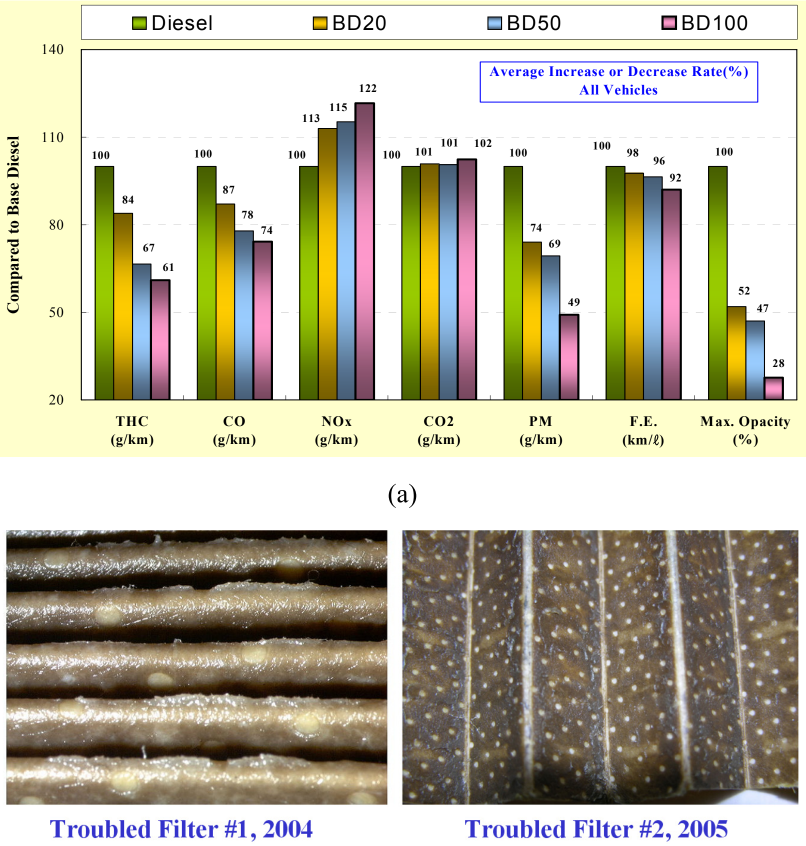
(3) Laboratory/equipment correlation

The ERTLS is also undertaking correlation between laboratories and their equipment among the government, industry players and third party testing facilities to minimize, if not totally avoid inconsistent and contestable test results.

6.3 Field Test of BD5, BD20 and BD100 Powered Diesel Vehicles in Republic of Korea

BD20 demonstration program was officially launched from 25th May 2002 by MOCIE (Ministry of Commerce, Industry and Economy) in Seoul metropolitan area and Jeonbuk provincial area. At this time, mainly transit buses and garbage trucks used BD20 fuel, and ASTM biodiesel standard was adopted.

However, some troubles on cold startability and fuel filter plugging were occurred in winter season occasionally. Then, KIER (Korea Institute of Energy Research) conducted the feasibility study of BD5 and BD20 on diesel vehicles, in which 3 test vehicles, 1 test engines, 2 common rail FIEs were tested and fuel quality was also analyzed, from August 2004 to July 2006 by government sponsored project. This project was also supported by auto makers, FIE (Fuel Injection Equipment) makers, petroleum companies, and biodiesel companies. In this field test as shown in Figure 49(a), there were no troubles found in two passenger RVs tested with BD5 during the first years. However, some running troubles and fuel filter plugging were observed during the second year. For one passenger RV tested with BD20, the plugging problem was quite serious, and it required changing the fuel filters more quickly to solve the problem. From these results, it was concluded that the quality standard of biodiesel is strongly required to strengthen. Therefore, MOCIE changed the BD100 quality standard from ASTM based one to EN based one from the end of 2006, and also BD20 should be used only restricted fleet user which has own oil storage capability and auto repair capability. Figure 49(b) shows some test results of fuel filter plugging by insufficient biodiesel quality.



(a)

Troubled Filter #1, 2004

Troubled Filter #2, 2005

(b)

Figure 49 KIER test results for (a) emission and fuel economy with rice bran biodiesel, and (b) troubled fuel filter due to insufficient biodiesel quality

6.4 Biodiesel Fuel Experience in China

There are three stages for the development of BDF from the eye of stock in China: the first stage (nowadays) is using waste cooking oil, the second and mid-term stage is using remain of vegetable oil and inedible oil, and the third and long-term stock will be algae.

(1) Waste Oil

Statistically, China has about 5 million tons of waste cooking oil, which is considered as a kind of energy waste and also polluting the environment if not used. Several years before, many small private company purchased the waste oil to produce BDF, and they achieved success and gained considerable money. At 2004, the price of waste oil is about 1,400RMB per ton for waste cooking oil and waste pork oil, then many companies set up the BDF produce lines, the sale price of BDF is just as ordinary diesel (about 4,000 RMB per ton). At 2007, the waste oil price is about

2,500-2,800RMB per ton while the Diesel price is about 5,000RMB~5,500RMB.

However, these BDF companies met insurmountable difficulty. At 2008, the diesel price in China increased to about 7,300～7,800RMB per ton while the price of waste oil is as high as nearly 8,000RMB per ton, the result is obviously that many companies has gone bankrupted. Besides the surge in oil prices, the inconvenient truth in China is that if the requirement of waste oil is small, it is really regarded as waste, which results the price of stock being low and hence the bio-diesel company can make money. On the other hand, if the requirement of feed stock, such as waste oil, becomes larger, the waste oil is thought by the collectors as moneybag. Thus, the price increases, and the result is obviously that the BDF companies will be hard to make money.

Besides the price, the volume of production is also a problem for the BDF companies featured by waste oil. The total resource of waste oil in a certain city is limited though most of the Chinese like oily food. The small production scale restricts the BDF quality, thus a vicious circle forms.

(2) Vegetable oil

Vegetable oil is the mid-term stock for BDF in China, but the ordinary edible oil such as rapeseed, soybean, peanut and cotton seed could not be used directed to produce BDF for the reason we have a too large population and are shortage of editable oil. Furthermore, China has determined its principles of developing non-food biomass liquid fuels, that is,

- it should not deprive people of food,
- it should not deprive food of land, and
- it should not deprive cattle of feed.

In China, the way of using vegetable oil seems lying in the remains of oil manufacture. The inedible oils such as Jatropha oil and Chinese pistachio are trying to find their ways of expansion, but still face the obstacles of cost and total yield. Till now, the acidification oil from remains of vegetable oil has been tried by many small companies, but for the obstacles of production scale and the high stock price, their situation is just as hard as the waste oil companies.

(3) Algae

Algae is given great expectations by the BDF companies and the government, but it still needs some technological breakthrough.

(4) BDF problems in China

- Stock is obviously the first obstacle for BDF industry in China.
- Production scale is small. It is statistics that there are more than 2000 BDF companies in China, only 26 companies exceed 10 thousand tons yield, 13 of which is 10-50 thousand tons, 7 of which is between 50~100 thousand tons, 6 of which exceed 100 thousand tons, only one of these company's gross output value is more than 1 billion RMB. In 2008, the total output of biodiesel is less than 300 thousand tons.
- For the above problems, the quality of BDF is not good enough for vehicle use generally speaking.

(5) BDF Vehicle Demo in Shanghai

The performances of many kinds of bio-diesel based on feedstock were measured and the engine performances were measured in China. Based on this, many BDF vehicle demos have been set, such as the BDF demo in Shanghai bus fleets.

In Shanghai, the same nine buses were demoed to verify the BDF vehicle performance. BD5 was used in 3 buses, and BD10 was used in 3 other similar buses, while the rest 3 buses used ordinary diesel. The specification of the buses is in Table 17.

Table 17 Technical specifications of the experiment buses

Type		SWB6100V2
Size (mm)	Length	10490
	Width	2500
	Height	3150
	Wheelbase	5000
Engine Type		C260 20
Power (kW/rpm)		191/2200
Torgue (N.m/rpm)		1025/1400～1500
Displacement (L)		8.3
Emission		Euro II

From the demo, the following conclusions can be made:

(1) The fuel consumption of BD5 is just equal to that of Diesel buses, less than that of BD10 buses, the difference is just less than the calorific value.

(2) The BDF vehicles had better and stable poison emission, especially the smoke emission is much better that of diesel vehicles.

(3) The power of BD5 vehicle is less 2% than that of diesel vehicle, while the BD10 vehicle is less about 4%.

(4) BDF with qualified quality can be used directly as bus fuel.

6.5 Community Biodiesel Standard for Agricultural Machine in Thailand

In Thailand, Department of Energy Business (DOEB) under Ministry of Energy (MOEN), is the governmental authority responsible for issuing the specification for biodiesel. In August 2005, DOEB has announced the FAME biodiesel standard (2005) [32] to allow biodiesel to be blended with diesel as B5 for commercial use in selected area. There are totally 24 items on the properties specification, which derive from either ASTM or EN standards on biodiesel, as shown in Table 18. Note that minor modification on the testing method in FAME biodiesel standard was announced in May 2007 [33], and the increase of oxidation stability from 6 to 10 hours effective in August 2009 [34], which has been used till now.

Table 18 Comparison between FAME and community biodiesel standards in Thailand

No	Specification	Biodiesel B100			
		< or >	FAME	Community	Method
1	Methyl Ester [%wt]	>	96.5	▨	EN 14103
2	Density at 15 °C [kg/m^3]	> <	860 900	860 900	ASTM D 1298
3	Viscosity [cSt] at 40 °C	> <	3.5 5.0	1.9 8.0	ASTM D 445
4	Flash Point [°C]	>	120	120	ASTM D 93
5	Sulphur [%wt]	<	0.0010	0.0015	ASTM D 2622
6	Carbon Residue, on 10% distillation residue [%wt]	<	0.30	▨	ASTM D 4530
7	Cetane number	>	51	47	ASTM D 613
8	Sulfated Ash [%wt]	<	0.02	0.02	ASTM D 874
9	Water [%wt]	<	0.05		EN ISO 12937
	Water and Sediment [%vol]	<		0.2	ASTM D 2709
10	Total Contaminate [%wt]	<	0.0024	▨	EN 12662
11	Copper Strip Corrosion	<	No. 1	No. 3	ASTM D 130
12	Oxidation Stability at 110 °C [hrs]	>	10	▨	EN 14112
13	Acid Value [mg KOH/g]	<	0.5	0.80	ASTM D 664
14	Iodine Value [g Iodine/100 g]	<	120	▨	EN 14111
15	Linolenic Acid Methyl Ester [%wt]	<	12.0	▨	EN 14103
16	Methanol [%wt]	<	0.2	▨	EN 14110
17	Monoglyceride [%wt]	<	0.8	▨	EN 14105
18	Diglyceride [%wt]	<	0.2	▨	EN 14105
19	Triglyceride [%wt]	<	0.2	▨	EN 14105
20	Free glycerin [%wt]	< <	0.02	 0.02	EN 14105 ASTM D 6584
21	Total glycerin [%wt]	< <	0.25	 1.5	EN 14105 ASTM D 6584
22	Group I metals (Na+K) [mg/kg]	<	5	▨	EN 14108 and EN 14109
	Group II metals (Ca+Mg) [mg/kg]	<	5	▨	prEN 14538
23	Phosphorus [%wt]	<	0.001	▨	ASTM D 4951
24	Additive (if any)				
25	Color			Purple	Visual Inspection

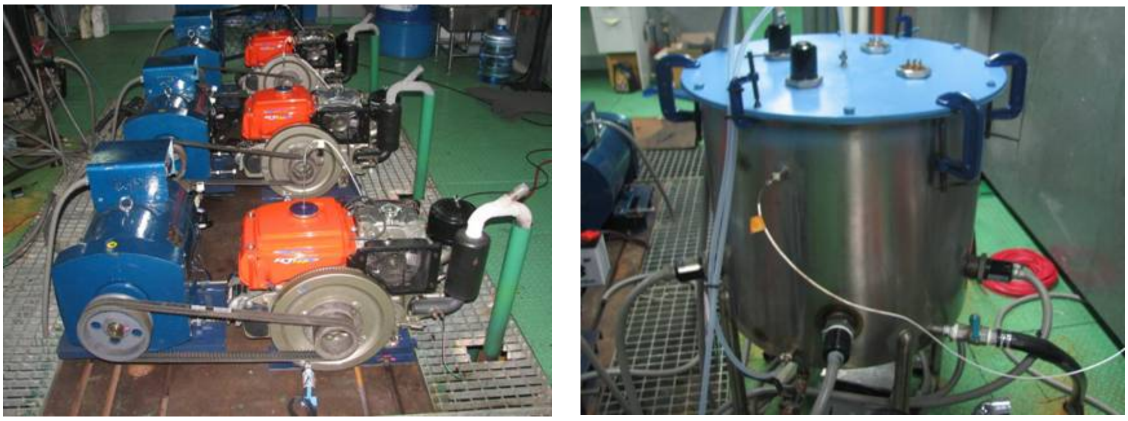
With increasing oil price after biodiesel standard was issued, Thai government has promoted the use of biodiesel, especially on the community level, where farmers can process their own biodiesel for agricultural machine without having to paying for fossil diesel. During 2005-2006, Department of Alternative Energy Development and Efficiency (DEDE) under Ministry of Energy (MOEN) has promoted biodiesel utilization in the community level, in accordance with His Majesty the King philosophy on 'Sufficiency Economy'. Many small biodiesel reactors (100 L/batch) were awarded to selected communities with technical training of the local villagers to use the reactor. Even though biodiesel production or transesterification process itself is not complicated, processing biodiesel using the simple reactor in the community within FAME specification, shown in Table 18, has posed a challenge. Hence, DOEB has announced the community biodiesel standard (2006) in July 2006 [35] in order to better regulate community biodiesel production so that the biodiesel production in the community level can practically benchmark with the fuel quality, not greatly harmful to the agricultural engine. As shown in Table 18, the requirement for community biodiesel has reduced from 24 to 13 items with more relax values, compared to the FAME biodiesel standard, with omission of certain properties such as %methyl ester, carbon residue, total contaminate, oxidation stability, iodine value, %methanol, %mono-/di-/tri-glyceride,%-metal and %phosphorous. For easy identification, the standard requires community biodiesel to be purple. This community biodiesel standard is strictly issued for use with agricultural machine, defined as a single four-stroke cylinder (horizontal type & water cool), and is not allowed to be blended with diesel for transportation vehicles.

To further illustrate any damage to the single-cylinder engine when fueled with biodiesel of community grade, DOEB has contracted PTT to investigate such effects via performance, black smoke and durability tests, as well as engine parts rating and lube oil analysis [36]. Community-grade biodiesel was sampled from over 20 communities among those 72 communities awarded from DEDE. Those with high viscosity, but still within the community biodiesel standard, and large enough capacity were selected as sources for durability test. Tested single-cylinder engines were Kubota model RT140ES since Kubota has about 70% market share in Thailand, and this model has a direct-injection technology for upper limit test. Some details of Kubota RT 140ES are shown in Table 19.

Table 19 Specific information of tested engine

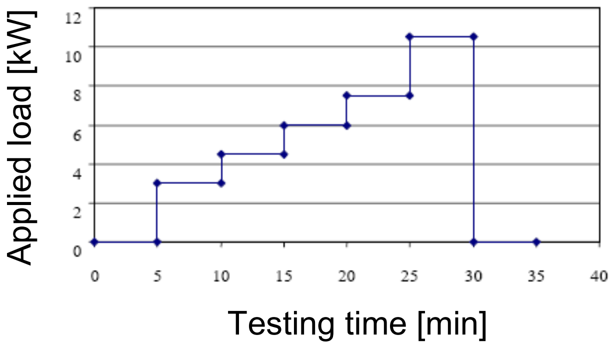
Detail	Specific information
Model	Kubota RT 140ES
Type	Direct-injection, horizontal type, water-cool
No. of cylinder	1
Bore x Stroke (mm x mm)	97 x 96
Displacement (cc)	709
Max power, hp at rpm	14 / 2,400 (10.3 kW / 2,400)
Max torque, Kilogram force at rpm	5.0 / 1,600
Specific fuel consumption (g/kW.h)	231
Compression ratio	18:1
Engine no. 1	Runs on diesel
Engine no. 2 & 3	Runs on community-grade biodiesel

Two Kubota engines were tested with community-grade biodiesel (Engine No.2 & 3) while one Kubota engine (Engine No.1) of the same model was tested with commercially available diesel fuel for comparison. All engines were coupled with electricity generator and subsequently resistance heater coil for boiling the water, as shown in Figure 50. Performance test was conducted before and after 2,000 hrs. durability test at full throttle and applied load of 3, 4.5, 6, 7.5 and 10.5 kW at 5 min interval each. On the other hand, durability test was conducted at full throttle and applied load of 10.5 kW for 5 hours with 1 hour break. Hence, four 5-hours engine-running slots result in 20 hours of durability test each day. Figure 51 shows testing pattern for both performance and durability tests.

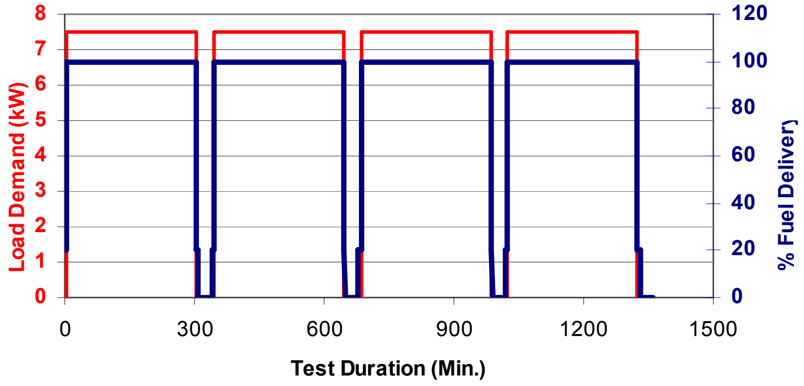


(a) (b)

Figure 50 Experimental setup showing (a) Kubota engine coupled with electricity generator and (b) resistance heater coil



(a)



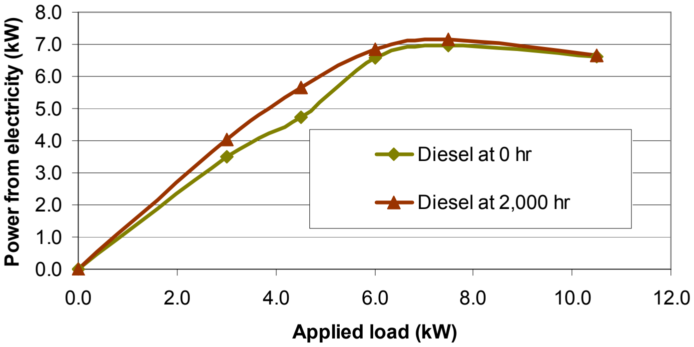
(b)

Figure 51 Applied load pattern of (a) performance test and (b) durability test, both at full throttle

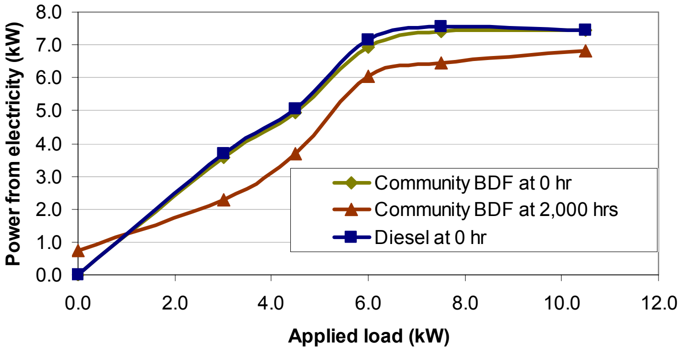
Figure 52 shows performance test results before and after 2,000 hrs durability tests for all three engines. It clearly shows that engine performance is similar for engine no. 1 after 2,000 hrs with diesel while slight drop in performance are shown in both engine no. 2 & 3 after 2,000 hrs with community-grade biodiesel.

For black smoke test, Figure 53 shows that running diesel for 2,000 hrs does not affect black smoke much but running community-grade biodiesel for 2,000 hrs significantly reduces black smoke by 27% for heavy applied load or at least 50% for light applied load.

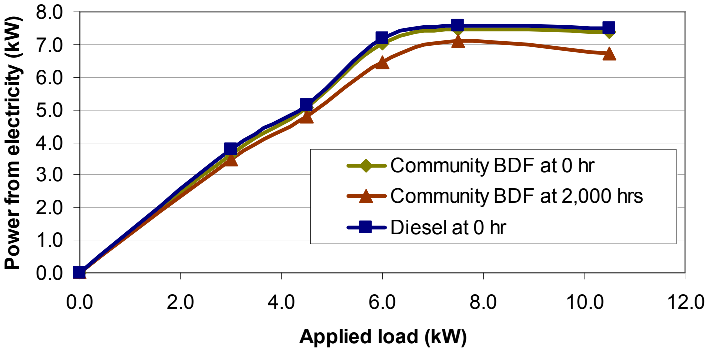
In term of specific fuel consumption (SFC), Figure 54 shows that slightly higher SFC with SFC increases over running time regardless of whether diesel or community-grade biodiesel is used.



(a)



(b)



(c)

Figure 52 Performance test results of engine before and after running on (a) diesel: engine no. 1, (b) biodiesel: engine no. 2 and (c) biodiesel: engine no. 3 for 2,000 hrs

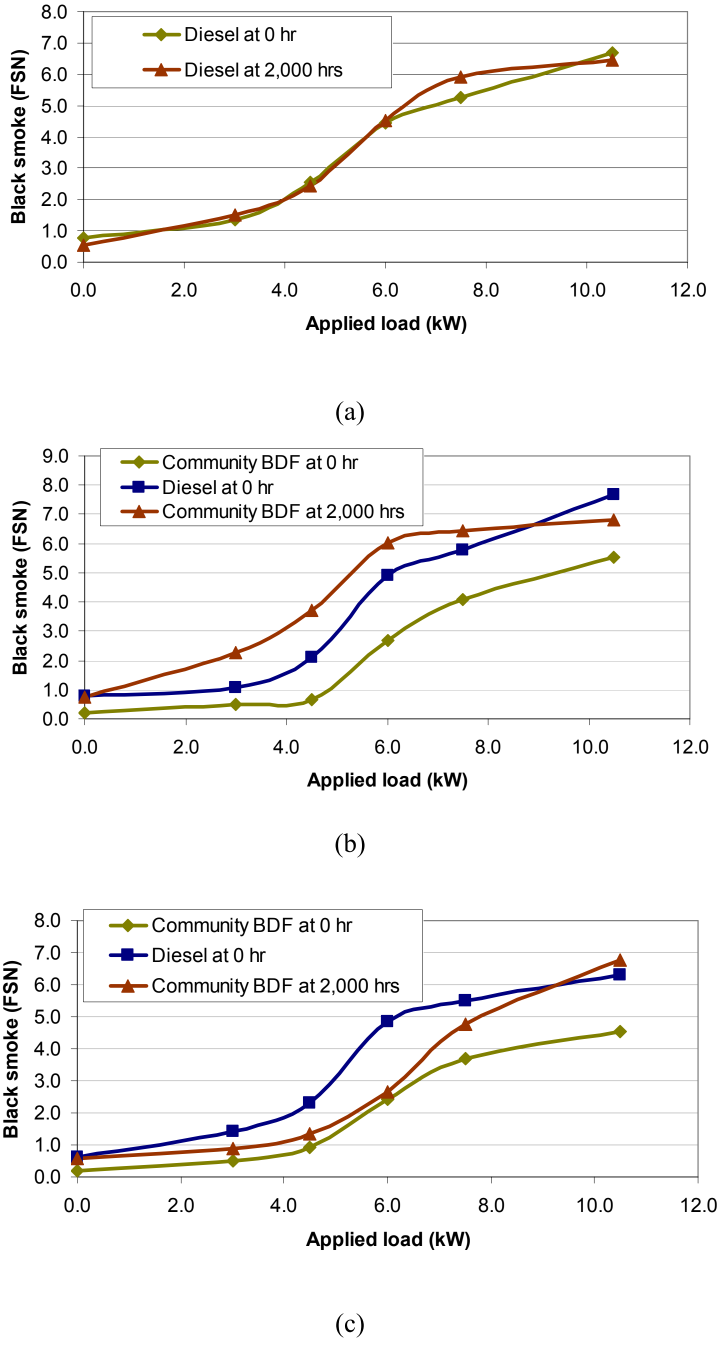
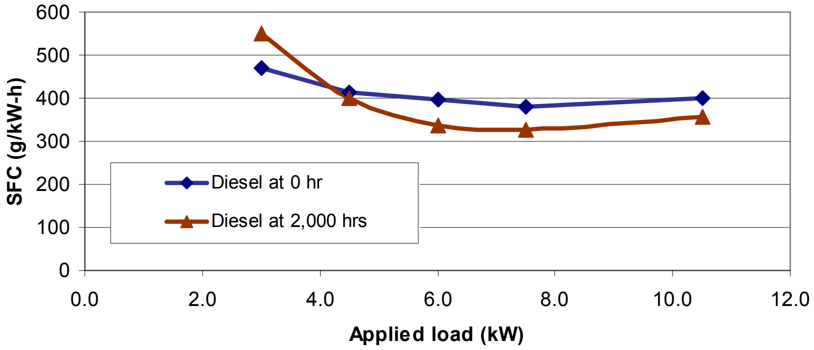
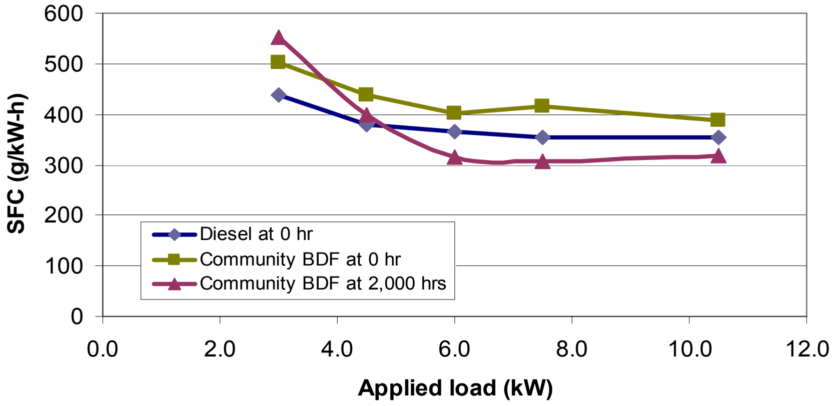


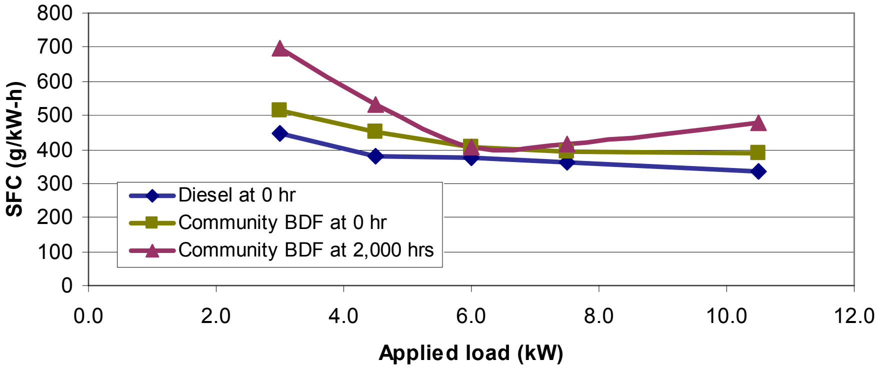
Figure 53 Black smoke test results of engine before and after running on (a) diesel: engine no. 1, (b) biodiesel: engine no. 2 and (c) biodiesel: engine no. 3 for 2,000 hrs



(a)



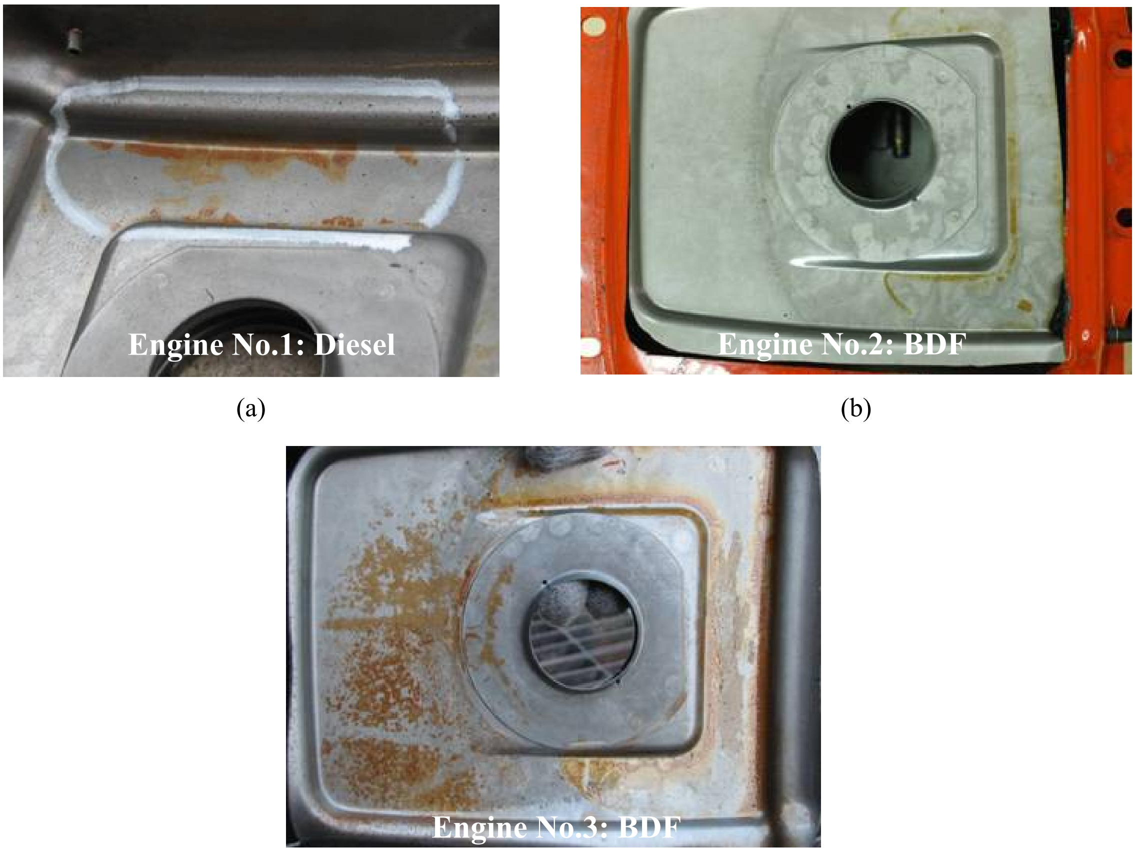
(b)



(c)

Figure 54 Specific fuel consumption test results of engine before and after running on (a) diesel: engine no. 1, (b) biodiesel: engine no. 2 and (c) biodiesel: engine no. 3 for 2,000 hrs

For engine part inspection after 2,000 hrs durability test, Figure 55 show that the top part of fuel tank shows certain degree of rust in both diesel and community biodiesel cases, with likely higher amount in the cases with community biodiesel.



(a) (b)

(c)

Figure 55 Visual inspection of top fuel tank (show inner surface) reveals rusty surface in all cases with highest amount in Engine No. 3

Visual inspections of other engine parts, such as injector tip, injector liner, piston, intake/exhaust valves, gear and bearing, do not significantly show wear or sign of damage in the community biodiesel cases compared to diesel case. However, fuel filter needs to be replaced at 300 hrs, sooner than the recommended 400 hrs from the manufacturer. Analysis of engine lube oil shows acceptable trace levels of Aluminum, Iron, Chromium, Copper, Silicon and Lead in all three engines.

In conclusion, the quality of biodiesel according to community level specification has proved acceptable to be used for single-cylinder agricultural engine without significant drop in performance with acceptable fuel consumption and significantly improve in black smoke. However, proper maintenance must be taken, especially on changing fuel filter sooner than the manufacturer’s recommendation and checking for potential rust in the top inner surface of fuel tank.

7. CURRENT STATUS OF BIODIESEL FUEL IN EAST-ASIA AND ASEAN COUNTRIES

7.1 Australia

7.1.1 Policy and Measure of BDF

(1) Target and strategy from energy and environment point of view

Alternative fuels are expected to play a small but important role in supplementing Australia's fuel supply. Currently, biofuels (ethanol and biodiesel) rank as the second most widely available alternative fuel in Australia after Liquefied Petroleum Gas (LPG). In developing the Government's policy for biofuels the Prime Minister requested that the Ministers for Resources, Energy and Tourism and Agriculture, Fisheries and Forestry conduct a review of existing Australian biofuels policies. The review, will assess the current state of play in the Australian and global biofuels industry, examine the existing support mechanisms and outlook for the Australian biofuels industry and will be used to inform future policy decisions. The Government is currently considering the outcomes of this review.

(2) Targets/strategies/regulations/incentives for BDF

The Australian Government does not support the mandating of the use of particular levels of biofuels in the fuel mix. Instead it believes in allowing individual consumers to make a choice regarding the fuel mix which best meets their individual preferences and needs.

The key component of the Government's support for non-fossil fuels is the concessionary excise regime. To encourage their wider uptake alternative fuels, including biodiesel, are effectively excise free until 1 July 2011. From 1 July 2011, effective excise will be phased in progressively until 2015 after which time these alternative fuels will have an ongoing 50 per cent excise discount compared to fuels with the same energy content. This will equate to 19.1 cents per litre for biodiesel (based on current excise of 38.143 cents per litre on diesel).

Energy Grants (Cleaner Fuels) Scheme

The Energy Grants (Cleaner Fuels) Scheme (EGCFS) provides a 38.143cpl subsidy for the production or importation of biodiesel until 30 June 2011. The grant offsets the excise or customs duty payable on biodiesel meaning the net effective excise for biodiesel is zero. From 1 July 2011, the fuel tax rate on biodiesel will progressively increase to 50 per cent of the initial subsidy in 2015.

Biofuels Capital Grants Program

The Biofuels Capital Grants program offered competitive grants from $800,000 to $10 million to fund one-off capital projects that provided new or expanded biofuels production capacity. The grants provided assistance for the construction of new or additional plants at a rate of 16 cents per litre of installed capacity. Four biodiesel plants were initially offered funding under the program. While the program closed in 2004, the Government still has contractual commitments with recipients.

Energy Grants Credit Scheme

Non-fossil fuels used on road in heavy vehicles are eligible for grants under the Energy Grants Credit Scheme (EGCS), subject to certain restrictions. These grants are being phased out between 1 July 2006 and 30 June 2010.

Biofuels mandates

The Australian Government does not support the mandating of the use of particular levels of biofuels in the fuel mix. Instead it believes in allowing individual consumers to make a choice regarding the fuel mix which best meets their individual preferences and needs.

On 6 December 2008, the New South Wales (NSW) Government announced that it would introduce a 2 per cent (B2) biodiesel mandate. It is expected that this mandate will come into effect in January 2010. Based on the current consumption of diesel transport fuel in NSW (4,000ML p.a.) a B2 mandate would equate to 80ML of biodiesel. This is approximately the current amount of biodiesel produced nationally. The NSW Government has indicated an increase to 5 per cent (B5) as supply is available. This would equate to 200ML of biodiesel based on 2009 consumption data. Sustainability criteria are also being included as a requirement and, at this stage, it is expected that they will align with the criteria of the Roundtable on Sustainable Biofuels (RSB).

The Australian biofuels industry

The Australian biofuels (ethanol and biodiesel) industry is, by international standards, a relatively small and immature sector, accounting for just 0.5 per cent of combined petrol and diesel use in Australia. The industry currently uses existing and proven technologies to produce first generation biodiesel. Australia’s biodiesel is mainly produced from processed waste (primarily used cooking oil) and tallow.

Biodiesel and diesel/biodiesel blended fuels can be purchased at only a small percentage of Australia’s retail fuel distribution network outlets and installed supply capacity is not fully used. The production of biodiesel in 2007/08 reached 50ML of biodiesel with predictions for 08/09 to be approximately 80ML. Current capacity is approximately 245ML per annum with 300ML of additional capacity expected in the next couple of years.

(3) Main crops for BDF and its production planning

Australia’s biodiesel is mainly produced from processed waste (primarily used cooking oil) and tallow. Some soy based product has recently been imported.

Table 20 Current status of biodiesel fuel in Australia

Country	Mixing rate	Main Feedstocks	Strategy / Goal	Standard
Australia	Up to 5% in automotive diesel.	Tallow Waste cooking oil Soy (imported)	No Federal mandate. Up to 5% allowed in automotive diesel.	Fuel Standard (Biodiesel) Determination 2003. Fuel Standard (Automotive Diesel) Determination 2001.
	NSW B2 mandate (January 2010)		NSW mandate - B2 in January 2010 and B5 in 2012 – as supply is available.	Biofuels Act 2007 (NSW Government).

7.1.2 Standardization of BDF

Table 21 B100 specifications for blending with diesel (for retail sale)

Items	Units	U.S.	EU	Australia	EAS-ERIA BDF Standard (EEBS):2008
		ASTM D6751-07b	EN14214:2003		
Ester content	mass%	-	96.5 min.	96.5 min.	96.5 min.
Density	kg/m3	-	860-900	860-900	860-900
Viscosity	mm2/s	1.9-6.0	3.50-5.00	3.5 - 5.0	2.00-5.00
Flashpoint	deg. C	93 min.	120 min.	120.0 min.	100 min.
Sulfur content	mass%	0.0015 max.	0.0010 max.	0.0010 max.	0.0010 max.
Distillation, T90	deg. C	360 max.	-	360 max.	-
Carbon residue (100%) or	mass%	0.05 max. -	- 0.30 max.	- 0.30 max.	0.05 max. 0.3 max.
Cetane number		47 min.	51.0 min.	51.0 min.	51.0 min.
Sulfated ash	mass%	0.02 max.	0.02 max.	0.02 max.	0.02 max.
Water content	mg/kg	0.05[vol%] max.	500 max.	.050 [vol%] max.(1	500 max.
Total contamination	mg/kg	-	24 max.	24 max.	24 max.
Copper corrosion		No.3	Class-1	Class-1	Class-1
Acid value	mgKOH/g	0.50 max.	0.50 max.	0.80 max.	0.50 max.
Oxidation stability	hrs.	3 min.	6.0 min.	6 min.	10.0 min. (****)
Iodine value		-	120 max.	-	Reported (***)
Methyl Linolenate	mass%	-	12.0 max.	-	12.0 max.
Polyunsaturated FAME (more than 4 double bonds)	mass%	-	1 max.	-	N.D. (***)
Methanol content	mass%	0.2 max. (*)	0.20 max.	0.20 max.	0.20 max.
Monoglyceride content	mass%	-	0.80 max.	-	0.80 max.
Diglyceride content	mass%	-	0.20 max.	-	0.20 max.
Triglyceride content	mass%	-	0.20 max.	-	0.20 max.
Free glycerol content	mass%	0.020 max.	0.02 max.	0.020 max.	0.02 max.
Total glycerol content	mass%	0.240 max.	0.25 max.	0.250 max.	0.25 max.
Na+K	mg/kg	5 max.	5.0 max.	5 max.	5.0 max.
Ca+Mg	mg/kg	5 max.	5.0 max.	5 max.	5.0 max.
Phosphorous content	mg/kg	10 max.	10.0 max.	10 max.	10.0 max.

(*) Equivalent to diesel fuel
(**) Meet diesel fuel specification
(1) Water and sediment

7.1.3 R&D Trends of Second Generation Biofuels in Australia

The Australian Government has established the $15 million Second Generation Biofuels Research and Development Program (Gen 2). Gen 2 is a competitive grants program that supports the research, development and demonstration of new biofuel technologies which address the sustainable development of the biofuels industry in Australia. Gen 2 will provide matching grants, ranging from $1 million to $5 million, for eligible projects. Applications under the Program closed on 30 January 2009 and are currently being assessed. Successful projects are likely to be announced mid year (2009). Guidelines for the program are available on the Australian Government's Department of Resources, Energy and Tourism website (www.ret.gov.au).

Another Commonwealth initiative, the CSIRO Energy Transformed National Research Flagship, includes a broad research program to address Australia’s biofuels knowledge gaps and moves towards achieving a low emission transport sector are in place. The program is assessing a range of new technologies for producing biofuels and other bio-based products, including the economic and environmental impacts.

Significant government and privately-funded biofuels research is also being conducted in the states and territories. The Western Australian Government is conducting trials on alternative oilseeds for biodiesel production, including Moringa oleifera and Pongamia pinnata and on early maturing canola varieties.

Research in the Northern Territory (NT) includes the identification of bio-fuel crops that are agronomically suitable for the NT and experimentation with a wide variety of crops such as mustard, sesame, sunflower, safflower, Pongamia and African oil palm. The University of Queensland has begun research into the use of the Pongamia in biodiesel production and the Queensland Premier recently announced funding for a project to convert sea algae into biodiesel.

In late 2007, the NSW Government established a biofuels research ‘pipeline’ for the production of alternative vehicle fuel from plant and crop waste at the universities of NSW, Sydney and Macquarie. Research in NSW focuses on sustainable non-food crop feedstocks, such as agricultural and forestry waste and dedicated energy crops. Research is being conducted into the potential for production of biofuels, particularly ethanol, via lignocellulose, from woody plants and applying overseas research to local feedstocks such as eucalypts. In Victoria, research is focusing on alternative feedstocks including algae and grasses. Some research is also underway on plant genetics for improve production.

Research in South Australia centres on the South Australia Research and Development Institute (SARDI) which has two streams of activity: sustainable production of biodiesel from microalgae which includes bio-prospecting native algae strains and evaluation and development of new crops as feedstocks for biodiesel which involves the selection and breeding of varieties tailored to biodiesel production.

7.2 China

7.2.1 Policy and Measure of BDF

(1) Target and strategy from energy and environment point of view

At the end of 2008, the population of vehicle in China is about 64.67 million, and the private vehicle is about 41.73 million, commercial vehicle is about 11.25 million. In the recent years, the vehicle increase in China is more than 15%.

As a result, the vehicle fuel is becoming more and more relying on abroad market although more than 94% of the Chinese energy consumption is from domestic. In 2008, the petroleum import in China is about 200 million tons, which is nearly 52% of the petroleum consumption in China. This status gives both the Chinese economic and energy safety a huge challenge.

On the other hand, the air environment in the middle and large cities is facing more and more heavy burden, especially the emission given by vehicle. Although the vehicle emission standards are becoming more and more strictly, majority of the air pollutions in big city, such as CO, HC, NOx, are still from vehicle emission.

According DOE of China, the Strategy of New Energy Development has begun to plan since April 2009, which will focus in two directions: the first is mainly on accelerating the development of wind energy, solar energy and bio energy, the other is clean using the traditional fossil energy such as coal based energy, new fuel for vehicle and intelligent power system.

According "Development Strategy of Renewable Energy in China" of NDRC, the new capacity of renewable power and the related investment in China are:

(1) the hydro power will be 190 million kW, investment is about 1.3 trillion RMB;
(2) the wind power will be 100 million kW, investment is about 0.9 billion RMB;
(3) the solar energy will be 1.73million kW, investment is 130 billion RMB;
(4) the solar water heater 200 million m2, investment is about 400 billion RMB;
(5) the bio energy power is 28 million kW, investment is about 200 billion RMB.

As a result, the evaluated total investment is about 3 trillion RMB.

For the influence of the economic crisis since 2008, the new energy strategy and investigation will be adjusted, which means both total adding new capacity of power output and investment will be increased, for example, the wind energy may be adjusted to 1 billion kW, the solar power may be adjusted to 10 million kW, and the total investigation before 2020 may be very huge.

(2) Concrete target and strategy for BDF

China has determined its principles of developing non-food biomass liquid fuels, that is, it should not deprive people of food, should not deprive food of land, and should not deprive cattle of feed.

As a result, the target of BDF is keeping adjusted. According "Development Strategy of Renewable Energy in China" (Issued on Sep.05, 2007), the target of bio fuel is 10 million tons, in which BDF is 2 million tons till 2020.

At the end of 2007, the total BDF production in China is about 300 thousand tons, but at the end of 2008, the total BDF production is even less than 300 thousand tons for the price increase of stock, that means the BDF market is suffering from atrophy.

Waste oil is a very important source in China. It is statistics that the total waste oil in China is 5 million tons, but it faces the problems of collection cost and hard to mass production.

(3) Main crops for BDF and its production planning

Many provinces have their own ambitious plan of plant cultivation for BDF several years before (especially 2005~2007). But two factors affect seriously the enthusiasm of the investors: one is the too high oil price, which influences the stock cost and results in almost no profit for BDF companies; the other is the global economic crisis, which influences the investment. Since the second half year of 2008, the BDF encountered harsh situation in China.

It is statistics that there will have about 25 million Mus (1Chinese Mu equals 0.0667 hectare) Jatropha plant potential in the three provinces including Yunnan, Sichuan and Guizhou within the next 10 years, and the total potential BDF cultivation area will be more than 0.1 billion Mus in China before 2020. But how to turn the potential to reality is still a huge challenge.

In China, many crops are trying to be planted recently years including:

Jatropha

Jatropha is the most important potential oil-bearing crop planted in south part of China. Thousands hectares of Jatropha has been planned to cultivate in Sichuan, Hainan, Guizhou and Yunnan province during the past few years, and millions hectares area are planned to planted within the next decade years.

The most important domestic energy companies and food & edible oil company have already involved in Jatropha cultivation, including the three biggest petroleum companies CNPC, PetroChina and CNOOC, as well as the biggest edible oil & food company COFCO.

Many foreign companies also have great interesting in investment in Jatropha cultivation in China, but till now, the mass production of Jatropha based biodiesel in China is still a dream.

Chinese pistache

Chinese pistache is another important woody oil plant in China besides Jatropha, which is mostly planted in Central and North China, such as in Hebei province, Henan province, Shanxi province and Shannxi province.

In Handan city Hebei province, the resource of Chinese pistache ranked No.1 in China. There is about 200 thousand Mu wild Chinese pistache and 100 thousand Mu artificial Chinese pistache, some BDF factories have been set up.

In Hebei province, about 110 thousand Mu Chinese pistache has been planted by Hainan Zhenghe Company in order to obtain BDF stock..

The largest area distribution of wild Chinese pistache is in Shannxi province, which is statistic to be more than 4 million Mu.

Acidification oil

The ordinary vegetable oil in china includes rapeseed, soybean, peanut, cotton seed and others, which composes the edible oil in China.

For a shortage of edible oil, no such oil is permitted to produce BDF by the government. As a result, the residual material named soapstock, is first changed to acidification oil and then to BDF, which is widely used in the small scale BDF companies in China

Oil alga

Oil algal is the largest potential resource for BDF, and the technology of gene breeding of oil alga is now being focused in China

7.2.2 Standardization of BDF

The non-compulsory standard for FAME blended diesel fuel, GB/T20828-2007, was issued in May 2007. This standard is for the quality control of Diesel fuel BD-100. The Chinese biodiesel standard is based on ASTM D6751-03a “Standard Specification for Biodiesel Fuel (B100) Blend Stock for Distillate Fuels”. GB/T20828-2007 has specified 17 items on biodiesel fuel (B100) blend stock for distillate fuels, as shown in Table 22.

Table 22 B100 specifications in China

Biodiesel properites	GB/T 20828-2007	Test-method
Density at 20 ^{O}C., kg/m^3	820-900	GB/T2540
Cetane Number, min	49	GB/T386
Flash point, deg C., min	130	GB/T261
CFPP, deg C., max	Report	SH/T0246
Sulfur, % , max	0.05 0.005	SH/T0689
10%, wt%, max	0.3	GB/T17144
Ash, wt %, max	0.020	GB/T2433
Water, vol%, max	0.05	SH/T0246
sediment	None	GB/T511
Copper corrosion (3hr at 50deg C.), max	1	GB/T5096
Oxidation stability at 110deg C., hr, min	6	EN14112
Acid value, mg KOH/g, max	0.8	GB/T 264
Viscosity at 40deg C., cSt, min-max	1.9-6.0	GB/T 265
Free glycerides, wt%, max	0.02	ASTM D 6584
Total glycerin, wt%, max	0.24	ASTM D 6584
Distillation T90, deg C., max	360	GB/T6536

The draft standard of B5 standard has been in state for examination in April 2009, the formal standard will be issued this year.

7.3 Indonesia

7.3.1 Policy and Measure of BDF

(1) Target and strategy from energy and environment point of view

Energy consumption in Indonesia increases rapidly in line with economic and population growth. Currently, Indonesia is still very much dependent on fossil fuel for its energy source and the non fossil alternative renewable energy has not been utilized optimally. Data of fossil energy reserves from Department of Energy and Mineral Resources shows that the proven reserve of oil is about 9 billion barrels and with an average production rate of 500 million barrels per year, the reserve will be exhausted in 18 years. The data also shows that around 63% of the Indonesian's final energy demand is still depend on oil. On the other hand, the national oil production facilities are limited and the capacity decreasing gradually. Therefore, to satisfy domestic energy consumption, Indonesia has to import crude oil and finished petroleum products, such as gasoline and diesel fuel. Indonesia becomes very dependent on overseas oil supply to fulfill the increasing demand. This situation may worsen the security of fuel supply.

The increase of the international crude oil and fuel price has become a burden to the state budget, due to the subsidizing policy of fuel products. When the crude oil price stays at around US$125 per barrel, Indonesia has to provide around 240 trillion Rupiah just for fuel subsidy. This will result in reduced government capacity to finance development programs in needed sectors such as health, education, basic human services, and infrastructures either in rural or in urban areas. It means that the government has very limited resources to stimulate and maintain productivity and economic growth.

In addition, air quality of major cities in Indonesia has been deteriorating especially in the city of Jakarta. Ambient air quality monitoring results suggest that NOx, CO and THC are a serious problem in almost all areas of Jakarta. PM10 may be considered as a problem in certain areas and motor vehicles are a major contributor of NOx, PM10, CO and THC emission (more than 70% of each parameter). To reduce the high dependency on oil and to meet the global environment requirement, there is no choice that the maximum utilization of environmental friendly alternative fuel should be developed. One alternative is converting plant oil to methyl esters or famously called biodiesel.

(2) Targets/strategies/regulations/incentives for BDF

The business of biodiesel in Indonesia is expected to grow as the government intends to boost the biofuel program since the new issuance of National Energy Policy in 2006 [37], [38]. The policy has stated that biofuels are parts of renewable energy sources besides other types of sources such as geothermal, biomass, biogas, wind, river flow, etc. The targets in this policy include the role of each renewable energy source in the energy consumption for optimum primary energy mix. In the latter, the role of biofuels is set for more than 5% in the national energy consumption by the year 2025. This policy has been reinforced by the issuance of President Instruction No. 1/2006 concerning the regulation of biodiesel utilization, National Biodiesel Standard SNI 04-7182-2006 and Decree of the Oil and Gas Directorate General on Biodiesel Blending regulation that allows maximum blending of 10%.

Decree of the Minister of Energy and Mineral Resources No. 32/2008 on mandatory utilization of biofuel has just been issued on September 2008. This policy regulates, among others, the targets schedule of biofuel mandatory utilization, as shown in Table 23.

Table 23 Biodiesel (B100) mandatory utilization mandatory phases in Indonesia

Sector	Oct.-Dec. 2008	January 2009	January 2010	January 2015	January 2020	January 2025	Remark
Household	-	-	-	-	-	-	Non mandatory
Transportation PSO	1% (existing)	1%	2.5%	5%	10%	20%	From total demand
Transportation Non PSO	-	1%	3%	7%	10%	20%	
Industry and commercial	2.5%	2.5%	5%	10%	15%	20%	From total demand
Power Plant	0.1%	0.25%	1%	10%	15%	20%	From total demand

Although the biodiesel development in Indonesia has been started since ten years ago, but it has just gained significant milestone in 2006, when PERTAMINA as a state-owned company dealing with business in oil & gas, LNG, energy and petrochemical industries, started to sell a blend of 95% diesel fuel and 5% SNI standard biodiesel (B5) with the trade name of BIOSOLAR on 20 May 2006. To date, PERTAMINA has been selling a BIOSOLAR at several hundred fuel outlets in Java and Bali Island. In line with the policy of biofuel mandatory utilization and the continuously growing domestic biodiesel producer, PERTAMINA plans to open the BIOSOLAR's fuel outlets in all parts of Indonesia and increase the biodiesel blending content at least up to B20 in 2025.

The most significant hurdle for broader commercialization of biodiesel in Indonesia is its cost. Thus acceptance of biodiesel in Indonesia is more influenced by pricing factor. The advantages of biodiesel such as a renewable energy, lower exhaust gas emission and favorable effect on engine life time are often ignored. As a resolution to this pricing problem, the government has issued Presidential Regulation No. 45/2009 on the alteration of President Regulation No. 71/2005 concerning the supply and distribution of "certain fuels". Through this new regulation, the status of biodiesel, which is previously classified as "other fuel" and thus receive no subsidy from the government, is now classified as "certain fuel" that could be subsidized by the government.

(3) Main crops for BDF and its production planning

The option of using biodiesel as alternative fuel is based on the availability of raw material. If rapeseed oil is the raw material for biodiesel in Germany and soybean for the United States, crude palm oil (CPO) is the logical option for Indonesia, due to its large production volume and thus ready availability in the country. Concerns on food versus fuel competition have driven researchers to seek and identify alternative, and preferably non-edible, fatty oil resources. Table 24 shows some potential vegetable oil plants found in Indonesia. As also the case in many other countries, Jatropha curcas is the non edible oil plant that has received most attention of government as well as other stakeholders.

Table 24 Potential vegetable oil plants in Indonesia

Name	Latin name	Oil Source	Oil, %-w dry	E / NE
Jarak pagar	*Jatropha curcas*	Kernel	40 – 60	NE
Sawit	*Elais guineensis*	Pulp + kernel	45-70 + 46-54	E
Kapok/randu	*Ceiba pentandra*	Kernel	24 – 40	NE
Kelapa	*Cocos nucifera*	Kernel	60 – 70	E
Kecipir	*Psophocarpus tetrag.*	Seed	15 – 20	E
Kelor	*Moringa oleifera*	Seed	30 – 49	E
Kusambi	*Sleichera trijuga*	Kernel	55 – 70	NE
Nimba	*Azadirachta indica*	Kernel	40 – 50	NE
Saga utan	*Adenanthera pavonina*	Kernel	14 – 28	E
Akar kepayang	*Hodgsonia macrocarpa*	Seed	≈ 65	E
Gatep pait	*Samadera indica*	Seed	≈ 35	NE
Kepoh	*Sterculia foetida*	Kernel	45 – 55	NE
Ketiau	*Madhuca mottleyana*	Kernel	50 – 57	E
Nyamplung	*Callophyllum inophyllum*	Kernel	40 – 73	NE
Randu alas	*Bombax malabaricum*	Seed	18 – 26	NE
Seminai	*Madhuca utilis*	Kernel	50 – 57	E
Siur (-siur)	*Xanthophyllum lanceatum*	Seed	35 – 40	E
Tengkawang. Terindak	*Isoptera borneensis*	Kernel	45 – 70	E
Bidaro	*Ximenia Americana*	Kernel	49 – 61	NE
Bintaro	*Cerbera manghas/odollam*	Seed	43 – 64	NE
Bulangan	*Gmelina asiatica*	Seed	?	NE
Cerakin/Kroton	*Croton tiglium*	Kernel	50 – 60	NE
Kampis	*Hernandia peltata*	Seed	?	NE
Kemiri cina	*Aleurites trisperma*	Kernel	?	NE
Nagasari (gede)	*Mesua ferrea*	Seed	35 – 50	NE
Sirsak	*Annona muricata*	Kernel	20 – 30	NE
Srikaya	*Annona squamosa*	Seed	15 – 20	NE

Note :
E ≡ Edible fat/oil, NE ≡ Non-Edible fat/oil

(Source: Soerawidjaja, T. H. 2003)

Commercialization of biodiesel in this country has gained significant milestone in 2006, when the Indonesian government issued blending permit regulation of up to 10% biodiesel with mineral diesel fuel. Following the issuance of this regulation, Pertamina started selling B5 at several fuel dispensing stations on 20 May 2006. Since then, the number of fuel dispensing stations selling B5 is continually increasing.

As shown on Table 25, the installed capacity of biodiesel plant in Indonesia has reached considerable size of around 3.07 million ton in 2009 [39]. The plant with capacity less than 5.000 tons/year has been fully designed and constructed by local institution and industries, whereas large scale commercial plants apply technologies of international licensors.

Table 25 Existing installed capacity (status up to Dec 2009)

No	Company/Institution Name	Location	Capacity (Ton/Year)
		Total	**3,069,440**
1.	PT. Energi Alternatif Indonesia	North Jakarta	7,000
2.	PT. Indo biofuels Energi	Merak, Banten	60,000
3.	PT. Anugrah Inti Gemanusa	Gresik, East Java	40,000
4.	PT. Eterindo Nusa Graha	Gresik, East Java	40,000
5.	PT. Eternal Buana Chemical Industries	Cikupa, Tangerang, Banten	40,000
6.	PT. Wilmar Bio Energi Indonesia	Dumai, Riau	1,050,000
7.	PT. Sumi Asih Oleo-Chemical	Bekasi, West Java	100,000
8.	PT. Darmex Biofuels	Bekasi, West Java	150,000
9.	PT. Pelita Agung Agri Industri	Bengkalis, Riau	200,000
10.	PT. Primanusa Palma Energi	North Jakarta	24,000
11.	PT. Sintong Abadi	Asahan, Sumut	35,000
12.	PT. Musim Mas	Batam	350,000
		Deli Serdang, North Sumatera	70,000
13.	PT. Multi Kimia Intipelangi	Bekasi, West Java	14,000
14.	PT. Cemerlang Energi Perkasa	Dumai, Riau	400,000
15.	PT. Petro Andalan Nusantara	Dumai, Riau	150,000
16.	PT. Bioenergi Pratama Jaya	Kutai Timur, East Kalimantan	6,000
		Berau, East Kalimantan	60,000
17.	PT. Wahana Abadi Tritatehnika Sejati	Cileungsi, West Java	132,200
18.	PT. Damai Sejahtera Sentosa Cooking	Surabaya, East Java	120,000
19.	PT. Alia Mada Perkasa	Tangerang, Banten	11,000
20.	PT. Pasadena Biofuels Mandiri	Cikarang, West Java	10,240

Source: Indonesian Biofuel Producers Association (APROBI).

7.3.2 Standardization of BDF

Commercial utilization of biodiesel especially as one alternative of automotive diesel fuels requires certain quality standard. To protect both biodiesel consumers and producers as well as to support the development of biodiesel industries, the biodiesel standard – so called SNI 04-7182-2006 has been approved by the National Standardization Agency (BSN) through a decree No. 73/KEP/BSN/2006 on 22 February 2006. The biodiesel standard has been formulated by technical committee of new and renewable energy in order to assure that the norm is accommodative to the interest of all parties involved in biodiesel issues. The member of committee consist of all related biodiesel stakeholder include of the government institution, private institutions and academicians. The committee has performed a series of discussion, procedural processes and finalized in the Consensus Forum XXIV on 6-7 December 2005 in Jakarta.

The content of SNI 04-7182-2006 has partially adopted the existing European and US standard (ASTM D6751 and EN 14214:2002) and other values were set based on several considerations including:

- The plant oil resources in Indonesia have wider range of carbon components compared to the plant oils from European and US. For example, coconut oil has a range of fatty carbon chains of C8 to C18.
- Some of Indonesian plant oil resources have unique fatty acids that their existence in a biodiesel fuel may have negative effect in the diesel engine.
- As biodiesel plants may be located dispersedly and operated by medium and large enterprises, all level of enterprises should be able to afford the testing methods. Hence such methods should be designed for the local condition without disregarding the quality assurance. The detail SNI 04-7182-2006 is shown in Table 26.

On 17 March 2006, the Oil and Gas Directorate General of Department on Energy and Mineral Resources has been issued the decree No. 3675K/24/DJM/2006 regarding the quality and specification of diesel oil type Solar 48 and Solar 51. This decree regulates the use of FAME (fatty acid methyl ester) up to the maximum of 10 percent of the volume of automotive diesel fuel with which it is to be blended. The biodiesel to be mixed has to meet the biodiesel standard SNI 04-7182-2006.

Table 26 Characteristic comparisons of Fossil Diesel Fuel (FDF) and Biodiesel

No	Parameter	Unit	FDF[1]	Biodiesel[2]
1	Density	kg/m^3	820 - 870 (15°C)	850 – 890 (40°C)
2	Kinematic viscosity (40 °C)	Mm^2/s (cSt)	1.6 – 5.8	2.3 – 6.0
3	Cetane number		min. 45	min. 51
4	Flash point	°C	min. 60	min. 100
5	Cloud point	°C		max. 18
6	Pour point	°C	Max. 18	
7	Copper strip corrosion	Rating (3 hours at 50°C)	max. no 1	max. no 3
8	Carbon residue - in undistilled sample, or - in 10 % distillation residue	 % (m/m) % (m/m)	 - max. 0.1	 max 0.05 max 0.30
9	Water and sediment	%-vol.	max. 0.05*	max 0.05*
10	90% (v/v) recovered at distillation temperature	°C	-	max. 360
11	95% (v/v) recovered at distillation temperature	°C	max. 370	-
12	Ash content (sulfated ash)	% (m/m)	max.0.01	max.0.02
13	Sulfur content	ppm-m (mg/kg)	max. 5000	max. 100
14	Phosphorous content	ppm-m (mg/kg)	-	max. 10
15	Acid number	mg-KOH/g	max.0.6	max.0.8
16	Free glycerol	% (m/m)	-	max. 0.02
17	Total glycerol	% (m/m)	-	max. 0.24
18	Ester content	% (m/m)	-	min. 96.5
19	Iodine number	% (m/m) (g-I2/100g)	-	max. 115
20	Halphen test		-	Negative

Note : can be separately tested as long as sediment content maximum 0.01 %-vol

1. Automotive Diesel Oil, www.pertamina.com (accessed 19 June 2006)
2. SNI Biodiesel No. 04-7182-2006, based on ASTM D 6751 & EN 14214.

7.4 Japan

7.4.1 BDF Policy and Measures

(1) Target and strategy from energy and environment point of view

The Japanese government has committed to the ***Kyoto Protocol***, meaning that in 2010 the amount of green house gas emissions shall be reduced by six percent from the 1990 level. To comply with its own plan to meet the Kyoto Protocol, it has a target to introduce 500,000 kl-crude oil equivalent of biofuels (including bio-ethanol) by 2010. The ***Ministry of the Environment (MOE)*** planed the introduction target of biofuels for the transport sector, based the Kyoto protocol, as shown in Table 27.

Table 27 Biofuel introduction targets for the transport sector

Targets	2010	2020	2030
Quantity of biofuels	500,000 kL (Crude oil equivalent)	about 2,000,000 kL (Crude oil equivalent)	about 4,000,000 kL (Crude oil equivalent)
Ratio of biofuels to total fuels	about 0.6 %	about 3%	About 10 %
Consumption restraint	The status quo (about 86,000,000 kL)	Reduction of about 20%	Reduction of about 50%

The introduction of 500,000 kl-crude oil equivalent of biofuels in 2010 is crucial to meet the commitment, as this measure alone could contribute to a one percent reduction in greenhouse gases, out of a total target of six percent.

In the ***New National Energy Strategy*** issued by ***Ministry of Economy, Trade and Industry (METI)*** in May 2006, the ministry raised the target for the reduction of crude oil dependence in the country's transportation sector to about 80% in 2030, compared to 100% at present, with the aim to reduce both carbon dioxide emissions and its huge dependence on fossil fuels.

Electric vehicles and hydrogen-fuel cell vehicles and intelligent transportation system could be promising mid- and long-term measures to reduce carbon dioxide emissions and the dependence on fossil fuels.

Those next generation vehicles are, however, still in their research and development stage. On the other hand, biofuels are liquid, can be used in existing vehicles and have an immediate effect on carbon dioxide emission reduction and fossil fuel dependence. Hence biofuels are useful.

Ethanol, ETBE (ethyl tertiary butyl ether) and fatty acid methyl esters (FAME) are under consideration as biofuels. The ***Petroleum Association of Japan (PAJ),*** a Japanese oil industry body has committed to introduce 210,000 kl-crude oil equivalent of ETBE into gasoline. Regarding the remaining 290,000 kl-crude oil equivalent, discussions are still ongoing.

To promote biomass energy and materials, "***Nippon Biomass Comprehensive Strategy***" was established in 2002 by the Prime Minister's cabinet, which was composed of several ministries, including major stakeholders ***MOE***, ***METI***, the ***Ministry of Agriculture, Fishery and Forest (MAFF)***.

The ***MAFF*** promotes the "***Biomass Town Concept***" with cities, towns and villages playing a central role in an overall plan for using regional biomass, as shown in Figure 56. As of March 31, 2007, 90 cities, town and villages have announced this concept. In these biomass towns, resources from cattle excrement or food waste, etc. are converted into energy at biomass conversion facilities such as power generation facilities or composting facilities to ensure that biomass is effectively used inside and outside the regions.

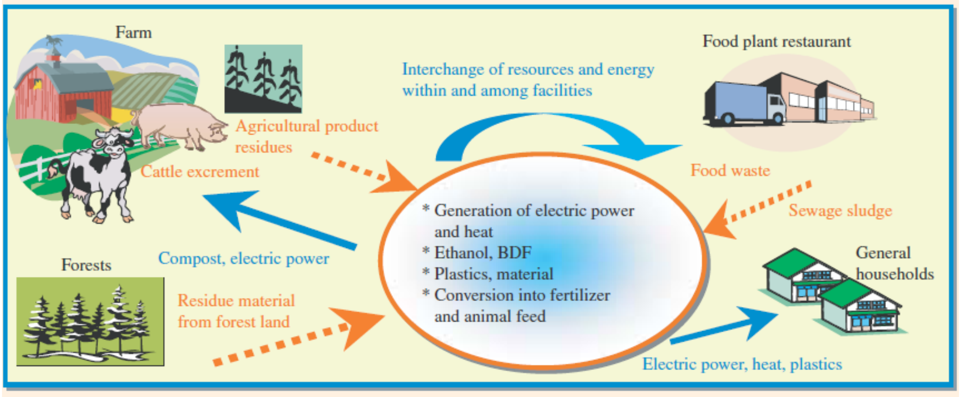


Figure 56 Biomass Town Concept in Japan

METI has established the ***Law on the Quality Control of Gasoline and Other Fuels*** (known also as the Quality Assurance Law). The Quality Assurance Law has been amended to allow up to 5 % by mass of FAME in diesel fuels, and to prevent the use of unprocessed vegetable oils. The requirements took effect in March of 2007. The diesel fuel properties specified in this law control sulfur, cetane index, T90 distillation temperature and upper limits of FAME and triglyceride content. For biodiesel fuel, additional requirements include limits for methanol, total acid number (TAN), low molecular weight acids and oxidation stability as acid growth measures. Both diesel fuel and biodiesel/diesel blends have limits on FAME and triglycerides to clearly distinguish between the two and to prevent the use of unprocessed triglycerides.

In this concept, biodiesel fuel is used in public vehicles, such as garbage trucks and city buses, as the fuel of choice for the concept of locally sourced – locally consumed.

In May 2007, the minister of ***METI***, the president of the ***Japan Automobile Manufacturers Association, Inc. (JAMA)*** and the president of ***PAJ*** published a plan for the future entitled "***Next-Generation Automobiles Initiative***", with reference to biofuels in "Worry-Free, Safe and Fair Expansion" and "Second-Generation Biofuels", as shown in Figure 57.

Outline--To Realize Innovations of Engines, Fuels and Infrastructures with Five Strategies

Innovation of Engines

Strategy 1: Battery--Battery Project for Next-Generation Automobiles

- ○ Next-generation battery technology development project [FY2007: 4.9 billion yen x 5 years]
- ○ Construction of charging stations and establishment of effective programs to secure safety, etc.
- ○ Aiming at wider use of compact EV in 2010, plug-in EV in 2015 and full-scale diffusion of EV in 2030.

Strategy 2: Hydrogen/Fuel Cells--Development of Fuel Cells and Establishment of Infrastructures

- ○ Fuel cell research and development project [FY2007: 32 billion yen. The research and development is slated to be continued at the same amount]
- ○ Hydrogen/fuel cell demonstration project (to conduct demonstration tests in consideration of establishment of hydrogen infrastructures in the future)
- ○ Aiming at reducing prices as low as that of gasoline-powered vehicles by 2030

Innovation of Fuels

Strategy 3: Clean Diesel--Refurbished Image of Fuel-Efficient and Clean Engine

- ○ Setting up the clean diesel promotion council
  (The industrial, academic and government sectors cooperate with each other in studying measures to improve the image of diesel engines and incentives to encourage the introduction of diesel engines)
- ○ Research and development of gas oil-based new fuels (GTL [FY2007: 6.9 billion yen or 24 billion yen for five years], hydrogenated bio light oil], bio hydrofined diesel, etc.)
- ○ Aiming at full-scale introduction of clean diesel passenger cars in the Japanese market in and after 2009 where the emission control is most rigorous in the world.

Strategy 4: Biofuels--"Worry-Free, Safe and Fair" Expansion and the Second-Generation Bio

- ○ **Setting up the bio fuel technology innovation council**
  (The industrial, academic and government sectors cooperate with each other to accelerate the development of next-generation biotechnology)
- ○ **Establishment of systems and infrastructures to secure quality and prevent tax evasion (the next ordinary Diet session)**
- ○ **Aiming at the advent of next-generation domestic bio fuel of 100 yen per liter in 2015 (Biomass Nippon)**
  Then, further aiming at bio fuel of 40 yen per liter (technology innovation case)

Innovation of Infrastructures

Strategy 5: World's Most Friendly Automobile Society Initiative
Creation of the World's Most Friendly Automobile Society, Capitalizing on IT

- ○ Technology development project associated with the next-generation automobile society [aiming at commencement of new project in FY2008]
  (Technology development such as automatic operation, IT technology development, next-generation traffic control software, etc.)
- ○ Creation of industry-university-government review program and consideration of specific measures for demonstration project [from FY2007]
- ○ Aiming at the speed twice as fast as the average traveling speed in urban areas by 2030 (18 kilometers per hour in Tokyo and 26 kilometers per hour in Paris at present)

Figure 57 Outline of Next-Generation Automobiles and Fuels

(2) Main Crops for Biodiesel Fuels: Production Planning

Japanese biodiesel is mainly produced from waste cooking oil, in current community usage. In some cases rapeseed (canola) is also used. However, there is no mandate to blend biodiesel into diesel fuel.

Table 28 Current status of biodiesel fuel in Japan

Country	Mixing rate	Main Feedstocks	Strategy / Goal	Standard
Japan	Up to 5% in diesel fuel (no mandate)	Waste cooking oil	No national mandate. Up to 5% allowed in automotive diesel. The reduction of crude oil dependence in the country's transportation sector to ca. 80% in 2030	Compulsory Diesel Fuel Standard (FAME Blended Diesel Fuel) JIS K2390:2008 (Blend-stock for B5)

7.4.2 Standardization of BDF

(1) Outline of Fuel Regulations in Japan

Fuel quality has a significant impact on vehicle lifetime and performance, thus it is very important to control the quality of fuels at the pump from the viewpoint of safety, environment and customer protection. If substandard fuels are distributed and used in vehicles, serious trouble may happen. Figure 58 shows an example of an actual incident cased by inadequate fuel. High alcohol content fuel corrodes metals in fuel system components. In the case at hand, fuel leakage occurred, leading to a fire.

Figure 58 Example of Consumer Incident caused by Fuel Quality

In Japan, the Ministry of Economy Trade and Industry (METI) is responsible for fuel quality in the consumer market. In accordance with the Japan fuel standards law, METI is obligated to:

- Monitor registration of gas stations: Gas stations are required to register with METI
- Develop fuel quality standards (mandatory and voluntary)
- Requiring gas stations to report quality check of gasoline once every 10 days, or annually if its supply chain is approved by METI
- Fuel quality monitoring at pump, which can be outsourced to four registered testing organizations

Table 29 shows current fuel quality standards in Japan. An asterisk (*) in the table indicates mandatory items, because these properties directly relate to issues of safety and the environment. There are about 50,000 filling stations in Japan. METI gathers about 200,000 fuel samples/year and investigates their quality. If METI finds any off-spec fuels, METI instructs fuel suppliers to follow fuel regulations. If they do not follow through, METI orders suspension of business up to 6 months and in some case, fuel distributors will be assessed criminal penalties. If FAME bended diesel fuel is made commercially available in Japan, the raw fuel has to be modified so that it is fully compatible with the FAME components in the blend.

Table 29 Quality standard items for Gasoline and Diesel Fuel

Items	Level	
Lead	No detection	*
Sulfur	< 10 ppm	*
MTBE	< 7 vol%	*
Oxygen Content	< 1.3 wt%	*
Benzene	< 1 vol%	*
Kerosene	< 4 vol%	*
Methanol	No detection	*
Ethanol	< 3 vol%	*
Existent Gum	< 5 mg/100mL	*
Color	Orange	*
Octane	Regular > 89	
	Premium > 96	
Density	< 0.786 g/cm3	
Distillation Temp.	(specified)	
Copper Corrosion	< 1 max	
RVP	44 - 65 kPa (Summer)	
Oxidation Stability	> 240 min	

Items	Level	
Sulfur	< 10 ppm	*
Cetane Index	> 45	*
90% distillation temp.	< 360 deg.C	*
Flash Point	> 45 deg.C	
Pour Point	Depend on region and month	
CFPP		
10% Carbon Residue	< 0.1%	
Kinematic Viscosity	> 1.7 mm2/s	

Note: * = mandatory

(2) Developing Biodiesel Fuel Standards in Japan

Currently biodiesel fuel has not been introduced commercially in Japan. However bio fuels like bioethanol and biodiesel fuel have been under discussion for reducing CO_2 from the transportation sector. In order to use biofuels for vehicles, developing adequate specifications is essential. METI organized its Fuel Policy Sub-committee which is a type of advisory committee, to discuss biodiesel fuel specifications. There are many kinds of biodiesel fuels in existence, such as crude vegetable oil, refined vegetable oil, FAME (Fatty Acid Methyl Ester), hydrogenated vegetable oil and BTL (biomass to liquid). First, it was agreed to select FAME as a biodiesel fuel to develop standards for because it was used as a fuel for fleet use in some local governments, and was expected to be used more widely in Japan.

The characteristics of FAME are quite different from fossil based diesel fuels. As shown in Figure 59, the characteristics of FAME depend on raw material feedstock. For example, SME (Soy Methyl Ester) has a tendency to easily oxidize. FAME from fish oils easily produces sludge. PME (Palm Methyl Ester) and TME (Tallow Methyl Ester) easily form wax. The specific refining process also influences the quality of FAME. If the washing process is insufficient, some impurities like methanol, glycerin and so on remain in the FAME.

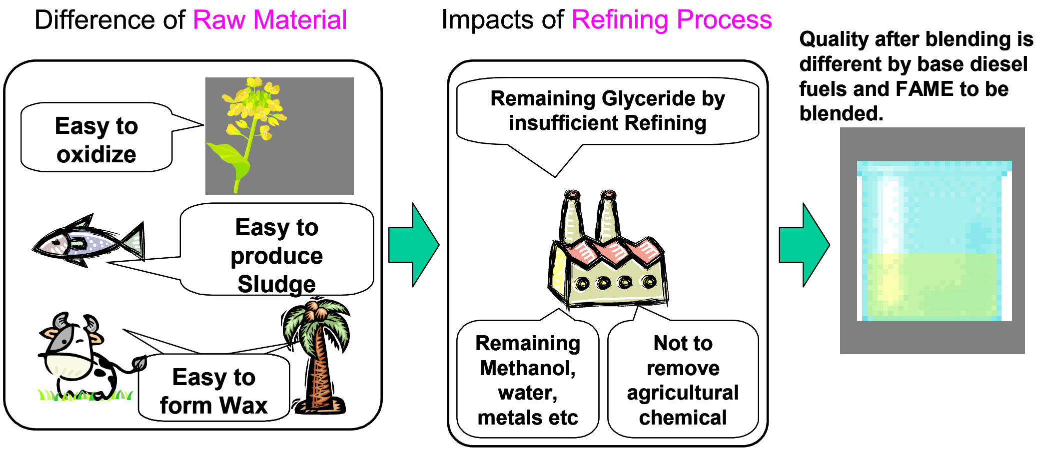


Figure 59 Influence of Raw Materials and Refining Process on FAME Characteristics

The preceding characteristics all closely relate to vehicle performance, as shown in Figure 60. If the quality of FAME is not controlled properly, serious trouble and/or fatal damage to vehicles may be expected.

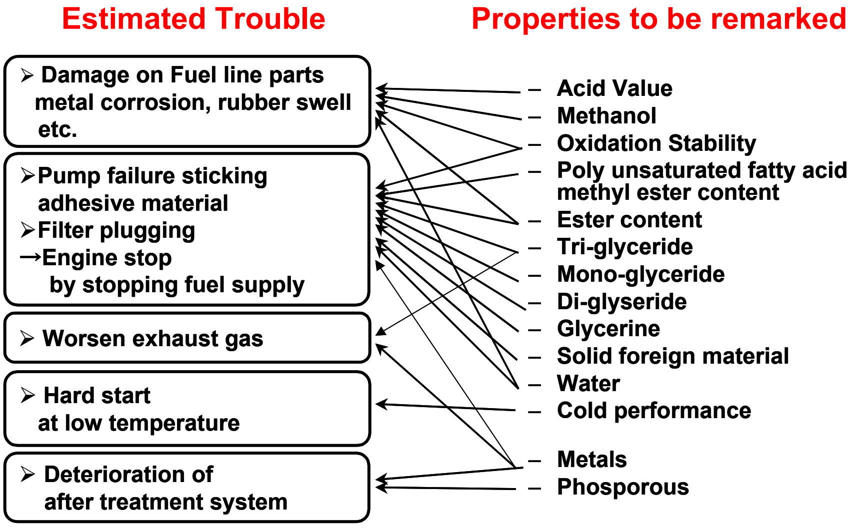


Figure 60 Important FAME Properties and their Expected impact on Vehicle Condition and Operation

For developing biodiesel fuel specifications, METI has conducted a series of FAME conformity tests to build out a technical knowledge base about FAME. In order to shorten the specification development period, the European FAME specification EN14214 was selected as a starting point. Even though starting from EN14214, more than two years and about four hundred million yen were spent refining the specifications.

Table 30 presents a summary of conformity tests in which FAME that completely meets EN14214 was prepared and blended into Japanese JIS No. 2 diesel fuel at a rate of 5 % by volume, and was then used for each test. One problem related to FAME properties is corrosion, which was observed in the fuel tank tests and metal dip tests, even though the test FAME used in the conformity tests met European requirements.

Table 30 Summary of METI Conformity Test Results

Test Items	Results	Summary
Material Compatibility **Metals**	**Fail**	**Corrosion in Tern Sheet**
Rubber & Plastics	Pass	No effects of Ester as far as less than 5v%
Cold Performance	—	Poor Startability
Long Storage Test	Pass	Slight Degradation
Fuel Line Parts Test Fuel Filter Test	Pass	Same as diesel fuel with B5
Fuel Tank Test	**Fail**	**Corrosion and melting plating in lead-tin alloy coated and electrolytic zinc-coated steel sheets**
Fuel Pipe Test	Pass	Same as diesel fuel with B5
Fuel Hose Test	Pass	Same as diesel fuel with B5
FIE Durability Test	Fail	Wear in Injectors with B5
Engine Durability Test LD, ID&DI	Pass	Observation of no trouble with B5
HD, DI	Fail	Flow loss and Wear in Injectors with B5
Vehicle Durability Test (LDV, IDI)	Pass	Observation of no trouble with B5
Emission Test	Pass	Little Impact with up to 10v%

Note) Test FAME consists of PME:RME:SME=60:38:2 and is blended in commercial diesel fuel by 5%.
Test FAME completely met EN14214.

Furthermore, Figure 16(top) shows an example of corrosion observed in the fuel tank tests. The cause of corrosion was a lack of oxidation stability. The FAME blended diesel fuel oxidized during the test period and produced corrosive acids. No other problems related to FAME were observed. These results suggested that using only the oxidation stability requirement in EN14214 would not ensure long-term performance in vehicles. Next, effects of improving FAME blended diesel fuel oxidation stability were investigated. Oxidation stability is easily improved with anti-oxidant agents, as shown in Figure 61. The test FAME oxidation stability was improved to 10 Hrs (Rancimat method) using additive technology and then blended into JIS No. 2 diesel fuel at the same 5% rate. Figure 16(bottom) shows a photograph of the inner fuel tank after concluding the test. No corrosion was observed and the effectiveness of improving oxidation stability was confirmed. Based on conformity tests such as these, Japanese biodiesel fuel specifications were developed.

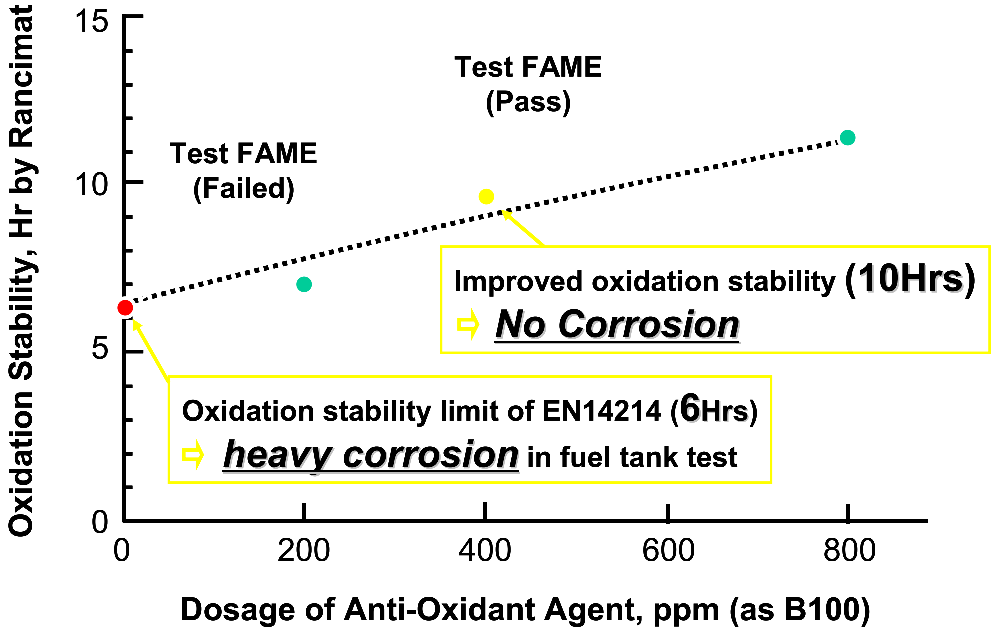


Figure 61 Effect of Anti-Oxidant Agent on Oxidation Stability

(3) Japanese B5 diesel fuel specification

In Japan, the quality of FAME blended diesel fuel is regulated by compulsory standards under the fuel quality control laws. The standard of neat FAME (B100) for use as blending stock is not included the compulsory standards, but rather as a voluntary specification.

Figure 62 shows the difference in fuel regulations between Europe and Japan. In Europe, there are two specifications for the quality of FAME blended diesel fuels. That is, one is the diesel fuel specification, EN590. The other is the FAME (B100) specification, EN14214. EN590 refers to only ester content in terms of FAME related properties.

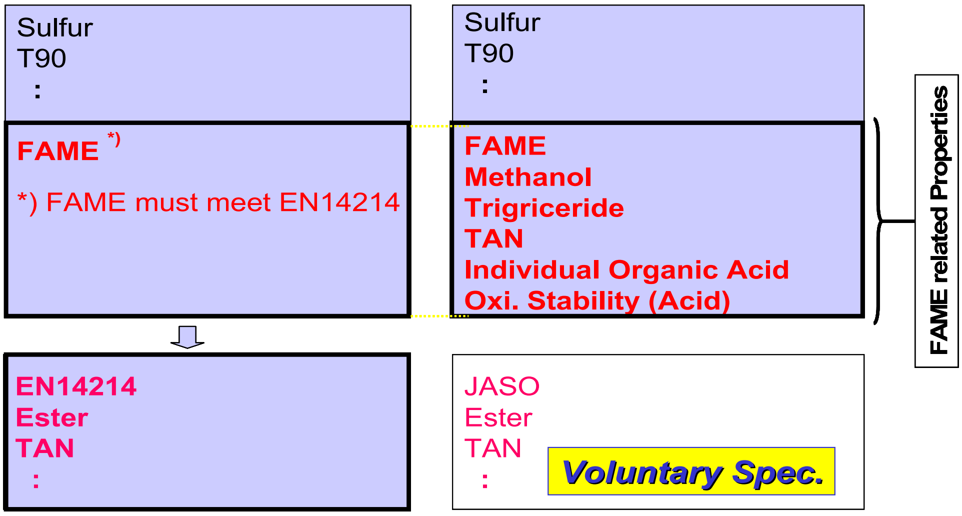


Figure 62 Difference in Fuel Regulations between Europe and Japan

The split specifications mean that both EN590 and EN14214 are necessary to specify the quality of FAME blended diesel fuels. European governments regulated both sets of specifications and monitor the quality of both diesel fuel and FAME before blending. There is no way to check the quality of the fuel after blending, because there are no specifications related to FAME except for the ester content in EN590. In case of Japan, the fuel quality is controlled at the dispensing pump. This principle is also applied to FAME blended diesel fuels. Then, the quality of FAME blended diesel fuel is regulated by the Japan “Fuel Law” as a set of compulsory standards, which do not include specifications of the neat FAME (B100) blending stock. Actually, the B100 specifications were developed as a “Guideline for FAME Producers” under JIS K2390:2008. These two standards will next be explained in more detail.

(i) Compulsory Diesel Fuel Standards (Specification of the Japan “Fuel Law”)

METI developed the specifications of FAME blended diesel fuel based on the conformity test results shown in Table 31. Existing items in the present diesel fuel standards consist of the following three items.

- Sulfur Content of 0.005% by mass, or less.
- Cetane index of 45 or higher.
- 90% distillation point of 360 C, or lower.

New additional items are classified into two groups. Either of the following must be satisfied, namely item (a) or (b).

⇒ Standard to be satisfied by diesel fuel not containing FAME

(a) FAME content of 0.1% by mass, or less

Triglyceride content of 0.01% by mass, or less

⇒ Standard to be satisfied by diesel fuel containing FAME

(b) FAME content of 5.0% by mass, or less

Triglyceride content of 0.01% by mass, or less

Methanol content of 0.01% by mass, or less

Acid value of 0.13 mg KOH/g or less

Total formic acid, acetic acid and propionic acid of 0.003% by mass, or less

Oxidative stability of 0.12 mg KOH/g or less, for acid value growth

Regulatory items need to be added to the diesel fuel standards in order to specify the upper limit of FAME content in diesel fuel (up to 5% is allowed), and the fuel properties satisfying points 1, 2 and 3 for the use of FAME conforming to the neat standards.

1. FAME sufficiently refined (high purity) may be blended. This covers triglyceride and methanol content.
2. FAME in fresh condition, not degraded with time, may be blended. This covers acid value and specific acid content.
3. Properties should be such that generation of acid and sludge from heat and oxidative degradation is controlled during storage. This establishes a baseline for oxidative stability.

Table 31 Compulsory Diesel Fuel Standards

Regulated Item		**FAME Blended Diesel Fuel**	**Diesel Fuel**
Existing Items	Sulfur	Max 0.001% by mass	
	Cetane Index	45 min	
	T90	Maximum of 360 C	
Additional Items	FAME Content	Max 5.0% by mass	Max 0.1% by mass
	Triglyceride Content	Max 0.01% by mass	Max 0.01% by mass
	Methanol Content	Max 0.01% by mass	-
	TAN	Max 0.13 mgKOH/g	-
	Individual Organic Acid*	Max 0.003% by mass	-
	Oxidation Stability (Acid Value Growth)	Max 0.12 mgKOH/g	-

* Total Formic, Acetic and Propionic acids

Differences from the regulated of European EN standard values are the limits for specific organic acids, and the oxidative stability (acid value growth) limit. Items to study based on the regulated value of EN Standard consist of FAME to diesel fuel blending ratio, Acid Value, Methanol content, Triglyceride content.

FAME Content

When the FAME to diesel fuel blend ratio (ester content) is increased, blotting of fuel from the fuel hose will take place. In the EN Standard (EN590), the blending ratio in diesel fuel is limited to 5% or less. The FAME to diesel fuel blend ratio can be used as an upper limit for the effect on safety, and also in identifying diesel fuel containing FAME or not containing FAME.

When the compulsory standard for diesel fuel is simply increased, items investigated regarding fuel quality by producers and distributors will also increase, whether or not FAME is contained in the diesel fuel. In order to avoid increasing the burden unnecessarily when diesel fuel not containing FAME is handled, the FAME blend ratio should be the main criteria.

Our conformity study was based on the fact that the FAME blending ratio is limited to 5% in Europe. A variety of tests were conducted within the sub 5% FAME blend ratio. No phenomena related to problems considered due to ester were confirmed. As to the soak test for plastics and rubber in which a significant effect was anticipated, no significant effect was observed for the FAME blend cases.

In fuel filter durability tests using the conventional test method, pressure-tightness decreased after the plastic filter case test. It was considered an effect of FAME on rubber (NBR) and plastics (Nylon 6). Effects of acid in addition to ester were also considered. In the fuel filter tests under the revised test conditions adjusted for actual in-use conditions, it was confirmed that no problems existed.

Triglyceride Content

Triglycerides are purely vegetable oils and animal fats. When blended with diesel fuel even at a concentration typical of impurities, they easily form sludge from oxidative degradation, which in turn causes clogging of the fuel filter or improper sliding of parts within the fuel system. As to the measuring method of neat FAME before blending with diesel fuel, a maximum of 0.2% by mass is specified by EN14214. Provisions are necessary because triglycerides (the actual fat) will blend with diesel fuel without forming methyl ether.

The triglyceride content is used as an index to measure the refinement level of FAME before blending with diesel fuel, similar to methanol. A value of 5%, equivalent to the EN standard, should be used as the standard value. Conformity test results showed that combustion residuals are easily formed from triglycerides (increase of carbon residue). No problems caused by triglycerides occurred in the conformity tests, including in durability tests using the triglyceride content equivalent to the EN Standard.

Methanol Content

Methanol aggressively corrodes certain metals. The present quality law specifies that 'no methanol shall be detected' in the compulsory standard item for gasoline. Currently, blending methanol in diesel fuel is not considered, but for FAME blended diesel fuel, methanol is used in the production of FAME, and residual methanol may be contained in the fuel. It is appropriate that the standard value should be 'not detected,' the same as for gasoline.

The level presently prescribed for 'not detected' in gasoline is a maximum of 0.5% by mass. In the case of FAME, methanol is not added intentionally but will be included as an impurity accompanying the synthesis process. In this compulsory standard, only the critical items to be prescribed for FAME should be applied after it is blended with diesel fuel, and it is necessary to decide whether the FAME quality before blending was appropriate. Among the items proposed as a compulsory standard, residual methanol and triglycerides (both are raw materials in FAME synthesis) constitute a measure of the refinement level of FAME before blending. Accordingly, it is considered appropriate to use the 5 % equivalent to the European Standard.

Acid Value and Specific Acid Content

When the acid value or the specific acid content is increased, metals used in motor vehicle fuel systems, begin to corrode. According to the European standard EN 14214, the limiting acid value for 100% FAME is 0.5 mgKOH/g or less.

The cause of corrosion is the acid originating in the FAME itself, and it is necessary to specify the combination of the acid value of FAME blended diesel fuel and the concentration of specific acids. When the acid value specified by EN 14214 (0.50 mgKOH/g) is applied to the 5% FAME blended diesel fuel, the acid value should not exceed 0.03 mgKOH/g.

There have been cases where fatty acids were added to diesel fuel to improve lubricity, but it was confirmed that this level would not cause corrosion with the present dosage, and the maximum available acid value in the existing diesel fuel is 0.10 mgKOH/g. Accordingly, 0.13mgKOH/g is taken as the upper limit for the standard.

Specifying the acid value only is not sufficient to limit corrosion, and it is necessary to specify a limit for short chain fatty acids, which demonstrate strong corrosiveness. From the study of acids generated by FAME and from the results of corrosion tests for each acid, the specifications for formic acid, acetic acid and propionic (propanoic) acid should be provided.

Formic acid, acetic acid and propionic acid are important according to the results of the study of corrosive acids generated by FAME that has exhibited oxidative degradation. The evaluation results of corrosiveness from these acids confirmed that no corrosion occurred when formic acid, acetic acid and propionic acid did not exceed 0.003 %, and when caproic acid was under 0.01 % by mass in a moisture-free system (tens of parts per million level).

A study of the acid content analysis method indicated that formic acid, acetic acid and propionic acid can be analyzed by relatively simple methods, but caproic acid cannot be analyzed with the same test method. Because it is known that caproic acid is generated by oxidative degradation of methyl linolenate (which also generates acetic acid), it is possible to restrict the caproic acid content to a certain maximum level by controlling the acetic acid content. It was confirmed that no problems such as a decrease in durability would occur in fuel filter durability tests using FAME blended diesel fuel with a maximum mass-based acetic acid content of 0.003 % or less, and acid value of 0.13 mgKOH/g.

Oxidative Stability

Organic acids, fatty acids and moisture are generated when FAME undergoes oxidative degradation, and these can corrode metals. Furthermore, when oxidative stability is decreased, polymers (sludge) are generated which can cause failure in sliding parts of the fuel pump and injectors. Regarding the pre-blend measurement method of the neat FAME, an organic acid oxidative stability of at least six hours is required by the European standard EN14214.

No measurement method or standard value for neat FAME are provided with respect to sludge; however, in the European Diesel Fuel Standard EN590, 25 g/m3 is specified in accordance with ISO 12205 (ASTM D2274). This remained the same when it was amended in 2004 to allow a 5% FAME blend.

A study of the oxidative stability was conducted based on the concept that it is necessary to specify both the acid value (yield of organic acid) and yield of sludge in

FAME blended diesel fuel. Because it is considered appropriate to evaluate the oxidative stability after some degree of thermal (oxidative) degradation, testing was conducted to determine the method by which the yield of sludge and acid value can be simultaneously measured by reviewing test conditions and referencing the existing oxidation test methods. Other examples of such oxidation stability tests are for gasoline, lubricants, etc.

Although corrosion occurred in the fuel tank circulation tests conducted with the fuel used for the fuel system rig durability test, corrosion did not occur with fuel with established oxidative stability (with antioxidant added) in the fuel tank circulation test performed with the test method under development. While the difference in results is significant, according to the testing laboratory, in both yield of sludge and acid value growth, even if the same sample was used, the difference was remarkably reduced for fuel with antioxidant added. There was some correlation between the yield of sludge and acid value growth on the whole, and it was decided that the restriction of yield in sludge can be controlled by specifying a standard limiting value of acid growth.

Because the average acid value growth for fuel assumed to be border in the fuel tank circulation test was 0.06 mgKOH/g, the standard value was decided to be 0.12 mgKOH/g, considering the 95% confidence level.

Results of fuel simulation tests at high temperatures and in a common rail injection system confirmed that the degradation of fuel was accelerated and problems like corrosion and deposit build-up also occurred. Build-up of deposits was observed in the suction control valve (a valve to regulate the volume and pressure of fuel) of the supply pump (a pump to boost fuel pressure and to supply fuel to injection nozzles) in fuel system durability test rig and in the fuel system piping. These results were obtained by significant on-road vehicle operating tests. While it may not be as significant a problem in practical use for all customers, it was considered necessary to maintain a certain minimum level of deposit and corrosion resistance for the fuel.

Although corrosion occurred in the fuel tank circulation test using the conventional test method, it was confirmed that no problems existed by conducting the fuel tank durability test again using fuel with antioxidant added.

Polyunsaturated Fatty Acid Methyl Ester Content

Since polyunsaturated acid methyl esters, such as methyl linolenate, are molecules having multiple unsaturated bonds, a large amount of sludge is easily generated by oxidative degradation, and blockage of the fuel system is likely to occur, even if the content of this contaminant is small. As to the specific make-up of methyl esters with unsaturated bonds, some are provided with the analysis method and the standard value for neat FAME according to the European standard EN14214. Specifically, the analysis method and standard value exist for the content of methyl linolenate, having three unsaturated bonds. As for polyunsaturated fatty acid methyl esters with four or more unsaturated bonds, the standard value exists while the analysis method does not exist. In EN14214, the content of methyl linolenate cannot exceed 12% by mass, and the content of polyunsaturated fatty acid methyl esters with four or more unsaturated bonds cannot exceed 1% mass.

While it was confirmed that the yield of sludge increases when the content of methyl linolenate was substantial, it was determined that the yield of sludge can be controlled by maintaining a standard value of oxidation stability (acid value growth). Polyunsaturated fatty acid methyl esters with four or more unsaturated bonds were more difficult to deal with. Analysis was extremely difficult after blending with diesel fuel, and it was considered appropriate to specify the limiting value according to the neat FAME standard instead.

The volume of sludge generated in the simulation tests increased when the content of methyl linolenate in FAME blended diesel fuel increased. It was found that the methyl linolenate decreased the oxidative stability significantly. It was considered necessary to maintain a certain minimum level of fuel robustness.

Build-up of deposits was observed in the suction control valve, which regulates the fuel pressure and volume of the fuel supply pump. This was observed in fuel system rig durability tests and in the fuel system tubing of the endurance test vehicle. While it may not be a problem in practical use, it was considered necessary to maintain the level of fuel used for the durability test as the minimum.

Regarding polyunsaturated fatty acid methyl esters with four or more unsaturated bonds, no confirmation was made through simulation tests or durability tests, and no results were obtained, sufficient to make firm conclusions. However, the fuel blend’s oxidative stability may decrease significantly even due to a small quantity of this contaminant.

Cetane Index

The cetane number and cetane index are indicators of the ignitability of diesel fuel, and the engine cannot be operated unless they are above a certain value. In Japan a compulsory standard cetane index of at least 45 is required. The cetane index is an indicator estimating the cetane value from the density and distillation characteristics. It is not always applicable when a substance with different composition is blended, because it is based on petroleum sourced components. While the variation is large to some extent when compared with conventional diesel fuels, the cetane index of biodiesel blends can be applied when the blend ratio is 5% or less.

When FAME is blended, the cetane index tends to be large compared with the cetane value. This tendency is more significant with the increase in the blending ratio of FAME. Variation in correlation between cetane value and cetane index is significant compared with diesel fuel without added FAME. Within the 5% FAME blending range, the cetane index is higher than cetane value by an average of 1.3.

Test Methods

The FAME and triglyceride content of diesel fuel are determined using high performance liquid chromatography (HPLC). The methanol content in FAME blended diesel fuel is determined using gas chromatography with an oxygen detector (GC-AED), with head space, or with water extraction. Since one of the initial intentions of this work was to add the intermediary contaminant methyl linolenate as a standard test item, measurement using the GC-AED method was evaluated to analyze methanol and methyl linolenate simultaneously. However, a more general test method can be considered if one were to analyze only methanol. Water extraction – gas chromatography and head space – gas chromatography were considered, after which the preferred method was established.

Acid values are determined by potentiometric titration. Formic acid, acetic acid and propionic acid in FAME blended diesel fuel are determined using water extraction ion chromatography. The oxidation stability of FAME blended diesel fuel is estimated by the total acid number (TAN) growth after thermal degradation. The rise of TAN is measured after 16 hours of heating to 115 C, while bubbling oxygen at 3.0 L/h through the sample. The test apparatus used in this method is defined in ISO-12205-1995 ‘Petroleum Products – Determination of the Oxidation Stability of Middle – Distillate Fuels.’

Other Regulatory Information

The test method and oxidation stability limit were newly developed by METI because the current oxidation stability test method and limitations were not suitable for application to FAME blended diesel fuel. This diesel fuel regulation went into effect starting March 2006. For reducing the workload of fuel distributors who do not actually blend FAME, two properties, ester content and triglyceride content are initially measured. If neither is detected, distributors do not need to sample and measure the other four properties.

(ii) Neat FAME for Blending Stock (JIS K2390:2008 Specifications for B100)

Along with standards for FAME blends described above, standards were also developed for the pure substance. Basically, the standard items and values were modeled after the FAME standards in Europe at the time, with EN 14214 as the starting point. The characteristics especially focused upon include oxidative stability, acid value, specific acid content, and cold temperature properties.

Oxidative Stability

A standard value was not established for oxidative stability of B100, but quality requirements are 'In accordance with the mutual agreement between parties concerned'. While a new evaluation method was established as the standard for FAME blended diesel fuel, based on a series of careful studies it was found that the oxidative stability could be different for the same FAME, because it actually depends on the diesel fuel component. However, the diesel fuel properties that affect the oxidation stability after it is blended with FAME have not been identified. If an oxidative stability standard of FAME is established that is applicable for blending with any kind of diesel fuel, it will be an excessively strict standard. Accordingly, this item was defined as 'Based on mutual agreement between the manufacturer and the user'. However, a 10 hr minimum oxidative stability is needed to meet the Japanese Compulsory Diesel Fuel Standards.

Acid Value and Content of Specific Acid

The standard value of acid content for B100 is a maximum of 0.5 mgKOH/g. This value is equal to the European Standard. Regarding the maximum acid value after blending with diesel fuel, a value was computed by taking 5% of the European Standard and adding this contribution of the FAME-originating acid to the acid value of the conventional diesel fuel.

When it is assumed that formic acid, acetic acid and propionic acid, which are specific acids, are contained FAME in the quantity equaling 0.5mgKOH/g, the concentration becomes 20 ppm, 27 ppm and 33 ppm, respectively. Because the total is 30ppm or less and the acid value of the FAME 0.5 mgKOH/g is almost equivalent, the standard for the content of a specific acid is not added to the neat standard.

Table 32 Japanese FAME Specification (JIS K2390:2008)

JIS K2390:2008 Neat FAME for use as Automotive Fuel Blend Stock

Item	Unit	Specification	
		Limit	Test Method
Ester content	mass %	96.5 min	EN 14103
Density (@15 deg.C)	g/cm^3	0.860-0.900	JIS K 2249
Kinematic viscosity (@40 deg.C)	mm^2/s	3.50-5.00	JIS K 2283
Flash point	Deg.C	120 min	JIS K 2265
Sulfur content	mg/kg	10 max	JIS K 2541-1，-2，-6 or -7
10% carbon residue	mass %	0.3 max	JIS K 2270
Cetane number		51.0 min	JIS K 2280
Sulfated ash content	mass %	0.02 max	JIS K 2272
Water content	mg/kg	500 max	JIS K 2275
Total contamination	mg/kg	24 max	EN 12662
Copper corrosion	rating	1 max	JIS K 2513
Oxidation stability	hours	Agreement between producer and distributor	
Acid value	mgKOH/g	0.50 max	JIS K 2501or JIS K 0070
Iodine value	gl/100g	120 max	JIS K 0070
Methyl linolenate	mass %	12.0 max	EN 14103
Methanol content	mass %	0.20 max	EN14110
Monoglyceride content	mass %	0.80 max	EN 14105
Diglyceride content	mass %	0.20 max	EN 14105
Triglyderide content	mass %	0.20 max	EN 14105
Free glycerol content	mass %	0.02 max	EN 14105 or EN 14106
Total glycerol content	mass %	0.25 max	EN 14105
Metals (Na+K)	mg/kg	5.0 max	EN 14108 and EN 14109
Metals (Ca+Mg)	mg/kg	5.0 max	EN 14538
Phosporous	mg/kg	10.0 max	EN 14107
Pour point	Deg. C	Agreement between producer and distributor	
CFPP	Deg. C		

Cold Temperature Properties

Standard values are not established for cold temperature performance characteristics, but the specified quality requirements are ‘Based on the mutual agreement between parties concerned.’ Because the low temperature performance of FAME blended diesel fuel depends significantly on the properties of both the FAME and the diesel fuel, it is difficult to specify the low-temperature performance of FAME in a useful manner. Although low-temperature performance specifications are provided in the European Standards, similar to the diesel fuel standards, this is intended for use with neat FAME, and it is difficult for use as an indicator when it is blended with diesel fuel.

7.5 Malaysia

7.5.1 Policy and Measure of BDF

(1) Target and strategy from energy and environment point of view

Under the National Energy Policy, three principal energy objectives are instrumental in guiding the future energy sector development; the supply, utilization and environmental. They are

(a) The Supply Objective: To ensure the provision of adequate, secure, and cost-effective energy supplies through developing indigenous energy resources both non-renewable and renewable energy resources using the least cost options and diversification of supply sources both from within and outside the country;

(b) The Utilization Objective: To promote the efficient utilization of energy and to discourage wasteful and non-productive patterns of energy consumption; and

(c) The Environmental Objective: To minimize the negative impacts of energy production, transportation, conversion, utilization and consumption on the environment.

In the Eighth Malaysian Plan, Renewable Energy was announced as the fifth fuel in the new Five Fuel Strategy in the energy supply mix. It is targeted that RE will contribute 5% of the country's total electricity demand by the year 2005, that is by the end of the Eighth Malaysia Plan period. With this objective in mind, greater effort is being undertaken to encourage the utilization of renewable resources, such as biomass, biogas, solar and mini-hydro, for energy generation. The Ministry has identified palm oil wastes as the biggest renewable resources that can be developed into bio-energy. Solar is another important option, particularly for rural electrification and water heating. The government is currently working on 'hands-on' applications of RE and EE with a number of on-going projects.

On the 9th pril 2009, the Ministry of Energy, Water and Communication has been named Ministry of Energy, Green Technology and Water. The strong commitment of Malaysian Government to address long term sustainability of our environment has resulted in the launching of National Green Technology Policy, which pathed the way forward on Malaysia’s commitment towards the path of green development. The National Green Technology Policy is built on Four Pillars:

- Energy – Seek to attain energy independence and promote efficient utilization;
- Environment – Conserve and minimize the impact on the environment;
- Economy – Enhance the national economic development through the use of technology;
- Social – Improve the quality of life for all.

Government has committed RM 1.5 billion fund for the promotion of Green Technology related activities.

One of the short-term national goals of the Green Technology Policy is to make significant progress and major improvements in the transportation sector by incorporating of Green technology in the infrastructure and vehicles, in particular, biofuels and public road transport. A study identified the renewable energy resource potential in the country, in ringgit (MYR) value, as shown in Table 33.

Table 33 Energy value for potential renewable energy resource in Malaysia, in ringgit

Renewable Energy Resources	Energy Value in RM million (Annual)
Forest residue	11,984
Palm oil biomass	6,379
Solar thermal	3,023
Mill residues	836
Hydro	506
Solar PV	378
Municipal waste	190
Rice husk	77
Landfill gas	4

To achieve the national objectives, the Government is pursuing the following strategies:

- **Secure supply**
  Diversification of fuel type and sources, technology, maximize use of indigenous energy resources, adequate reserve capacity to cater for contingencies, adequate reserve margin for generation, upgrading transmission and distribution networks and distributed generation (islanding);
- **Sufficient supply**
  Forecast demand, right energy pricing and formulate plans to meet demand.
- **Efficient supply**
  Promote competition in the electricity supply industry.
- **Cost-effective supply**
  Promote competition and provide indicative supply plan to meet demand based on least cost approach using power computer software such as WASP;
- **Sustainable supply**
  Promote the development of renewable and co-generation as much as possible.
- **Quality supply (low harmonics, no surges and spikes, minimal variation in**

voltage)
Match quality with customer demand with variable tariffs;

- **Efficient utilization of energy**
  Bench marking, auditing, financial and fiscal incentives, technology development, promotion of ESCOs, Labeling, Ratings, correct pricing, energy managers; and
- **Minimizing Negative Environmental Impacts**
  Monitor the impacts, improve efficiency of utilization and conversion and promote renewable.

(2) Concrete target and strategy for Biofuel

Under the leadership of the Ministry of Plantation Industries and Commodities, the National Biofuel Policy was announced by the Honorable Prime Minister of Malaysia in March 2006. In May 2006, the Biofuel Bill 2006 has passed the Parliament of Malaysia. The National Biofuel Policy encourages the use of biofuels in line with the nation's Five-Fuel Diversification Policy. It spells out a comprehensive framework with concrete initiatives in line with the objectives of the United Nations Framework Convention on Climate Change (UNFCC) to which Malaysia is a party. The National Biofuel Policy was formulated after extensive consultation with all the stakeholders and as a result of research findings by PORIM/MPOB since 1982. The policy focuses on blending processed palm oil with petroleum diesel and also converting palm oil into biodiesel (methyl ester), mainly for export. The implementation of the National Biofuel Policy is spearheaded by the Ministry of Plantation Industries and Commodities.

The National Biofuel Policy envisions (a) the use of environmentally friendly, sustainable and viable sources of energy to reduce the dependency on depleting fossil fuels and (b) the enhancement of prosperity and well-being of all stakeholders in the agriculture and commodity based industries through stable and remunerative prices. The policy is underpinned by five strategic thrusts:

Thrust 1: Biofuel for transportation
Thrust 2: Biofuel for Industry
Thrust 3: Biofuel technologies
Thrust 4: Biofuel for export
Thrust 5: Biofuel for cleaner environment

Announcement of mandatory use of biodiesel was made in October 2008 by the Prime Minister of Malaysia. The Malaysia Biofuel Industry Act was gazetted on 1st

November 2008 to regulate and ensure orderly development of the Malaysian biofuel industry. The Act provide for the mandatory use of biofuel, prescribing the type of biofuel, percentage of blending, licensing of activities related to biofuel and other related matters.

The Government noted that a policy has been put in place to ensure a balance in the supply of sustainable palm oil to the food sector while meeting the demand in the biofuel sector. As a rule, palm oil supply for the biodiesel production of biodiesel will not exceed more than six (6) million tonnes per year in order to ensure the supply of sustainable palm oil to the food sector would not be jeopardized.

The local implementation of B5 programme by the Government Departments took place started on 3rd February 2009. The splash blending of B5 was done at Klang Valley Distribution Terminal (KVDT) by Petronas. The Government Departments involved in the B5 implementation are the Armed Forces (ATM) and Kuala Lumpur City Hall (DBKL). For duration 3rd February – 30th September 2009, the supply of B5 to ATM and DBKL reached to 4.05 million litres (equivalent to 3,439 tonnes). It involved the utilization of biodiesel amounted to 202,293 litres (equivalent to 178 tonnes).

Currently, there is no biodiesel limit set in diesel fuel. The Malaysian Standard on Palm Methyl Esters (MS 2008:2008) which similar to EN 14214 / ASTM D6751 was published in November 2008 and also ready to be enforced.

The biodiesel industry is considered a new emerging growth area for Malaysia. As of December 2009, a total of 70 licenses applications were received by the Ministry of Plantation industries and Commodities, 43 licenses have been approved and 27 applications in various review stages. A total of 28 biodiesel plants with annual biodiesel production capacity of 2.7 million tonnes per year have been established. Fifteen (15) plants are under construction with production capacity of 1.9 million tonnes per year (Table 34).

Table 34 Biodiesel Approved Licencees in Malaysia (as at December 2009)

Implementation Phase	No.	Biodiesel Capacity (Tonnes/Year)
Commercial Production	17	2,340,700
Production Trial	11	405,000
Under Construction	15	1,940,200
Total	43	4,685,900

(3) Main crops for BDF and its production planning

At present, the major crop for BDF production in the country is palm oil. Malaysian and Indonesian Governments pact agrees to use 40% (~6 million tonnes) of palm oil production (15.8 million tonnes in 2006) for the production of biodiesel. This 6 million tonnes of palm oil is a moral pledge between the two Governments and no legal implications on either country should biodiesel usage fall below or shoot above this level. Jatropha curcas is another crop of interest of the Malaysian Government. The government has planned on a demonstration project on cultivation of Jatropha curcas to establish the economic feasibility study of the crop for biodiesel production. Biofuel from algae is also under extensive R&D programme.

(4) Regulations and incentives to promote BDF utilization

Under the Promotion of Investment Act 1986, numerous incentives have been given to promote the private sector involvement to capitalize on this new development. These incentives are provided for producers and generally available for all the manufacturing industries including biodiesel industry.

The major tax incentive is Pioneer Status. A company granted Pioneer Status enjoys a 5-year partial exemption from paying income tax. It pays tax on 30% of its statutory income. To encourage investment in the states of Sabah and Sarawak and the designated Eastern Corridor of Peninsular Malaysia, companies located in these areas will enjoy a 100% tax exemption on their statutory income during their 5-year exemption period.

The incentives for strategic and high technology projects, and commercialization of R&D findings of the public sector in resource based industries also have been given to the relevant companies. A company which invests in its subsidiary company engaged in the commercialization of R&D findings will be given tax exemption equivalent to the amount of investment made in the subsidiary company. At the same time, the subsidiary company that undertakes the commercialization of R&D findings will be given pioneer status with 100% tax exemption on statutory income for 10 years.

7.5.2 Standardization of BDF

(1) Concept of BDF standards and regulations

The Malaysian specification/standard of palm biodiesel was formulated based on European biodiesel specifications, EN 14214 as a basis. The test methods are based on ASTM, ISO, EN and Malaysian test methods which are identical to ASTM or ISO methods. The standard drafting for biodiesel was undertaken by the Technical

Committee (TC) on Petroleum Fuels which it membership includes oils and gas companies (e.g. Shell, Petronas, Caltex, Exon Mobile etc.), government agencies (e.g. MPOB, Department of Environment, Department of Transportation, etc.) and representatives from Malaysian Automotive Association (MAA). The provisional voluntary Malaysian standard on B5 palm olein biofuel blend (MS 2007:2007) was published in March 2007. The Malaysian standard on palm biodiesel was published in November 2008.

(2) Standards of BDF

(i) Current status of BDF standardization

The Malaysian standard on palm methyl ester MS 2008:2008 has been published. Drafting of B5 standard is underway.

(ii) Reference standards

Reference standards for Malaysian biodiesel standard is ASTM D6751 and EN 14214.

(iii) Remarkable items

The parameter on CFPP for Malaysian biodiesel is +15°C. We acknowledged the important of polyunsaturated methyl esters in biodiesel and maintained it as 1 %wt. maximum. The iodine value was 110°C as certain oil palm species is highly unsaturated.

(3) Specification values

The specification of palm methyl ester is shown in Table 35.

Table 35 Malaysian FAME Specification MS 2008:2008 – Automotive Fuels – Palm Methyl Esters (PME) for Diesel Engines – Requirements and Test Methods

Property	Unit	Limits		Test methods
		Min	Max	
Ester content	% (m/m)	96.5	-	EN 14103
Density at 15 °Cc	kg/m3	860	900	ISO 3675 ISO 12185 ASTM D 4052
Viscosity at 40 °C	mm2/s	3.50	5.00	ISO 3104 MS 1831
Flash point	°C	120	-	ISO 3679e MS 686
Sulfur content	mg/kg	-	10.0	ISO 20846 ISO 20884 ASTM D 5453
Carbon residue (on 10% distillation residue – ISO 10370)f (on 100% distillation sample – ASTM D 4530)	% (m/m)	-	0.30 0.05	ISO 10370 ASTM D 4530
Cetane number		51.0	-	ISO 5165 MS 1895
Sulfated ash content	% (m/m)	-	0.02	ISO 3987 ASTM D 874
Water content	mg/kg	-	500	ISO 12937 ASTM E 203 ASTM D 1160
Total contamination	mg/kg	-	24	EN 12662 ASTM D 5452
Copper strip corrosion (3 h at 50 °C)	rating	Class 1		ISO 2160 MS 787
Oxidation stability, 110 °C	hours	6.0	-	EN 14112
Acid value	mg KOH/g	-	0.50	EN 14104 MS 2011
Iodine value	g iodine/100 g	-	110	EN 14111
Linolenic acid methyl ester	% (m/m)	-	12.0	EN 14103
Polyunsaturated (>=4 double bonds) methyl esters	% (m/m)	-	1	-
Methanol content	% (m/m)	-	0.20	EN 14110
Monoglyceride content	% (m/m)	-	0.80	EN 14105 ASTM D 6584
Diglyceride content	% (m/m)	-	0.20	EN 14105 ASTM D 6584
Triglyceride contenth	% (m/m)	-	0.20	EN 14105 ASTM D 6584
Free glycerolh	% (m/m)	-	0.02	EN 14105 EN 14106 ASTM D 6584
Total glycerol	% (m/m)	-	0.25	EN 14105 ASTM D 6584
Group I metal (Na+K) Group II metals (Ca+Mg)	mg/kg mg/kg	-	5.0 5.0	EN 14108 EN 14109 EN 14538
Phosphorus content	mg/kg	-	10.0	EN 14107 ASTM D 4951
CFPP	°C	-	15	EN 116

7.6 New Zealand

7.6.1 Policy and Measure of BDF

(1) Target and strategy from energy and environment point of view

The New Zealand Government released the final New Zealand Energy Strategy (NZES) in October 2007. The NZES also notes an in-principle goal to halve domestic transport emissions per capita by 2040 relative to 2007 emissions. It includes an emphasis on reducing transport emissions and reducing our dependence on imported oil, which will require a combination of energy sources for vehicles, including biofuels and electricity. The NZES is currently being updated.

(2) Targets/strategies/regulations/incentives for BDF

The biodiesel grants scheme commenced on 1 July 2009 and will continue for three years. A grant of up to 42.5 cents per litre for biodiesel or the biodiesel content of a diesel/biodiesel blend will be available to biodiesel producers. The grant is for domestic production of biodiesel for a range of end uses.

(3) Main crops for BDF and its production planning

There is currently around 15 million litres of biodiesel production capacity in New Zealand, and the biodiesel being produced is predominately sold via the contractual market, rather than being incorporated in the retail fuel mix.

For the most part, the feedstocks being utilised are tallow, rapeseed and waste-cooking oil. Algae is being investigated as a feedstock for second generation biofuels. Table 36 shows the current status of biodiesel in New Zealand.

Table 36 Current status of biodiesel in New Zealand

Country	Mixing rate	Main Feedstocks	Strategy / Goal	Standard
New Zealand	Up to 5% for retail sales	Tallow, Rapeseed, Waste cooking oil	Up to 5% biodiesel permitted in diesel for retail sale.	Engine Fuel Specifications Regulations 2008 (B100 and biodiesel blend quality requirements)

7.6.2 Standardization of BDF

The quality of petrol and diesel in New Zealand is regulated by the Engine Fuel Specifications Regulations 2008 [40]. Up to 5% biodiesel content is permitted in diesel for retail sale. Table 37 shows the B100 specifications for blending with diesel (for retail sale).

Table 37 New Zealand FAME Specification

Property	Units	New Zealand Engine Fuel Specifications Regulations 2008
Ester content	Mass%	96.5 min
Density	Kg/m³	860 – 900
Viscosity	Mm²/s	2.0 – 6.0
Flash Point	Deg C	100 min
Sulfur Content	Mass%	10 max
Distillation, T90	Deg. C	-
Carbon residue 100% or 10%	Mass%	 0.05 max 0.30 max
Cetane Number		47 min
Sulfated ash	Mass%	0.020 max
Water content	Mg/kg	500 max
Total contamination	Mg/kg	24 max
Copper corrosion		Class 1
Acid value	mgKOH/g	0.50 max
Oxidation Stability	Hours	10.0 min
Iodine Value		140 max
Methyl Linolenate	Mass%	12.0 max
Polyunsaturated FAME (more than 4 double bonds)	Mass%	1 max
Methanol content	Mass%	0.20 max
Monoglyceride content	Mass%	0.80 max
Diglyceride content	Mass%	0.20 max
Triglyceride content	Mass%	0.20 max
Free glycerol content	Mass%	0.020 max
Total glycerol	Mass%	0.25 max
Na + K	Mg/kg	5.0 max
Ca + Mg	Mg/kg	5.0 max
Phosphorous content	Mg/kg	10.0 max

7.7 Philippines

Oil, which is practically 100% imported as raw material crude oil and as finished products, dominates the energy sources in the Philippines. In 2008, oil constituted 33% of the energy mix. The thrust towards diversification and development of indigenous and renewable energy sources resulted in the present 7% oil share in the power sector demand mix. Therefore, diversification of fuel sources in the transport sector is a major program of the Philippines.

The high and volatile price of this finite resource (oil), and its being a major contributor to the deteriorating air quality further drives the thrust towards energy independence of the Philippine Government thru the Department of Energy (DOE). With the Philippines having vast agricultural and underutilized lands, the promotion and use of biofuels as an alternative fuel for transport have become a national strategy.

7.7.1 Policy and Measure of BDF

(1) Biodiesel Policy

It is the policy of the State “to achieve energy independence and fuel diversification while meeting environmental challenges through the utilization of agricultural-based feedstocks”. The Biofuels Act of 2006 (Republic Act No. 9367), mandating the use of biofuels, including biodiesel, was signed into law on January 12, 2007 and became effective on February 6, 2007 after its publication in 2 newspapers of general circulation. This landmark legislation is one of, if not the quickest-passed legislation, as it was pursuant to the government’s thrust to reduce dependence on oil, increase self-sufficiency, improve air quality, as well as improve the economic condition in the countryside and promote rural development, thereby encouraging “balik probinsiya” and at the same time decongesting the urban centers.

Specifically for biodiesel, Section 5.3 of the law provides that: “Within three (3) months from the effective date of this Act, a minimum of one percent (1%) biodiesel by volume shall be blended into all diesel engine fuels sold in the country: *Provided,* that biodiesel blend conforms to PNS for biodiesel.” The law further states that “Within two (2) years from the effective date of this Act, the National Biofuels Board (NBB) created under this Act is empowered to determine the feasibility and thereafter recommend to DOE to mandate a minimum of two percent (2%) blend of biodiesel by volume which may be increased taking into account considerations including but not limited to domestic supply and availability of locally-sourced biodiesel component.” Effective May 7, 2007, a 1% biodiesel blend (B1) was required for all diesels sold in the country.

On February 6, 2009, the mandated 2% biodiesel blend (B2) in all diesels became effective by virtue of DC 2009-02-0002. This was after the supply and availability of locally-sourced biodiesel, as well as its compatibility with the in-use vehicle fleet, especially for those vehicles under warranty, was ascertained with the concerned stakeholders. Discussions for a higher blend are underway, with due consideration for its impact on the local diesel (B2) pump prices. It may be noted that because of its use in the public transport, the price of diesel is one of the most critical and sensitive factors in the prices of goods and commodities, and transport fares. Qualified transports, both local and international, as well as qualified product tankage are concerns especially as they add to the cost of doing business.

The policy towards use of biofuels is further enhanced by the passage of the Renewable Energy Law on December 10, 2008, with biofuels classified under biomass which is among the renewable energy sources.

(2) Policy Background

The use of biodiesel is actually the result of several initiatives of the government over the years. During the early 1980's, the Philippine National Oil Company and the Ministry of Energy, now with DOE, embarked on a Cocodiesel Program using pure coconut oil as a diesel blend. However, technical problems (e.g., gumming resulting in filter clogging), the improvement of vegetable oil prices in the world market, and the relatively lower prices of diesel caused the program to be discontinued. Nonetheless, researches continued.

To promote the utilization of coco-biodiesel, President Gloria Macapagal-Arroyo launched the coco-biodiesel program on April 21, 2004 in San Pablo City, Laguna, one of the biggest coconut-producing areas.

Earlier, in February 2004, the President issued Memorandum Circular (MC) No. 55 mandating all government offices, including all government-owned and controlled corporations, to use 1% coco-biodiesel blend in all their diesel fuel requirements. MC 55 was meant to serve as a pilot test to determine the techno-economic viability of coco-methyl ester (CME) as an alternative transport fuel. To implement MC 55, Department Circular (DC) No. 2004-04-003 was issued in March 2004.

A year later, DC No. 2005-04-003 was issued to promote the wider utilization of coco-biodiesel in the transport sector as a blending component of petroleum diesel. Under the said Circular, oil companies in the Philippines were enjoined to support the alternative energy program of the DOE by making available coco-biodiesel (in bottles) as a retail shelf item in all their gas stations nationwide. Local Government Units (LGUs) were likewise enjoined to issue the proper ordinances to ensure compliance with the said circular.

The program gained another boost in August 2005 with the intensified implementation of the energy efficiency and conservation. Through the issuance of Administrative Order (A.O.) No. 126, all government agencies were subjected to energy audit. Their compliance to MC 55 (use of B1) formed part of their efficiency rating.

(3) Strategy for Biodiesel

Learning from experiences of other countries that have embarked on a program on biofuels, the Biofuels Law made sure that every aspect of the biofuels program has lead agency to take care of. A National Biofuels Board (NBB) was created, composed of heads of concerned Departments and Authorities, and chaired by the Secretary of the Department of Energy (DOE), namely: the Department of Trade and Industry (DTI); Department of Science and Technology (DOST); Department of Agriculture (DA), Department of Finance (DOF); Department of Labor and Employment (DOLE); Philippine Coconut Authority (PCA); and the Sugar Regulatory Administration (SRA). The Board also agreed to include as non-voting members the heads of the Department of Agrarian Reform (DAR), the Department of Environment and Natural Resources (DENR), Department of Transportation and Communication (DOTC), and National Commission on Indigenous People (NCIP).

Research and Development / Promotions

AS shown in Figure 63, there are numerous on-going research and development studies for each level in the supply chain, i.e., from the agri-based feedstocks to the extracted oil, biodiesel and the blended petroleum fuel. In all of these levels, considerations are made on the following.

(1) process/infrastructure/logistics for land use, viable basestocks, agro-industrial development, quality products, etc.;

(2) marketing and distribution to ensure supply security – availability and accessibility, supply competition, export market, etc;

(3) implementation / enforcement of regulations/guidelines, standards, as well as monitoring compliance; and

(4) incentives to encourage investments and sustainability of the program.

Research, development and extension (RD&E) and promotions are underway at the various levels. The NBB, DOE and the oil companies are working together for extensive information, education and communication (IEC) campaign on biofuels and blends, even as the oil and car companies are having their respective IEC campaigns on their customers.

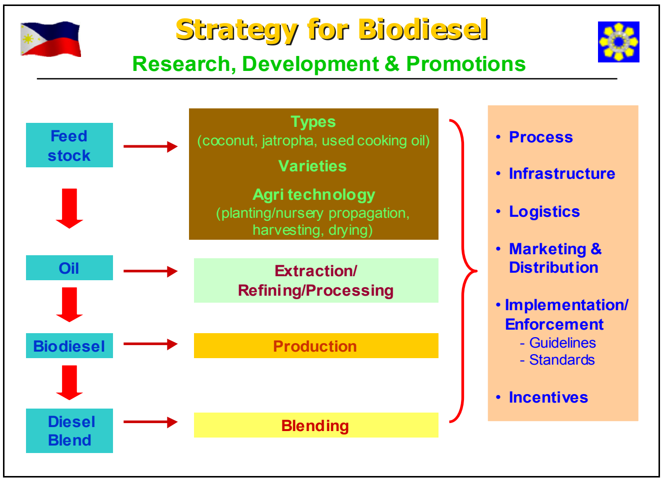


Figure 63 Strategy for biodiesel research, development and promotions in The Philippines

Supply Management

The NBB has to ensure adequate and continuous agricultural supply for the fuel program, without sacrificing food and other traditional uses of the feedstocks. Thus, one of the key functions of the NBB is to recommend to the DOE the level of the mandatory blend of biodiesel to petroleum diesel considering availability of biodiesel from local supply.

The DA is in-charge for the biodiesel feedstocks, and assisted by the PCA, with coconut as the feedstock of accredited biodiesel producers. To handle jatropha, which is a potential feedstock, the Philippine Forest Corporation is actively involved in the plantation/propagation. The Alternative Fuels Corporation (PAFC), a subsidiary of the Philippine National Oil Company, was recently created to cover RD&E and investment promotions for jatropha and other alternative fuels. Of course, the DOE is lead for the products – biodiesel and the diesel fuel blends.

On October 8, 2008, the NBB issued Joint Administrative Order (JAO) No. 2008-1 Series of 2008 "Guidelines Governing the Biofuel Feedstocks Production, and Biofuels and Biofuel Blends Production, Distribution and Sale Under Republic Act No. 9367". Among the objectives are to ensure the availability of alternative and renewable clean energy without detriment to the natural ecosystem, biodiversity and food reserves of the country; to ensure that lands devoted to food crops shall not be utilized for biofuel feedstocks; to ensure compliance to the PNS; and to ensure compliance with the mandated biofuel blends, among others.

(4) Feedstocks

There are many possible feedstocks for biodiesel. At the moment, the following are the present and high potential feedstocks.

Coconut

Coconut, known in the Philippines as the tree of life, is at present the only feedstock that can meet the Philippine National Standard for biodiesel and the diesel blend B2 (Diesel with 2% biodiesel), having consistently passed all the necessary tests. The National Research and Energy Laboratory of the US-DOE was among the laboratories that conducted tests on coconut methyl ester samples, confirming its high oxidation stability, among other properties.

Coconut is a favored biodiesel feedstock because its composition closely resembles diesel, and it is grown in large areas all over the country. Coconut methyl ester (CME) adds value to coconut, and there is more than sufficient CME capacity in the country.

Coconut and its products are major exports of the Philippines. CME started as a by-product of oleo-chemical plants. Researches led to its “refinement”, making it suitable for use as a blending component of diesel. Over time, it was established that CME not only substitutes part of our diesel requirements, as a blend, but also enhances its quality, in terms of detergency and solvency, thus contributing to cleaner air. Not all CME, though, are of fuel grade.

With surplus coconut for its traditional uses in the food and oleo-chemicals sector, CME as fuel was encouraged. As of December 2009, 11 commercial plants and one (1) LGU-based plant , with a combined annual capacity of close to 400 million liters, that have been accredited by the DOE for biodiesel production. Local requirement (potential diesel displacement) is about 130 million liters per year at 2% blend.

The NBB, particularly the Department of Agriculture, has adopted a feedstock program. These include ensuring that its use as a biofuel feedstock will not conflict with existing agro initiatives, guaranteeing local market for biofuels pursuant to the Biofuels Act; meeting domestic demand first before exports; continuing support to feedstock development as such also supports development in the countryside through employment/income generation for the farmers; intercropping other high-value crops in coconut plantations; and provision of social amelioration for coconut farm workers, among others. Coconut is a beneficiary of the FIELDS Program 2008, which covers Fertilizer, Irrigation and other infrastructure, Education and extension, Loans, Dryers and other post harvest facilities, and Seeds and other genetic materials.

Jatropha

Jatropha, known locally as *tuba-tuba* or *tubang bakod,* has been identified as a potential feedstock for biodiesel, being a non-food crop, and supposed to grow well anywhere. Speciation studies are on-going, to determine appropriate varieties/species for commercialization, considering climate, rainfall, soil, geography, etc. While jatropha does not compete with food, it must not also be allowed to compete with land use. The afore-mentioned JAO provides the guidelines.

Others

The DOE is also in receipt of proposals for registration and accreditation of biodiesel from used cooking oil. Consistency of the biodiesel product quality is seriously being looked into, as well as its indigenous component which is a requirement of the Biofuels Law.

(5) Incentives

There is no direct government subsidy for biodiesel production, blending and marketing. Moreover, with the liberalized environment in the oil downstream sector investments have been expected to come from the private sector. To encourage the investments, various incentives applicable to the biodiesel sector are contained in at least three laws.

(i) Omnibus Investments Code of 1987

Investment Priority Projects (IPP) identified and updated annually may be registered with the Board of Investments and would thus be entitled to incentives. Production facilities, vehicles, etc. for the biofuels program have been part of the IPP.

(ii) Biofuels Act

Incentives to jumpstart the program are explicitly provided. These are on top of those applicable under the Omnibus Investments Code.

- ***Specific Tax*** Biofuels are zero (0)-rated, regardless of source – local or imported.
- ***Value Added Tax (VAT)***. The sale of raw materials used in the production of biofuels is exempted from the 12% VAT.
- ***Philippine Clean Water Act Fees and Charges.*** Water effluents from biofuels production used as liquid fertilizer and other agricultural purposes which are considered "reuse" are exempted under by RA 9275.
- ***Government Financial Institutions' Loans***. High priority will be accorded to Filipino entities that shall engage in production, storage, handling and transport of biofuels and biofuel feedstocks, including the blending of biofuels with petroleum, as certified by the DOE.

(iii) Renewable Energy (RE) Act

With biomass, including biofuels categorized as renewable energy sources, the expanded incentives also apply to biodiesel and projects related to its commercialization and use. Further, there are also incentives for RE commercialization (for all manufacturers, fabricators and suppliers of locally-produced RE equipment and components duly recognized and accredited by the DOE) as well as for farmers engaged in the plantation of biomass resources.

- ***Income Tax Holiday (ITH)***. For the first 7 years of the commercial operation, biofuels manufacturers shall be exempt from income taxes.
- ***Duty-free importation of RE Machinery, Equipment and Materials.*** Within the first 10 years upon the issuance of an RE developer, the importation of the above, including parts thereof, and control and communication equipment, shall not be subject to tariff duties.

- ***Special Realty Tax Rates on Equipment and Machinery.*** Applicable to those actually and exclusively used for RE facilities not exceeding 1.5% of of their original cost less accumulated depreciation or net book value.
- ***Net Operating Loss Carry-Over.*** Applicable during the first 3 years from the start of commercial operation.
- ***Corporate Tax Rate.*** After 7 years of ITH, all RE Developers shall pay a corporate tax of 10% on its net taxable income.
- ***Accelerated Depreciation.*** If and only if an RE project fails to receive an ITH before full operation, it may apply for Accelerated Depreciation in its tax books and be taxed based on such.
- ***Value Added Tax (VAT)***. The sale of fuel or power generated from renewable sources shall be subject to zero percent (0%) VAT
- ***Tax Exemption of Carbon Credits.*** All proceeds from the sale of carbon emission credits shall be exempt from any and all taxes.
- ***Tax Credit on Domestic Capital Equipment and Services.*** A tax credit equivalent to 100% of the value of the VAT and customs duties that would have been paid had the items been imported, within the validity period of the RE operating contract.

(6) Regulations / Prohibited Acts for Biodiesel.

Laws, rules and regulations, standards, etc. guide entities dealing with biofuels. Compliance is enforced by various units in the DOE, as follows.

(i) The Oil Deregulation Law (Republic Act (RA) 8479)

This law is the mother law for the fuel sector. This includes provisions to cover fuel security, quality and quantity, and environmental protection. As such it requires the registration by fuel marketers of all fuel additives, and the compliance to the Philippine National Standards (PNS) of all petroleum products, biofuels and petroleum-biofuel blends that are put into commerce in the country. DC 2007-05-006 required a 1% blend of biodiesel in all diesel fuels (B1) effectively on May 6, 2007, and DC 2009-02-0002 required increasing the blend to 2% (B2) effectively on February 5, 2009.

(ii) The Clean Air Act (RA 8749)

This Act explicitly provided specifications on fuel quality and the technical committee that will review and formulate standards. It also required the registration of all fuel additives by the manufacturers, processors and traders. Even prior to any government mandate for biodiesel, coconut derivatives have been considered as an additive. A Certificate of Fuel Additive Registration (CFAR) is issued to manufacturers, processors and marketers, including repackers who comply with the requirements of

DOE Department Circular DC2007-02-0001. Biodiesel producers are required to have a quality control laboratory.

(iii) The DOE Memorandum Circular (MC) No. 55

This Ciruclar mandates diesel-fed government vehicles to use biodiesel blend, requires biodiesel manufacturers to secure a Certificate of Accreditation before they can sell their biodiesel.

(iv) The Biofuels Act (RA 9367)

This Act implementing rules and regulations DC 2007-05-006 reiterate the requirements for CFAR and the Certificate of Accreditation. The DC also clarifies on the Prohibited Acts, which include among others, the sale of biodiesel blends not conforming to the PNS. Penalties include fine and imprisonment of the persons or officials of the oil company responsible for the violation.

(v) The Joint Administrative Order (JAO) No. 2008-1, series of 2008

This order was issued by the NBB detailing the roles of the various stakeholders, both government and private. The order recognizes community biodiesel to promote the development of the biofuel industry in the country and encourage private sector participation.

(vi) The Renewable Energy Law (RA 9513)

This Law, with implementing rules and regulations DC 2009-05-0008, required certification from the DOE through the Renewables Energy Management Bureau (REMB) to qualify RE developers to avail of the incentives provided in the Law.

(7) Roles of the Various DOE Units on Biodiesel

The Oil Industry Management Bureau (OIMB) processes the CFAR, as it oversees the downstream oil industry sector and monitors quality, quantity, price, supply and demand, and production and marketing processes of fuels, as well as developments in the sector.

The Energy Utilization Management Bureau (EUMB) processes applications for Certificate of Accreditation, for which the CFAR is a prerequisite. The EUMB presently handles the monitoring of biodiesel producers and marketers. However, this function will eventually be moved to the Renewable Energy Management Bureau that is currently being organized pursuant to the new law. For manufacturers, the CFAR and Accreditation are both signed simultaneously by the DOE Secretary.

To ensure consumer safety and welfare, especially as far as quality of biodiesel and blends are concerned, the OIMB and EUMB inspects and gathers samples from various supply points of their respective areas of jurisdiction. The product samples are then submitted to the Energy Research and Testing Laboratory Service (ERTLS) which conducts tests pursuant to the PNS. The ERTLS is also undertaking correlation between laboratories and testing equipment among the government, industry players and third party testing facilities to minimize, if not totally avoid inconsistent and contestable test results.

Cases of non-compliance are forwarded by the OIMB and EUMB, as the case may be, to the Legal Service (LS) which prosecutes such cases and impose the corresponding penalties.

7.7.2 Standardization of BDF

(1) Mandate

Consumers, particularly the motorists have to be assured of the appropriate quality of fuels sold in the country, especially the new fuels. Thus, diesel blended with biodiesel must conform with the diesel standard.

The standard setting mandate is provided in the Clean Air Act, while its enforcement is provided in the Oil Deregulation Law. The Biofuels Law mandates compliance to the Philippine National Standards (PNS) and imposes severe penalties for violations, which include fine and imprisonment. Various authorities are as follows.

Technical Committee for Standards

The Technical Committee on Petroleum Products and Additives (TCPPA) created by virtue of the Clean Air Act undertakes the mandate. The TCPPA took over the role of the Technical Committee on Petroleum Products & Lubricants (TC 12) of the Bureau of Product Standards (BPS). The TCPPA is co-chaired by the DOE and the DENR, with members coming from concerned government agencies, fuel sector, engine/vehicle suppliers, consumers, non-government organizations, and the academe. The TCPPA follows the standards development and review procedure of the product standards body where its representative sits as a regular member of the TCPPA.

For the biodiesel standards, the TCPPA membership is expanded to include chemists from the oleochemical industry. The country’s leaders in the oleochemical industry are now members of the biodiesel industry, forming themselves into the Philippine Biodiesel Manufacturers’ Association.

Bureau of Product Standards (BPS)

As the main standards body, the BPS promulgates the draft prepared by the TCPPA into a Philippine National Standard (PNS), pursuant to the Clean Air Act.

Department of Energy (DOE)

The PNS, while providing specifications, can only be enforced with a regulation issued by the pertinent authority. For fuels, a DOE regulation, usually in the form of a Department Circular DC, is issued to require compliance to the PNS. In the case of biodiesel, the IRR of the Biofuels Law DC 2007-05-006 required such compliance. This requirement is reiterated in the earlier-mentioned JAO. Thus any update on the PNS is circulated thru publication in newspapers of general circulation, and a notice to the concerned entities through a DOE DC, after stakeholders' consultations.

(2) Product Standards

Standards are prepared and/or reviewed for updating as necessary. Recognizing that biodiesel feedstocks have varied properties owing to their composition, the government deemed it appropriate to also set standards for pure biodiesel (B100), which will eventually be a critical blending component of diesel. Thus, there are standards for the pure biodiesel (B100) and the allowable biodiesel blends (initially B1, and now B2), and which are updated pursuant to the Biofuels Law and the biodiesel program. For example, the PNS for B1 was effective May 2007 up to Jan 2009. At present the PNS is for B2.

Biodiesel - PNS/ DOE QS 002:2007- Coconut Methyl Ester (B100) specification

This is the current standard, in effect at the start of this ERIA biodiesel standardization project and is shown in Table 38.

Table 38 PNS/DOE QS 002:2007 - Coconut Methyl Ester (B100) Specification

PROPERTY	Limits	Test Method
Appearance	clear	Visual
Acid number, mg KOH/g, max.	0.50	PNS ASTM D 664 / PNS ASTM D 974 / PNS EN 14104
Carbon residue on 100% sample, % mass, max.	0.050	PNS ASTM D 4530 or PNS ISO 10370
Cetane number, min.	55	PNS ASTM D 613 or PNS ASTM D 6890 or PNS ISO 5165 or PNS IP 498/03
Cloud point, °C, max.	5	PNS ASTM D 2500
Copper strip corrosion 3 hrs @ 50°C, max.	No. 1	PNS ASTM D 130 or PNS ISO 2160
Density @ 15°C, kg/L	0.86-0.90	PNS ASTM D 1298 or PNS ASTM D 4052 or PNS ISO 3675
Distillation AET 90% recovered, °C, max	360	PNS ASTM D 1160 or PNS ASTM D 86
FAME content, % m/m, min.	96.5	PNS EN 14103 modified *
Flash point, Pensky-martens °C min.	100	PNS ASTM D 93
Glycerin, % mass, max.		
Free glycerin, % mass, max.	0.02	PNS AOCS Ea 6-94 (1997) / PNS ASTM D 6584 modified [a] or PNS EN 14105 modified [a]
Total glycerin, % mass, max.	0.24	PNS AOCS Ca 14-56 (1997) or PNS ASTM D 6584 modified [a] or PNS EN 14105 modified [a]
Glyceride content, % m/m, max.		
Monoglyceride content	0.80	PNS EN 14105 modified * or PNS ASTM D 6584
Diglyceride content	0.20	
Triglyceride content	0.20	
Group Metals, mg/kg, max.		
Group I metals (Na + K)	5	PNS EN 14108 / PNS EN 14109
Group II metals (Ca + Mg)	5	PNS EN 14538
Methanol content, % m/m, max.	0.20	PNS EN 14110
Methyl Laurate, % mass, min.	45	PNS EN 14331 modified [a] or PNS EN 14103 modified [a]
Oxidation Stability, 110 °C, hours, min*.	6	PNS EN 14112
Phosphorus, % mass, max.	0.001	PNS ASTM D 4951
Sulfated ash, % mass, max.	0.020	PNS ASTM D 874
Sulfur, % mass, max.	0.050	PNS ASTM D 2622 / PNS ASTM D 5453 / PNS ASTM D 4294
Viscosity, kinematic @ 40 °C, mm^2/s	2.0 – 4.5	PNS ASTM D 445
Water, % vol. max.	0.05	PNS ASTM D 6304 or PNS ISO 12937 or PNS ASTM E 203
Water & sediments, % vol. max.	0.05	PNS ASTM D 2709

Notes: [a] interim ; [b] to be reported quarterly

*This standard is in the process of updating to harmonize with the ERIA Benchmark Standard of 2008, especially on the 10 hours minimum limit for oxidation stability.

As early as 2003, a standard for coconut-based biodiesel or coco-methyl ester (CME) was promulgated (PNS 2020:2003, renamed PNS/DOE QS 002:2003 as the DOE got the mandate for standards of petroleum fuels. Coconut was the only available feedstock then. While patterned after ASTM D6751 (2002) for B100, the PNS took cognizance of the fact that ASTM considered a set of biodiesel from feedstocks which have composition and properties different from coconut oil. A technical working group was created, led by oleo-chemical sector representatives. Thus for the properties of free glycerin and total glycerin, for which the ASTM standard noted their non-applicability to B100 using coconut oil feedstock, the test methods of the American Organization of Chemical Scientists (AOCS) were adopted, modified accordingly, and interim limits set, pending further studies.

In 2005, the review of the standard started, this time considering EN 14214 and studies, findings and suggestions from JAMA. Moreover, the advent of other potential feedstocks in the country caused the TCPPA to initiate standards for Jatropha, as well as for a generic B100 standard. However, due to the shortage of sustainable jatropha samples, as well as the undertaking of this ERIA BDF standardization project for the East Asia Region, the TCPPA agreed to just update the CME standard.

The updated standard was officially promulgated by BPS in 2007. Other than the modified AOCS methods already adopted in the previous version, applicable ASTM and EN methods for fatty acid methyl esters (FAME), methyl laurate, glycerins and glycerides were also incorporated, modified accordingly, and interim limits set, pending further studies. Highlights of this update include: provisions on 96.5% mass, min. FAME Content, 45 % mass, min. Methyl Laurate (C12 ME) content, and JAMA / EN 14214 specs on oxidation stability, glycerides, group metals, density, methanol content & water. ASTM D6751 (2007a) was the available standard at the time of finalization of the standard.

In 2008, the TCPPA initiated the drafting of a standard test method for esters and lauric acid content in diesel and biodiesel blends by gas chromatography. This is the result of tests and correlations conducted by chemists from the oil and biodiesel companies and deliberations by the TCPPA since existing methods cover esters whose carbon chain range from C14-C20. CME has carbon chain range of C8- C18. The resulting test method, a modification of EN14103 has been submitted for promulgation into a PNS.

Biodiesel Blends - PNS/DOE QS 004:2009- Fatty Acid Methyl Ester (FAME)-Blended Diesel Oils specification.

This year, pursuant to the mandatory requirement for 2% biodiesel in all diesel fuels sold in the country, the standard for FAME-blended diesel B1 was updated, and PNS for B2 was promulgated. The requirement for compliance to this standard is contained in the rules and regulations implementing the Biofuels Law. The standard covers both automotive and industrial diesel fuel and became mandatory effective February 6, 2009, by virtue of DC 2009-02-0002. Table 39 presents the summary of properties and limits for B2.

Table 39 PNS/ DOE QS 004:2007 - FAME -Blended Diesel Oils (B2) Specification

PROPERTY	ADO	IDO	TEST METHODS
Calculated cetane index, min or	50		PNS ASTM D 976 or PNS ASTM D 4737
Centane number min. Or			PNS ASTM D 613
Derived cetane number, min			PNS ASTM D 6890 or PNS ASTM D 7170
Carbon Residue on 10% distillation residue, %mass, max	0.15	0.35	PNS ASTM D 189 or PNS ASTM D 524 or PNS ASTM D 4530
Color	2.5 max.	5.0 min.	PNS ASTM D 1500
Copper strip corrosion 3 h at 50 ^{0}C, max.	No. 1	No. 1	PNS ASTM D 130 or PNS ISO 2160
Density at 15^{0}C, kg/L	0.820-0.860	0.880 max.	PNS ASTM D 1298 or PNS ASTM D 4052
Distillation, 90% recovered, ^{0}C, max.	370	Report	PNS ASTMD D 86
FAME content, % volume	1.7 - 2.2	1.7 - 2.2	PNS EN 14078 modified or PNS EN 14103 modified or PNS EN 14331 modified
Flash Point, Pensky Martens, ^{0}C, min.	55	55	PNS ASTMD D 93
Kinematic viscosity, mm^{2}/s at 40^{0}C	2.0 - 4.5	1.7 - 5.5	PNS ASTMD D 445
Lubricity, (HFRR), wear scar dia. @60oC, micron, max	460		PNS ASTM D 6079
Methyl laurate (C12 ME), % mass, min.	0.80	0.80	PNS EN 14103 modified or PNS EN 14331 modified
Sulfur, % mass, max.	0.05	0.30	PNS ASTM D 129 or PNS ASTM D 4294 or PNS ASTM D 2622
Water, %volume, max.	0.05		PNS ASTM D 6304 or PNS ISO 12937 or PNS ASTM E 203
Water and Sediment, %volume, max.	0.10	0.10	PNS ASTMD D 2709

Note: ADO – automotive diesel oil; IDO – industrial diesel oil

Euro 4 Fuels.

The TCPPA has started discussion on what should be the equivalent fuel for vehicles to meet Euro 4 emission requirements. The Department of Environment is about to formalize the Euro 4 mandate for new vehicles that may be allowed to enter and be registered in the country.

(3) Implementation and Enforcement

The DOE conducts spot checks at the different supply points in the distribution chain of both biodiesel and biodiesel-diesel blends, and collect samples for laboratory tests to determine compliance to the PNS. Supply points include manufacturing/ production facilities, bulk storage depots/terminals, gasoline stations.

To minimize conflicts of test results, the DOE is coordinating with the oil and biodiesel industry participants on the type of equipment, especially on portable diesel analyzers that also detect FAME content, among others. The DOE is also conducting laboratory reconciliation with the industry players.

Moreover, since not all the biodiesel manufacturers have complete laboratory facilities to test their product pursuant to the PNS, quality assurance of B100 is still a concern. One possible option being considered by the producers is for DOE to accredit laboratories that can conduct complete test for B100 and to provide the list of the accredited laboratories to the biodiesel manufacturers to help the industry comply with the PNS requirement.

7.7.3 Thrust Towards Harmonization

In the Philippines, no less than our President Gloria Macapagal Arroyo has been advocating for harmonization. The country has thus been involved in projects towards harmonization. It is worth-noting that the thrust towards harmonization is actually not only limited to fuel quality, but also on facilities (including vehicles, engines and parts) giving due consideration on the issue of compatibility. The harmonization thrust also covers codes of practice.

This ERIA Biodiesel Fuel (BDF) Standardization Project is a very welcome development, it being a positive reaction to the call of President Arroyo during the January 2007 East Asian Summit in Cebu City, Philippines for the harmonization of standards for biodiesel.

While there are ASTM and EN standards, there are contentions of them being international since they have been based on select feedstocks, besides being in a different climate and other local conditions. It has been established that properties and behaviors of different biodiesel feedstocks vary, thus supposed standards and test methods cannot just be adopted for different feedstocks. This situation became more obvious as the Working Group Meetings progressed.

Theoretical and empirical data show excellent results for coconut as a feedstock for the blending component (CME) of diesel, with its carbon chain composition closely resembling petroleum diesel. However, since only the Philippines is basically using

CME, studies outside the country hardly, if at all, take CME into consideration.

The ERIA BDF Benchmark Standard has been very instrumental in having coconut recognized as a major biodiesel feedstock not only among East Asian countries, but globally. The March 2009 Biodiesel Guidelines of the Worldwide Fuel Charter providing for values and methods has eliminated earlier concerns on CME vis-a-vis EN 14214, particularly for iodine number, viscosity and flash point. With coconut as a major agricultural product of the country, and the establishment and accreditation of CME manufacturers, the high export potential of the country cannot be argued. A harmonized standard would thus facilitate trade across boarders, ensuring supply availability and better economics, not only for the fuel, but also for the vehicles. A harmonized fuel standard would also provide better access to improvements in technology, leading to improved air quality, mitigating, if not arresting, global warming and climate change.

Trade facilitation is expected to eventually reduce cost of biodiesel. The price of biodiesel is crucial in the Philippines as 70% of the diesel fuel demand is by the public transport sector. Local price of biodiesel feedstock (e.g., coconut oil) is linked to Rotterdam (export) price. Local biodiesel producers hope to create a bigger local market demand rather than struggle with export prices. Thus biodiesel producers propose to increase the mandated blend from B2 to B5.

Finally, higher demand for biodiesel is deemed to encourage and facilitate capacity additions, including expansion of feedstock sources such as jatropha, thus enhancing supply security and sustainability, improvement in the environment with cleaner air as a result of reduction in CO_2 and other emissions, as well as enhancing economic activity in the countryside.

7.7.4 Status of Biodiesel Implementation

The biodiesel implementation in the Philippines is summarized in Table 40. Specifically, biodiesel development in the Philippines is anchored on the Biofuels Act of 2006, and the biodiesel program is administered by the DOE along with other agencies lead by the NBB.

Table 40 Current status of biodiesel fuel in The Philippines

Country	Mixing rate	Main Feedstocks	Strategy / Goal	Standard
Philippines	- B1 (2004) for government -owned and controlled vehicles	Coconut	Memorandum Circular #55	- PNS/DOE QS 002:2003 (B100) (Biodiesel: Cocomethyl ester)
	- B1 (2007) for all diesels	Coconut	Biofuel Law 2006 ➢ National Biofuels Board	- PNS/DOE QS 002:2007 (B100) - PNS/DOE QS 004:2007 (B1)
	- B2 (2009) for all diesels	Coconut		- PNS/DOE QS 004:2009 (B2)
		(Research on-going for Jatropha and other feedstocks)	Renewable Energy Law 2009	

The Philippine government is promoting the utilization of biodiesel from coconut and continuously conducting extensive research and development on other biomass feedstock for biodiesel production. In the implementation of the biodiesel mandate, commercially available crops and the most advantageous use of land are carefully being considered to promote sustainable development, and most especially, not sacrificing food for fuel.

Various concerns are being worked out with all the stakeholders. These would include quality assurance capabilities of the biodiesel producers, qualified storage and transport facilities, compatibility of the higher biodiesel blends on the existing (in-use) vehicle fleet as well as those under warranty, etc. Other than technical issues, the higher price of biodiesel compared with pure diesel is a major consideration in the thrust for higher blends to maximize the utilization of the present production capabilities. Finally, in order to gain greater support from different sectors, an intensified information, education and communication campaign is being worked out.

7.8 Singapore

7.8.1 Policy and Measure of BDF

(1) Target and strategy from energy and environment point of view

Singapore is a small island state at a size of 25 × 15 miles and area of 710.02 km^2 [41]. It has a population of 5.0 millions [42]. Singapore's GDP was S$257 billion in 2008 and with a GDP per-capita of S$59,192 [41]. There are more than 7,000 multinational corporations in Singapore, attributing to its high rate in competitiveness and globalization indices. Singapore is also a major oil & gas hub in the world, with activities covering exploration and production support services, refining (>1.3 billion bpd of oil), petrochemical and chemical industries, storage, trading, etc.

The energy situation in Singapore is summarized as follows: the energy needs are almost entirely (>95% [43]) imported as oil and gas for electricity and also feedstocks for refining, petrochemical and chemical industries. The power generation capacity of Singapore is about 10 GW with peak demand at 6.07 GW as at 31 Dec 08. The electricity market was liberalized with the key restructuring involving the separation of the contestable and non-contestable parts of the electricity market, establishment of an independent system operator and the liberalization of the retail market.

Competition in the electricity market has lead to the introduction of more cost-effective, energy efficient and cleaner natural gas into the market. Natural gas is imported via pipelines from Malaysia and Indonesia and contributes to >80% of power generation output. To diversify its energy sources, Singapore will import LNG and the building of a LNG terminal of capacity 3 mtpa is expected to be completed by around 2013.

As a small city-state with limited indigenous resources, a strong and growing economy is the only means to provide Singapore with the resources to meet the challenges of rising energy prices and climate change. Singapore accounts for ~ 0.15% of the world's CO2 emissions and the government announced to do its fair share as part of the global effort to mitigate greenhouse gas emissions. Singapore acceded to the Kyoto Protocol in 2006 and has been actively looking at "climate change strategy" through improving energy efficiency, setting up carbon trading market, offering CDM projects etc. under the National Climate Change Committee (NCCC) and Climate Change Working Group (CCWG). In 2006, the Energy Policy Group (EPG) was set up to formulate and coordinate Singapore's energy policies and strategies in a more holistic way.

Singapore's energy strategies: The national energy policy framework outlines six key strategies to bring together the Government, industries, business and households to adopt practical and effective measures to strength Singapore's competitiveness, enhance energy security, and protect the environment. They are elaborated as below:

- First, to **promote competitive markets**. The Energy Market Authority (EMA) is now piloting the Intelligent Energy System, to review the option of full contestability in the electricity retail market.
- Second, to **diversify the energy sources**. Singapore is building a liquefied natural gas terminal to diversify the source of NG. The government is promoting further

energy diversification by supporting R&D, test bedding and demonstration of promising new energy technologies.

- The third strategy is to **improve energy efficiency**. The government has developed a comprehensive national energy efficiency plan to promote the adoption of energy efficiency measures, raise public awareness, and build capability in energy efficiency.
- Fourth, is to **develop the energy industry**. Besides growing its oil refining and energy trading sector, Singapore is also pursuing growth opportunities in clean energy, including solar energy, biofuels and fuel cells. The government has committed more than S$300 million to build up its energy R&D capabilities. The goal is to increase the value-added of the energy industry from S$20 billion to S$34 billion by 2015, and to triple the employment in the industry from 5,700 to 15,300. There are some early successes in the clean energy sector in Singapore. In Oct. 2007, Norway's Renewable Energy Corporation announced that they will build a $6.3 billion solar manufacturing complex in Singapore. When completed, it will be the world's largest solar manufacturing facility. In November 2007, Neste Oil also announced their plans to build a biorefinery that will produce NExBTL renewable fuel. With a capacity of 800,000 metric tonnes per annum, the plant will be the largest renewable fuel refinery in the world. In addition, Singapore has attracted investments in biofuels production from Nexsol (joint venture between Peter Cremer and Kulim Group), Continental Bioenergy and Natural Fuels. Singapore will have a biodiesel production capacity of 1,650,000 metric tonnes per annum when these projects are completed.
- The fifth strategy is to **set up international cooperation**. Singapore is developing closer relations with key energy producers, and participating actively in energy and energy-related discussions in major fora such as ASEAN, the East Asia Summit, the Asia-Pacific Economic Cooperation, and the United Nations Framework Convention on Climate Change.
- Strategy Six is to **take a whole-of-Government approach**. Apart from the Energy Policy Group, several government agencies have formed new units to manage the energy challenges. The Ministry of Trade and Industry now has an Energy Division. The Economic Development Board and the National Environment Agency have set up inter-agency programme offices for clean energy and energy efficiency respectively.

The Energy Market Authority (EMA) has also set up an Energy Planning and Development Division to plan and review Singapore's energy policies; and develop scenarios for formulation of strategic plans to secure Singapore's energy needs.

(2) Concrete target and strategy for BDF

However, blending will not be mandated in Singapore, nor are there currently any plans to do so. Nevertheless, Singapore does not rule out any energy options for the future.

Singapore’s biodiesel production output is expected to exceed one million tons per annum by 2010, Most of these plants will use palm oil as feedstocks, and increasingly diversifying into non-food feedstocks such as jatropha oil, algal oils and waste cooking oil.

(3) Main crops for BDF and its production planning

Singapore has a solid foundation in the petrochemical industry, and our strong R&D base will facilitate the development of next generation biofuels. However, we face constraints in terms of feedstock for biofuels. Furthermore, biofuels are generally more expensive than their fossil fuel equivalents.

Biodiesel plants built/building in Singapore:

- Small domestic plants are in operation (e.g. Alpha Biofuels has a production capacity of 120,000 mt/year. The feedstock for biodiesel are waste cooking oil, grease trap oil and waste palm oil.
- Neste Oil also announced their plans to build a biorefinery that will produce patented NExBTL renewable fuel (the cleanest diesel fuel in the world). With a capacity of 800,000 metric tonnes per annum, the plant will be the largest renewable fuel refinery in the world. The plant (at an investment of US$776 million) will be operational in June 2010 and initially cater to Europe’s growing biofuel requirement. Neste has partnered with French company Technip to provide engineering, procurement and project construction management services for the Singapore project. Separately, Singapore Oxygen Air Liquide Pte Ltd (SOXAL), a unit of French company Air Liquide, is investing 250 million Singapore dollars in setting up a new hydrogen facility and expanding its pipeline network on Jurong Island that will allow it to deliver hydrogen to Neste Oil. Neste Oil and Air Liquide have signed a long-term hydrogen supply deal. Hydrogen is used to reduce the impurities in gasoline and diesel.

(4) Regulations and incentives to promote BDF utilization

There is no government mandate to regulate the use of biofuel in Singapore and therefore the adoption of bio-diesel is highly dependent on free market forces. Presently, biodiesel produced for domestic market is at ~120,000 liter per month to supply ~500-600 vehicles in Singapore running at B100. The National Environment Agency (NEA) of Singapore is in charge of promoting clean air and setting vehicular emissions standards. NEA allows the use of bio-diesel for vehicles so long as the vehicle operators can demonstrate via certification by reputable independent testing bodies that vehicles using such fuel will be able to meet the prevailing vehicle emission standards.

7.8.2 Standardization of BDF

(1) Concept of BDF standards and regulations

In Singapore, bio-diesel can be used for vehicles so long as the vehicle operators can demonstrate via certification by reputable independent testing bodies that vehicles using such fuel will be able to meet the prevailing vehicle emission standards Singapore for new and existing motor vehicles, as shown in Table 41.

Table 41 Current emission regulation for vehicles in Singapore

Vehicle Type	Emission Standard	Implementation Date
Petrol vehicles	EURO II	1 Jan 2001
Diesel vehicles	EURO IV	1 Oct 2006
Motorcycles/scooters	97/24/EC	1 Jul 2003

All existing vehicles are subject to mandatory inspections periodically to ensure that they comply with the prescribed standards as follows:

(a) Petrol-driven vehicles:
Carbon Monoxide (CO)
- 6% by vol (registered before Oct 1986)
- 4.5% by vol (registered between Oct 1986 and Jul 1992)
- 3.5% by vol (registered on or after Jul 1992)

(b) Diesel-driven vehicles:
Smoke Opacity Limit: 50 HSU

(c) Motorcycles/scooters:
CO - 6% by vol (registered before Oct 1986)
- 4.5% by vol (registered on or after Oct 1986)

(2) Standards of BDF

(i) Current status of BDF standardization

Singapore does not have any National Standards for biodiesel. There is currently negligible biodiesel market in Singapore. There only three biodiesel producers - Continental Bioenergy, Peter Cremer and Natural Fuel, and their products are for export. International standards are followed for biodiesel producers: European EN14214 and/or ASTM 6751 specifications, depending on the buyer.

(ii) Reference standards

European EN14214 and ASTM 6751 specifications are followed.

(iii) Remarkable items

Nil.

(3) Specification values

Details of values can be seen in European EN14214 and ASTM 6751 specifications. Singapore has the Intertek Testing Services (S) Pte Ltd, Singapore Technical Centre set up on Jurong Island. The methods used for testing biodiesel fuels are provided by Intertek, in the separated sheets.

7.9 Republic of Korea

7.9.1 Policy and Measure of BDF

(1) Target and strategy from energy and environment point of view

The energy consumption in road transportation sector is around 17% of total energy consumption in Korea, and gasoline, diesel oil and LPG were consumed respectively 60,896, 101,623 and 47,641 thousand barrels in 2008.

In Korea, BDF has been introduced to reduce the petroleum dependency, to expend renewable energy, to reduce green house gas, and to improve air quality. In May 2002, Korean government MOCIE (Ministry of Commerce, Industry and Energy) launched BD20 demonstration program in Seoul metropolitan area and Jeonbuk provincial area. This biodiesel program has been shifted into two ways from July 2006. One is the change of diesel oil specification, in which diesel oil for road transportation can include maximum 5% of biodiesel, and this fuel is distributed and sold at gas station by petroleum companies in nationwide. Another case is BD20, which is distributed and sold by biodiesel company for the restricted fleet user, who has own oil storage capability and auto repair capability.

Biodiesel is mixed in diesel oil by voluntary agreement between government and petroleum companies. This agreement started from BD0.5 in July 2006 and changed to annul 0.5% increase from 2008, and up to 3% in 2012, resulting in an increase in biodiesel sale shown in Figure 64. Taxes for automotive fuel are composed of traffic tax, education tax, driving tax, and 10 % of VAT (Value Added Tax) for final price, but biodiesel mixed in diesel oil has been taxed only VAT. However, blending ratio and tax policy will be discussed in 2010.

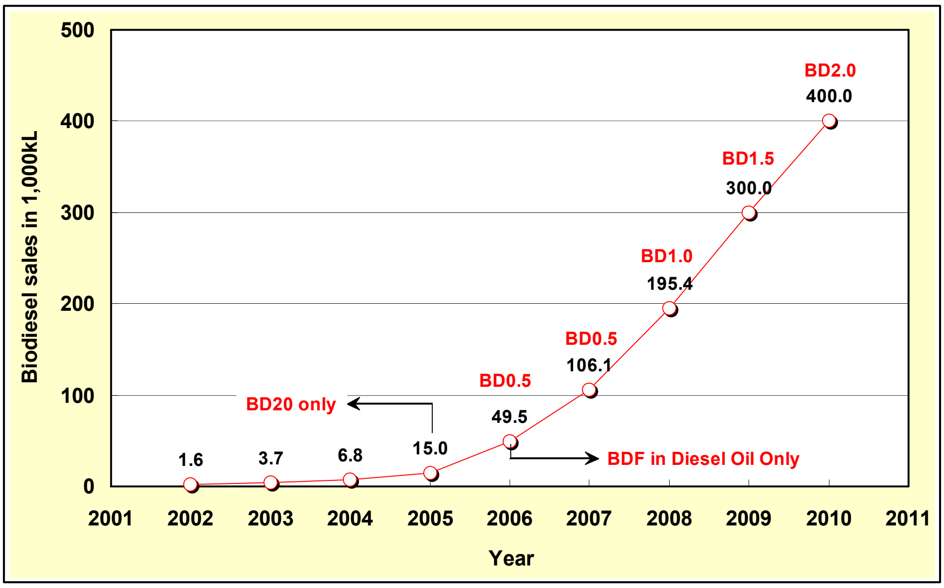


Figure 64 Biodiesel sales in Korea

(2) Main crops for BDF and its production planning

Main feedstock for BDF is imported soybean oil and domestic waste cooking oil, and some imported palm oil recently. To increase domestic feedstock, MOF (Ministry of Agriculture and Forestry) has been conducting demo-plantation program of rapeseed which covers 49.5 million m^2 in three provincial areas from 2007 to 2009. Overseas plantation such as Jatropha Curcas in East Asian countries has been conducting also by some Korean energy companies.

There are 21 biodiesel production companies in Korea and current production capacity is around 1 million tons per year. Total sales amount of biodiesel was around 200 thousand kilo liters, which is equivalent to BD1.0, in 2008 and will be expected around 300 thousand kilo liters in 2009.

7.9.2 Standardization of BDF

The quality of automotive fuels in Korea is regulated by the Petroleum and Petroleum Alternative Fuel Business Act. Specifications of BD100 for blending use and specification of BD20 specifications for fleet users are in Table 42 and Table 43, respectively.

Table 42 B100 specifications for blending with diesel (for retail sale) in South Korea

Items	Units	U.S.	EU	Rep. of Korea	EAS-ERIA BDF Standard (EEBS):2008
		ASTM D6751-07b	EN14214:2003	PPAFB Act	
Ester content	mass%	-	96.5 min.	96.5 min.	96.5 min.
Density	kg/m3	-	860-900	860-900	860-900
Viscosity	mm2/s	1.9-6.0	3.50-5.00	1.9-5.0	2.00-5.00
Flashpoint	deg. C	93 min.	120 min.	120 min.	100 min.
Sulfur content	mass%	0.0015 max.	0.0010 max.	0.0010 max.	0.0010 max.
Distillation, T90	deg. C	360 max.	-	-	-
Carbon residue (100%) or	mass%	0.05 max. -	- 0.30 max.	- 0.10 max.	0.05 max. 0.3 max.
Cetane number		47 min.	51.0 min.	-	51.0 min.
Sulfated ash	mass%	0.02 max.	0.02 max.	0.01 max.	0.02 max.
Water content	mg/kg	0.05[vol%] max.	500 max.	500 max.	500 max.
Total contamination	mg/kg	-	24 max.	24 max.	24 max.
Copper corrosion		No.3	Class-1	Class-1	Class-1
Acid value	mgKOH/g	0.50 max.	0.50 max.	0.50 max.	0.50 max.
Oxidation stability	hrs.	3 min.	6.0 min.	6.0 min.	10.0 min. (****)
Iodine value		-	120 max.	-	Reported (***)
Methyl Linolenate	mass%	-	12.0 max.	-	12.0 max.
Polyunsaturated FAME (more than 4 double bonds)	mass%	-	1 max.	-	N.D. (***)
Methanol content	mass%	0.2 max. (*)	0.20 max.	0.20 max.	0.20 max.
Monoglyceride content	mass%	-	0.80 max.	0.80 max.	0.80 max.
Diglyceride content	mass%	-	0.20 max.	0.20 max.	0.20 max.
Triglyceride content	mass%	-	0.20 max.	0.20 max.	0.20 max.
Free glycerol content	mass%	0.020 max.	0.02 max.	0.02 max.	0.02 max.
Total glycerol content	mass%	0.240 max.	0.25 max.	0.24 max.	0.25 max.
Na+K	mg/kg	5 max.	5.0 max.	5.0 max.	5.0 max.
Ca+Mg	mg/kg	5 max.	5.0 max.	5.0 max.	5.0 max.

Table 43 B20 specifications for the fleet user

Item	Unit	Specifications	
		Limit	Test Method
Ester content	mass %	20 +/- 3 Winter (10 +/- 3)	EN 14078
Density (@15°C)	g/cm^3	0.815-0.845	ISO 3675 (KS M 2002)
Kinematic viscosity (@40°C)	mm^2/s	1.9-5.5	ISO 3104 (KS M 2014)
Flash point	deg.C	40 min	ISO 3679 (KS M 2010)
Sulfur content	mg/kg	30 max	ISO 20846, ISO 20884 (KS M 2027)
10% carbon residue	mass %	0.15 max	ISO 10370 (KS M ISO 10370)
Cetane number (Cetane Index)		45 min	KS M ISO 5165, 4264
Ash content	mass %	0.02 max	KS M ISO 6245
Water & contamination	vol.%	0.02 max	(KS M 2115)
Copper corrosion (100°C, 3h)	rating	1 max	(KS M 2018)
Acid value	mgKOH/g	0.1 max	EN 14104 (KS M ISO 6618)
T90	deg.C	360 max	KS M ISO 3045
Pour point	deg.C	0.0 max (winter -17.5 max)	KS M 2016
CFPP	deg.C	-16 max (winter)	KS M 2411
HFRR(@60°C)	micron	460 max	KS M ISO 12156-1

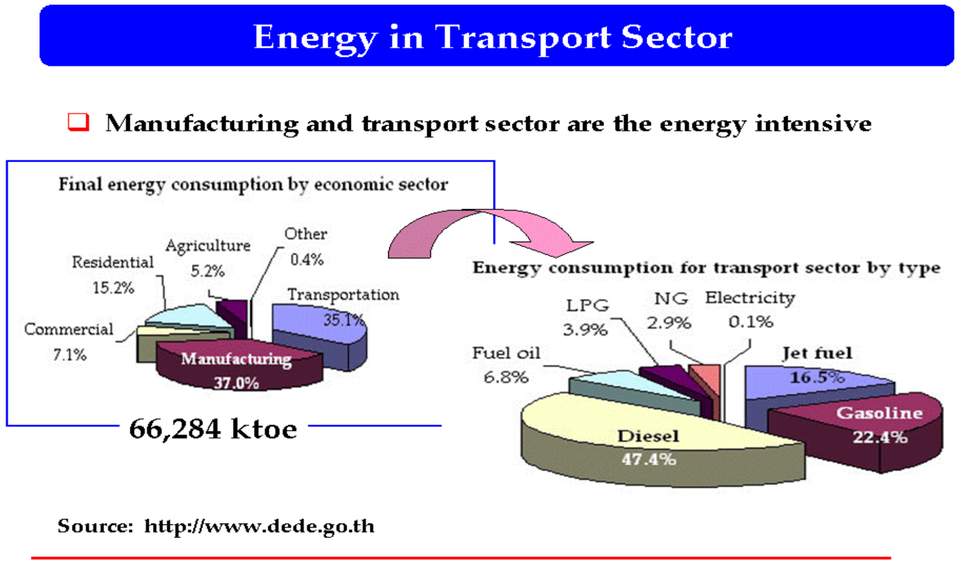
7.10 Thailand

7.10.1 Policy and Measure of BDF

(1) Target and strategy from energy and environment point of view

The fossil fuel resources in Thailand are limited and inadequate to meet the national energy demand, which relies about 49 % on imported energy. In 2008, Thailand final energy consumption accounted about 1.0455 ton of oil equivalent (toe) per Capita, which had been increasing gradually from the average of 0.9885 toe per capita in 2004. The domestic production of primary energy amounted to 61,930 thousand tons of oil equivalent (ktoe) with the import of 59,386 ktoe. The final energy consumption was 66,284 ktoe of which 72% consumed in the transportation and manufacturing sectors.

Energy in transportation sector consumes about 35.1% of the total energy consumption in 2008. Of this amount, the energy consumed were mainly petroleum products including diesel oil 47.4%, gasoline 22.4%, jet fuel 16.5%, fuel oil 6.8% and liquid petroleum gas 3.9%. In addition, natural gas and electricity were consumed as energy source for transportation sector as well, about 2.9% and 0.1%, respectively as shown in Figure 65.



Energy in Transport Sector

- ☐ **Manufacturing and transport sector are the energy intensive**

Source: http://www.dede.go.th

Figure 65 Energy consumption in transport sector

To strengthen the national energy security and competitiveness, Thailand has set up the policy on fifteen-year plan to promote the alternative energies for fossil fuel substitution. It is targeted to increase the proportion of the use of alternative energy to be 20% of the final energy consumption by 2022. The objectives of the fifteen-year National Alternative Energy Plan (2008-2022) are the following:

1. To use mainly alternative energy instead of importing energy
2. To enhance the energy security in supply energy for the country
3. To promote the implementation of green community energy
4. To support the local manufacturing of alternative energy technology
5. To promote the R&D on the high efficient technology for alternative energy production

The alternative energy includes solar, wind, mini-hydropower, liquid biofuels, biomass and natural gas. The portions of 20% are categorized into 2.4%, 7.6%, 4.1% and 6.2% for electricity generation, heat generation, liquid biofuels, and natural gas vehicle respectively. According to the plan, the ethanol and biodiesel have been targeted to 9.0 and 4.5 million litres per day in 2022. In addition, it is emphasized to promote the new and renewable energy technology for bio-energy production.

(2) Targets/strategies/regulations/incentives for BDF

In 2005, Thailand developed the strategic plan for biodiesel promotion and development. Under the national biodiesel policy, biodiesel is promoted to be produced domestically and targeted to replace diesel consumption by 10% in 2012. The national strategic plan for development and promotion on the use of biodiesel fuel classifies biodiesel production into 2 categories, which are community-based biodiesel production and commercial-based biodiesel production. The community-based biodiesel is used for agricultural machines in the communities, while commercial biodiesel is used to be blended with normal diesel for selling at fuel service stations.

The action plan on biodiesel promotion and development was set in May 2005 and revised in the fifteen-year Alternative Energy Plan in January 2009 as the following:

- Promotion of community-based biodiesel production and use since 2006.
- Announcement of the specification of fatty acid methyl ester in 2007.
- Announcement of the specification of the regular high speed diesel oil (or B2) and the B5 high speed diesel oil in 2007.
- Mandate of B2 in February 2008, while B5 is optionally used.
- Target the amount of biodiesel use of 4.5 million litters per day in 2022.

The National Energy Policy Council (NEPC) has established measures to promote biodiesel utilization in Thailand. The measure includes regulations and incentives for biodiesel production and blends. Prior to getting the permission to sell

B100 from the facility, it is necessary for the biodiesel producer to register or get approval from the Department of Energy Business (DOEB). The incentives provided to the oil blender are the tax exemption and payment exemption to the Oil Fund for B100. In addition, oil blender or oil trader get compensation for the price of biodiesel B100 from the Oil Fund. The Department of Energy Business (DOEB) also sets the retail price for 5% FAME blended diesel oil or so-called B5 high speed diesel oil cheaper than regular high speed diesel oil (B2) by at least 0.70 baht/Litre.

(3) Main crops for BDF and its production planning

Oil crops in Thailand are oil palm, soybean, coconut, castor, and sunflower. Recently, the Office of Agricultural Economics reported the harvesting area and production volume of oil crops in Thailand during 2004-2007 as shown in Table 44. Oil palm shows its potential to be the feedstock for commercial biodiesel production for Thailand. In 2007, oil palm presented as the main oil crop in which its harvesting area and production were 426,080 hectares and 6,390,000 tons.

Table 44 Harvesting area and production volume of oil crops during 2004-2007

Oil crops	2004		2005		2006		2007	
	Harvested area (Hectares)	Production (Tons)	Harvested area (Hectares)	Production (Tons)	Harvested area (Hectares)	Production (Tons)	Harvested area (Hectares)	Production (Tons)
Oil Palm	309,120	5,182,000	324,160	5,003,000	379,840	6,715,000	426,080	6,390,000
Soybean	145,920	218,000	144,160	226,000	137,600	215,000	128,800	204,000
Coconut	270,400	2,126,000	265,440	1,940,000	258,240	1,815,000	255,680	1,722,000
Castor	13,280	10,000	13,440	10,000	12,960	10,000	12,960	10,000
Sunflower	28,640	22,000	42,080	38,000	33,280	24,000	30,560	23,000

(Source: Office of Agricultural Economics 2007, http://www.oae.go.th)

Oil palm is the main feedstock for biodiesel production for Thailand. To meet the target of the national strategic plan for biodiesel development and promotion on the use of biodiesel fuel, the feedstock supplied for the biodiesel production is promoted accordingly. It is planned to promote the additional oil palm plantation area to 2.5 million rais or 400,000 hectares by 2012. According to the plan, its productivity will be improved to be 2.7-3.3 ton/rai-yr or 16.87-20.62 ton/hectare-yr.

Beside oil palm, jatropha and waste cooking oil also show its potential to be the feedstocks for community-based biodiesel production. At present, several R&D studies report the production of biodiesel from jatropha or physic nut oil (*Jatropha curcas* Linn) in Thailand. However, there are no report on harvesting area and production of jatropha. It is only planted in the experimental stations.

7.10.2 Standardization of BDF

(1) Concept of BDF standards and regulations

The Department of Energy Business under the Ministry of Energy set up the standard specifications for commercial-based and community-based biodiesel. The standard of commercial biodiesel, Fatty Acid Methyl Ester or so-called B100 was established by using EN 14214:2003 as a guideline. The FAME standard has been enforced since October 1, 2006. The B100 is used to be a FAME blend stock in regular high speed and B5 high speed diesel oils. In April 2009, the selling amount of regular high speed diesel oil was 9,980 million litres in every oil service stations, while the selling amount of B5 high speed was 8,155 million litres in 3,676 oil service stations.

The community-based biodiesel is used for agricultural engines in the communities and not allowed to be sold at any fuel service stations. Its standard specifications were notified on July 21, 2006.

(2) Specification values

Thailand has set the specifications for FAME or commercial biodiesel for blend stock, regular high speed diesel oil (or B2) and B5 high speed diesel oil. The standard specifications of FAME or biodiesel known as commercial-based biodiesel and their test methods are shown in the Table 45. The regular high speed diesel oil (B2), B5 high speed diesel oil and low speed diesel oil are shown in Table 46.

The introduction status of biodiesel fuel and B100 specifications for blending with diesel for retail sale are shown in Table 47 and Table 48, respectively.

Table 45 Thailand standard specification of biodiesel B100-FAME

Items	Fuel properties	Unit	Specification		
			Limit		Test method
1.	Methyl ester	% wt	min	96.5	EN 14103
2.	Density at 15° C	kg/m^3	min max	860 900	ASTM D 1298
3.	Viscosity at 40°C	CSt	min max	3.5 5.0	ASTM D 445
4.	Flash Point	°C	min	120	ASTM D 93
5.	Sulphur	% wt.	max	0.0010	ASTM D 2622
6.	Carbon Residue on 100% distillation residue	% wt	max	0.30	ASTM D 4530
7.	Cetane Number		min	51	ASTM D 613
8.	Sulfated Ash	% wt.	max	0.02	ASTM D 874
9.	Water	% wt.	max	0.050	EN ISO 12937
10.	Total Contamination	% wt.	max	0.0024	EN 12662
11.	Copper Strip Corrosion		max	No. 1	ASTM D 130
12.	Oxidation Stability at 110°C	Hours	min	10	EN 14112
13.	Acid Number	mg KOH/g	max	0.50	ASTM D 664
14.	Iodine Value	g Iodine/100 g	max	120	EN 14111
15.	Linolenic Acid Methyl Ester	% wt.	max	12.0	EN 14103
16.	Methanol	% wt.	max	0.20	EN 14110
17.	Monoglyceride	% wt.	max	0.80	EN 14105
18.	Diglyceride	% wt.	max	0.20	EN 14105
19.	Triglyceride	% wt.	max	0.20	EN 14105
20.	Free glycerin	% wt.	max	0.02	EN 14105
21.	Total glycerin	% wt.	max	0.25	EN 14105
22.	Group I metals (Na+K)	mg/kg	max	5.0	EN 14108 and EN 14109
	Group II metals (Ca+Mg)	mg/kg	max	5.0	prEN 14538
23.	Phosphorus	% wt.	max	0.0010	ASTM D 4951
24.	Additives	Approved by DG of Department of Energy Business			

(Source: Government Gazette, Volume 124, Special Section 62, 23 May 2007, p 7.)

Table 46 Thailand standard specification of diesel oil

Items	Fuel Properties	Limit	Diesel oil High speed Regular	 B5	 Low speed	Test method
1.	Specific Gravity at 15.6/15.6 °*C*	min	0.81	0.81	-	ASTM D 1298
		max	0.87	0.87	0.920	
2.	Cetane Number or					ASTM D 613
	Calculated Cetane Index					ASTM D 976
	Before 1 January 2012	min	47	47	45	
	From 1 January 2012	min	50	50	45	
3.	Viscosity, (*cSt*)					ASTM D 445
	3.1 at 40 °C	min	1.8	1.8	-	
		max	4.1	4.1	8.0	
	or 3.2 at 50 °C	max	-	-	6.0	
4.	Pour Point, (*°C*)	max	10	10	16	ASTM D 97
5.	Sulphur, (*%wt.*)					
	Before 1 January 2012	max	0.035	0.035	1.5	ASTM D 4294
	From 1 January 2012	max	0.005	0.005	1.5	ASTM D 2622
6.	Copper Strip Corrosion	max	No. 1	No. 1	-	ASTM D 130
7.	Oxidation Stability, (g/m^3)	max	-	25	-	ASTM D 2274
8.	Carbon Residue, (*%wt.*)	max	0.05	0.05	-	ASTM D 189
9.	Water and Sediment, (*%vol.*)	max	0.05	0.05	0.3	ASTM D 2709
10.	Ash, (*%wt.*)	max	0.01	0.01	0.02	ASTM D 482
11.	Flash Point, (*°C*)	min	52	52	52	ASTM D 93
12.	Distillation, (*°C*)					ASTM D 86
	(90% recovered)	max	357	357	-	
13.	Polycyclic Aromatic Hydrocarbon,					ASTM D 2425
	Before 1 January 2012	-	-	-	-	
	From 1 January 2012	max	11	11		
14.	Colour					
	14.1 Hue		-	green	-	
	14.2 Dye, *(mg/L)*	min	-	4.0	-	
	14.3 Intensity	min	-	-	4.5	ASTM D 1500
		max	4.0	-	7.5	
15.	Methyl Ester of Fatty Acid, (*%vol.*)	min	1.5	4	-	EN 14078
		max	2	5	-	
16.	Lubricity, (μm)	max	460	460	-	CEC F-06-A-96
17.	Additives (if any)	Approved by DG of Department of Energy Business				

(Source: Government Gazette, Volume 125, Special Section 10, 16 January 2008, p 1 and Government Gazette, Volume 125, Special Section 124, 29 July 2008, p 1)

Table 47 Current status of biodiesel fuel in Thailand

Country	Mixing rate	Main Feedstocks	Strategy / Goal	Standard
Thailand	B2 (2008) B5 (optional)	Palm	Biodiesel Development and Promotion Strategy nationwide / Mandate B2 in Feb. 2008, Optional B5 (4.5 ML/D in 2022 target)	Have DOEB-2006 (B100 Community level) DOEB-2007 (B100 Industrial level) DOEB-2008 (B2 and B5)

Table 48 B100 specifications for blending with diesel for retail sale in Thailand

Items	Units	U.S.	EU	Thailand	EAS-ERIA BDF Standard (EEBS):2008
		ASTM D6751-07b	EN14214:2003	DOEB: 2009	
Ester content	mass%	-	96.5 min.	96.5	96.5 min.
Density	kg/m3	-	860-900	860-900	860-900
Viscosity	mm2/s	1.9-6.0	3.50-5.00	3.5-5.0	2.00-5.00
Flashpoint	deg. C	93 min.	120 min.	120 min	100 min.
Sulfur content	mass%	0.0015 max.	0.0010 max.	0.0010 max	0.0010 max.
Distillation, T90	deg. C	360 max.	-	-	-
Carbon residue (100%) or Carbon residue (10%)	mass%	0.05 max. -	- 0.30 max.	- 0.30 max.	0.05 max. 0.3 max.
Cetane number		47 min.	51.0 min.	51.0 min	51.0 min.
Sulfated ash	mass%	0.02 max.	0.02 max.	0.02 max	0.02 max.
Water content	mg/kg	0.05[vol%] max.	500 max.	0.05[Wt%] max	500 max.
Total contamination	mg/kg	-	24 max.	24 max.	24 max.
Copper corrosion		No.3	Class-1	Class-1	Class-1
Acid value	mgKOH/g	0.50 max.	0.50 max.	0.50 max.	0.50 max.
Oxidation stability	hrs.	3 min.	6.0 min.	10.0 min.	10.0 min. (****)
Iodine value	g Iodine/100 g	-	120 max.	120 max.	Reported (***)
Methyl Linolenate	mass%	-	12.0 max.	12.0 max.	12.0 max.
Polyunsaturated FAME (more than 4 double	mass%	-	1 max.	-	N.D. (***)
Methanol content	mass%	0.2 max. (*)	0.20 max.	0.20 max.	0.20 max.
Monoglyceride content	mass%	-	0.80 max.	0.80 max.	0.80 max.
Diglyceride content	mass%	-	0.20 max.	0.20 max.	0.20 max.
Triglyceride content	mass%	-	0.20 max.	0.20 max.	0.20 max.
Free glycerol content	mass%	0.020 max.	0.02 max.	0.02 max.	0.02 max.
Total glycerol content	mass%	0.240 max.	0.25 max.	0.25 max.	0.25 max.
Na+K	mg/kg	5 max.	5.0 max.	5.0 max.	5.0 max.
Ca+Mg	mg/kg	5 max.	5.0 max.	5.0 max.	5.0 max.
Phosphorous content	mg/kg	10 max.	10.0 max.	10.0 max.	10.0 max.

7.11.1 Vietnam

7.11.1. Policy and Measure of BDF

(1) Target and strategy from energy and environment point of view

On 20 November 2007, Vietnam Government released the Decision 177/QD-TTg signed by Prime Minister, this Decision 177/QD-TTg approving the “Project for development of bio-fuel by 2015, with prospect to 2025”. The Decision 177/QD-TTg states: Developing bio-fuel, a new source of renewable energy is to partially substitute conventional fossil fuels and ensure energy security and environment protection, its main content is as follows:

The objective by 2010

- Establish and develop a test model for pilot production and use of bio-fuel in the scale of 100,000 tons of E5 and 50,000 tons of B5 per annum, meeting 0.4 % of the country's total demand for petroleum.
- By 2010 Vietnam plans to complete 5 biofuel plants to meet a small part of domestic demand for petrol and diesel.
- The 5 plants will churn out a combined 100,000 tons of ethanol 5 percent gasoline (E5) and 50,000 tons of biodiesel 5 percent (B5) per year to meet 0.4 % of national demand.
- The plants will use cassava and sugarcane as feedstock.

The objective for the period 2011-2015

- Develop establishments producing and using biofuels nationwide.

The objective for the period by 2015

- Ethanol and vegetable oil outputs are projected to reach 250,000 tons, meeting 1 % of the country's total demand for petroleum.

(2) Targets/strategies/regulations/incentives for BDF

Vietnam National Standards (TCVN)

In the year 2007, Ministry of Science and Technology of Vietnam declared voluntary Vietnam National Standard for biodiesel. TCVN 7717: 2007 Biodiesel fuel blend stock (B100) – Specification. This TCVN 7717: 2007 is prepared on the base of ASTM D 6751–06e1 and EN 14214:2003

In June 2009, Vietnam National Standards on B5 was declared and published by the Ministry of Science and Technology of Vietnam: TCVN 8064:2009, 5 % fatty acid methyl esters blended diesel fuel oils – Specification.

Vietnam National Regulation (QCVN)

In September 2009, the Minister of Ministry of Science and Technology of Vietnam approved the first National Technical Regulation (regulations are mandatory): QCVN 01:2009/BKHCN National Technical Regulation on gasoline, diesel fuel oils and biofuels. Among other requirements, the regulation specified the mandatory properties for: (1) Diesel fuel oils and biodiesel B5 and (2) Biodiesel fuel blend stock (B100).

(3) Main crops for BDF and its production for planning

Biodiesel produced from catfish fat as Basa fish: From Mekong River Delta with estimated production capacity of catfish of 10 million litres a year (Agrifish Company)

7.11.2 Standardization of BDF

The quality of diesel in Vietnam is regulated by Vietnam National Technical Regulation QCVN 01: 2009/BKHCN and Vietnam national Standards TCVN 5689: 2005 Diesel – Specifications. For biodiesel fuel blend stock (B100), Table 49 shows the specification regulated by TCVN 7717: 2007, prepared on the base of ASTM D 6751–06e1 and EN 14214:2003. Table 50 shows the comparison with other biodiesel standard.

Table 49 Biodiesel fuel blend stock (B100) specifications in Vietnam

Property		limit	Test methods*
1.Ester, % m/m	min	96,5	TCVN (EN 14103)
2.Density,15 oC, kg/m3		860-900	TCVN (ASTM D 1298)
3.Flash point, oC	min	130.0	TCVN (ASTM D 93)
4.Water and sediment, % v/v	max	0,05	TCVN (ASTM D 2709)
5. Viscosity, 40 oC, mm2/s		1.9-6.0	TCVN (ASTM D 445)
6.Sulphated ash, % m/m	max	0.020	TCVN (ASTM D 874)
7.Sulfur, % m/m	max	0.05	TCVN (ASTM D 5453)
8.Copper strip corrosion	No.	No.1	TCVN (ASTM D 130)
9.Cetane number	min	47	TCVN (ASTM D 613)
10.Cloud point, oC	max	Report	TCVN (ASTM D 2500)
11. Carbon residue, % m/m	max	0.050	TCVN (ASTM D 4530)
12.Acid number, mgKOH/g	max	0.05	TCVN (ASTM D 664)
13.Iod value, g iod/100g	max	120	TCVN (EN 14111)
14.Oxydation stability, h	min	6	TCVN (EN 14112)
15.Free Glycerin, %m/m	max	0.020	TCVN (ASTM D 6584)
16.Total Glycerin, % m/m	max	0.240	TCVN (ASTM D 6584)
17.Phosphous, % m/m	max	0.001	TCVN (ASTM D 4951)
18.Distillation, 90 %, oC	max	360	TCVN (ASTM D 1160)
19. Na and K	max	5.0	TCVN (EN 14108 and EN 14109)

*TCVN test method is equivalent to ASTM/EN test method.

Table 50 EAS-ERIA Biodiesel Fuel Standard 2008 compared to Vietnam existing standard TCVN 7717: 2007 (B100).

Items	Units	U.S.	EU	Vietnam	EAS-ERIA Biodiesel Fuel Standard:2008
		ASTM D6751-07b	EN14214:2003	TCVN 7717:2007	
Ester content	mass%	-	96.5 min.	96.5 min.	96.5 min.
Density	kg/m3	-	860-900	860-900	860-900
Viscosity	mm2/s	1.9-6.0	3.50-5.00	1.90-6.00	2.00-5.00
Flashpoint	deg. C	93 min.	120 min.	130 min.	100 min.
Sulfur content	mass%	0.0015 max.	0.0010 max.	0.05 max.	0.0010 max.
Distillation, T90	deg. C	360 max.	-	360 max.	-
Carbon residue (100%) or Carbon residue (10%)	mass%	0.05 max. -	- 0.30 max.	0.050 max. -	0.05 max. 0.3 max.
Cetane number		47 min.	51.0 min.	47.0 min.	51.0 min.
Sulfated ash	mass%	0.02 max.	0.02 max.	0.020 max.	0.02 max.
Water content	mg/kg	0.05[vol%] max.	500 max.	.05[vol%] max	500 max.
Total contamination	mg/kg	-	24 max.	-	24 max.
Copper corrosion		No.3	Class-1	No.1	Class-1
Acid value	mgKOH/g	0.50 max.	0.50 max.	0.50 max.	0.50 max.
Oxidation stability	hrs.	3 min.	6.0 min.	6.0 min.	10.0 min. (****)
Iodine value		-	120 max.	120 max.	Reported (***)
Methyl Linolenate	mass%	-	12.0 max.	-	12.0 max.
Polyunsaturated FAME (more than 4 double bonds)	mass%	-	1 max.	-	N.D. (***)
Methanol content	mass%	0.2 max. (*)	0.20 max.	-	0.20 max.
Monoglyceride content	mass%	-	0.80 max.	-	0.80 max.
Diglyceride content	mass%	-	0.20 max.	-	0.20 max.
Triglyceride content	mass%	-	0.20 max.	-	0.20 max.
Free glycerol content	mass%	0.020 max.	0.02 max.	0.020 max.	0.02 max.
Total glycerol content	mass%	0.240 max.	0.25 max.	0.240 max.	0.25 max.
Na+K	mg/kg	5 max.	5.0 max.	5.0 max.	5.0 max.
Ca+Mg	mg/kg	5 max.	5.0 max.	-	5.0 max.
Phosphorous content	mg/kg	10 max.	10.0 max.	10.0 max.	10.0 max.

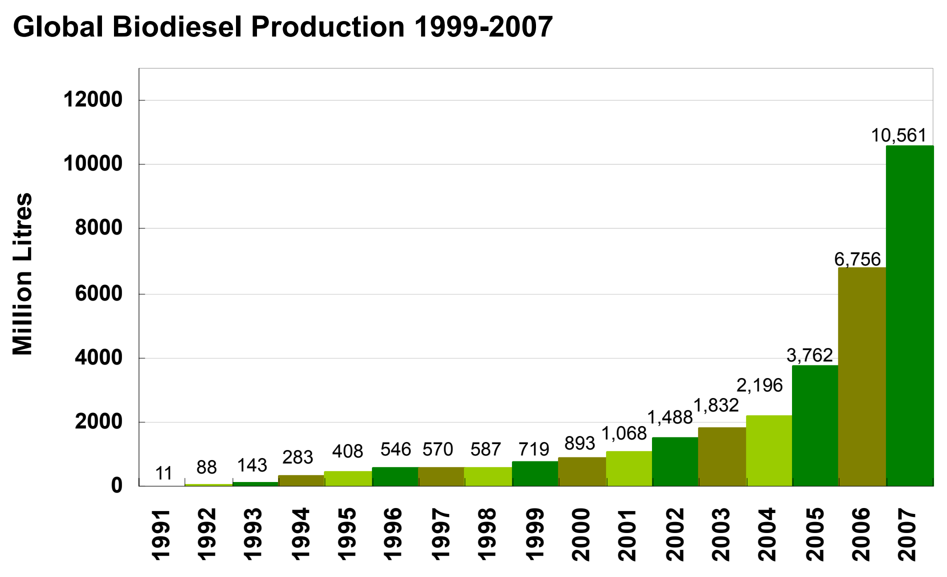
8. TRADE AND MARKET DYNAMICS OF BIODIESEL

8.1 Global Biodiesel Market

Over the past decade, global biodiesel market has been growing around the world [44] and the market growth is being driven mainly through three key factors:

(1) reduction of petroleum dependence;
(2) mandated biodiesel blends; and
(3) fiscal incentive.

The substantial growth of biodiesel production, also considered as biodiesel consumption, from 1999 to 2007 is shown in Figure 66.



Source: Adapted from Earth Policy Institute (2006) and Biodiesel Platform

Figure 66 World Biodiesel Production

An average world growth rate from 2002-2006 is estimated to be around 40% per annum. In 2005, global biodiesel production reached around 3,762 million litres with 85% of this production in Europe, 7% in the USA and 8% in the rest of the world (predominantly Brazil and China) [45], [46]. This resulted from specific biofuel support policies as well as the fact that diesel-fuelled vehicles are more widely used in Europe, Asia and Brazil than in the USA [45]. For the year 2007, a total world biodiesel production was 10,561 million litres, with 61% processed in Europe, 16% in the USA and 23% in the rest of the world, i.e. Indonesia, Brazil, China and Malaysia. Although, Europe is currently the biggest producer and consumer of biodiesel in the world, the

United State is accelerating its biodiesel production capabilities. In addition, Brazil is expected to surpass European and the United States production by 2015 [47]. More detailed information on biodiesel production and consumption in EU, USA, Asia and Brazil is provided below.

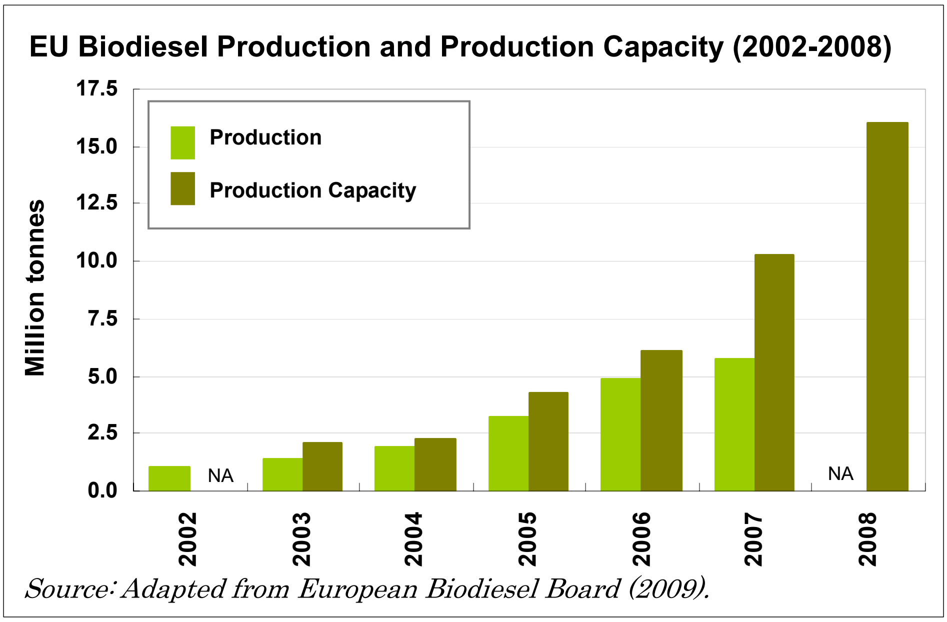
8.1.1 The European Union (EU)

The biodiesel production capacity has increased in the EU as a result mainly from the biodiesel blending target set by the EU of 2% in 2005, 5.75% in 2010 and 8% in 2015. Based on the total diesel fuel consumption and these blending targets of biodiesel, the estimates of biodiesel consumption from 2005 to 2010 is shown in Table 51. Although the EU could achieve their first target of 2% in 2005, achieving their next target (5.75% by 2010 and 8% by 2015) will depend mainly on feedstock availability, government commitment and market economics [48]. Figure 67 shows the biodiesel production and production capacity of the EU from 2002 to 2008[49]. In 2007, the biodiesel production in the EU was over 5.7 million tonnes with an increase of 16.8% from the production in 2006. For the most of the EU countries, the production capacity is two to three times higher than the actual production and this is mainly caused by the availability of feedstocks. According to Frost & Sullivan, Europe’s terrestrial biodiesel feedstock availability will not be able to meet the 5.75% EU blending target in 2010 [50].

Table 51 Biodiesel Action Plan of the EU and demand according to the plan

Estimate	2005	2010	2015
Quantity target (%)	2%	5.75%	8%
Diesel fuel consumption (million tons)	158.6	165	165
Diesel fuel consumption (million litres)	188,810	196,429	196,429
Biodiesel demand (million tons)	3.69	11	16.7
Biodiesel demand (million litres)	4,155	12,387	18,806

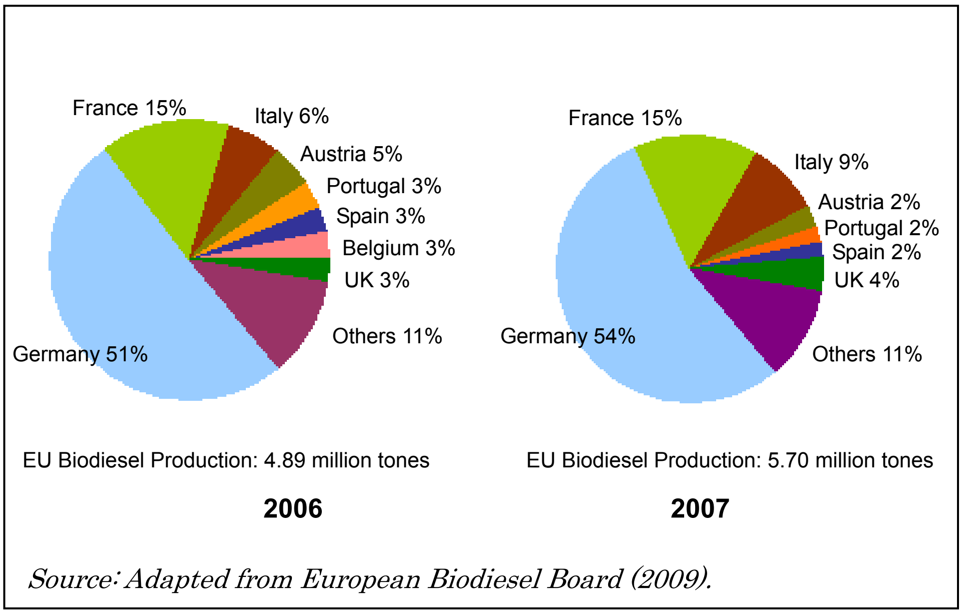
(Source data: Adapted from [51])



Source: Adapted from European Biodiesel Board (2009).

Figure 67 Biodiesel production and installed capacity of the European Unions

Figure 68 shows a breakdown of biodiesel production in the European Union for 2006 and 2007. Germany is the world's leader in producing biodiesel in terms of capacity as well as plant technologies [51]. Germany will be the first member state fulfilling the EU-promotion directive in the diesel market.



Source: Adapted from European Biodiesel Board (2009).

Figure 68 A breakdown of biodiesel production in the European Union

In 2008 the biodiesel capacity stood at 15.1 million tons/year, a 30% increase from the capacity of 11.6 million tons at the end of 2007, with new plants coming online in Spain, Italy and France. Despite this increase most capacity remained idle in 2008 due to lack of consumption and increase in imports [52].

In 2008 German biodiesel consumption fell by 14% to 2.8 million tons from 3.3 million tons in 2007. This was mainly a result of the sharp drop in B100 (pure biodiesel) consumption from 1.8 million tons to 1.2 million tons in 2008. The biodiesel share in low blends actually increased in 2008 compared to 2007 from 4.9 wt% in 2007 to 5.5 wt% in 2008. [53].

EU Renewable Energy Directive and amended Fuel Quality Directive - April, 2009

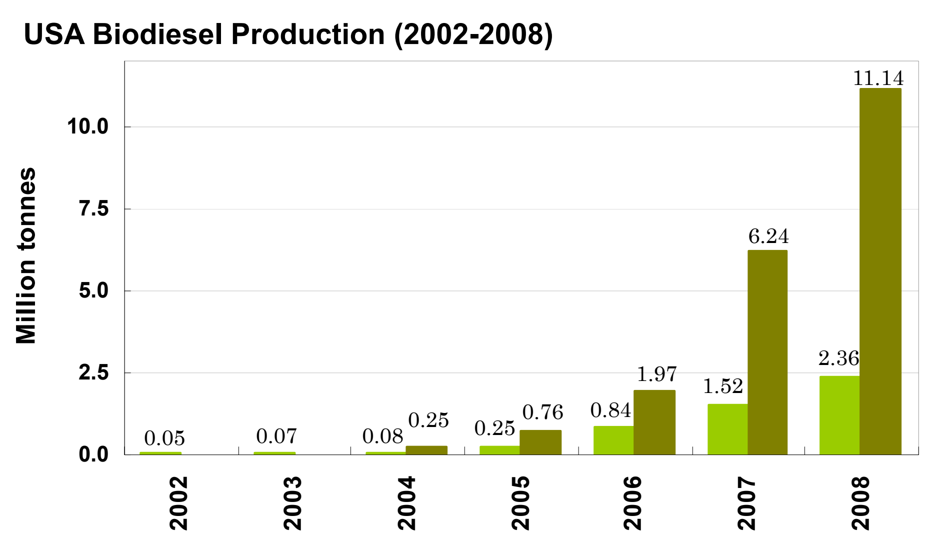
The recently announced Renewable energy Directive (RED) and the amended Fuel Quality Directive signal a move away from the drivers of the Biofuels Directive – agricultural support, fuel security and environmental protection – and directly targets climate change and GHG reductions. The RED calls for a 20% share of renewable energy in the EU's total energy consumption by 2020 – 10% share of energy from renewable sources in each member state's transport energy consumption. The 10% target aims ensures consistency in transport fuel specifications and availability. The directive also establishes:

- Sustainability criteria – biodiversity, protection of rare, threatened or endangered species and ecosystems, and greenhouse gas savings;
- CO_2 standards for new passenger cars (2012); and
- New environmental quality standards for fuels and biofuels.

The standards for fuels facilitate more widespread blending of biofuels into petrol and diesel and, avoid negative consequences, sets ambitious sustainability criteria for biofuels. For the first time a GHG target for fuels will be in place requiring a 6% decrease over entire life-cycle of product by 2020. This can be reached by mixing biofuels, as well as improving production technology in refineries. The directive allows for 7 vol% FAME content in diesel or more if marked at the pump [52], [54].

8.1.2 The United States

In the USA, interest in biodiesel is stimulated by the Clean Air Act of 1990 combined with regulations requiring reduced sulphur content in diesel fuel and reduced diesel exhaust emissions. In the USA, biodiesel industry efforts are mostly concentrated in four markets and these are urban transit, government/regulated fleets, marine and underground mining. Biodiesel is used in three primary applications to address three different market segments: B100 (neat Biodiesel); B20 (20% Biodiesel/80% fossil diesel); and B2 (2%Biodiesel). The largest market is probably within Energy Policy Act-affected fleets, which requires covered fleets to use alternative fuels. Figure 69 shows the US biodiesel production in 2002 to 2008 [55], [56]. The nascent US market for biodiesel is growing at a staggering rate from 0.25 million tonnes in 2005 to 0.84 million tonnes in 2006. The amount of biodiesel produced grew more than threefold over the course of that period. Biodiesel production was estimated to reach 1.52 million tonnes by the end of 2007 and to reach 2.36 million tonnes by the end of 2008. As of 2008, a total production capacity was around 8.81 tonnes [56]. The USA is considered as the second largest biodiesel producer and/or consumer in the world after Germany.



Source: Adapted from The National Biodiesel Board - USA (2009) and Thurmond, W. (2008).

Figure 69 Biodiesel production and installed capacity in the USA

Proposed Renewable Fuel Standard (RFS2)

In May 2009 the US Government announced the release of a Notice of Proposed Rule Making (NPRM) on the expansion of the Renewable fuel Standard (RFS2) program. The NPRM proposes regulatory requirements for increasing the RFS under the Energy Independence and Security Act of 2007, which mandates that the country's motor fuel supply use 36 billion gallons (136 billion litres) of renewable fuel per year by 2022. The 2009 renewable fuels volume requirement is 1.10 billion gallons (4 billion litres), of which 0.500 billion gallons (1.9 billion litres) is to come from biomass-based diesel fuel and 0.100 billion gallons (0.38 billion litres) from non-cellulosic advanced biofuel. Lifecycle greenhouse gas reductions relative to lifecycle emissions from gasoline and diesel fuel (baseline fuels) have been proposed for renewable fuel, advanced biofuels, biomass-based diesel and cellulosic biofuel. 'Biomass-based diesel' - includes biodiesel, non-ester renewable diesel and any other diesel fuel made from renewable biomass as long as it is not 'co-processed' with petroleum. It must achieve a lifecycle GHG emission displacement of 50% compared to the gasoline or diesel fuel it replaces [57].

The California Air Resources Board (CARB) released a proposal for a Low Carbon Fuel Standard (LCFS) in March 2009. This policy aims to reduce California’s transportation fuels by 10% by 2020, and proposes lifecycle GHG emissions targets including measurement of the carbon intensity of fuels and signals a push to advanced low carbon fuels (non-crop based).

The US EPA has proposed that atmospheric concentrations of GHGs endanger public health and welfare within the meaning of the Clean Air Act and propose that the emissions of a mix of some GHGs from new motor vehicles and new motor vehicle engines are contributing to air pollution, which is endangering public health and welfare. Comprehensive climate change legislation is being considered in Congress in late April 09 that includes a provision to require a low carbon fuels standard (LCFS) nationwide.

8.1.3 Asia

Most Asian countries are significant agricultural producers and have excess production of commodities that could be used for biodiesel production (such as palm and coconut). The largest palm oil producers in the world are located in Malaysia and Indonesia creating huge potential for biodiesel production. In addition the Philippines is the world’s largest coconut producer and exporter. Furthermore, Thailand and Vietnam are agricultural-based countries that are able to grow various kinds of crops as feedstock to meet national and global biofuels demand. Countries such as Japan, Singapore and South Korea would most likely depend on biodiesel and/or feedstock imports because of a lack of sufficient land to produce domestic feedstock for biodiesel. In the Asia-Pacific region the existing total annual capacity (see Table 52) for biodiesel production is 12.5 billion litres (3.3 billion gallons) (2008) with a further 38.5 billion litres (10.2 billion gallons) per year capacity planned [58].

Table 52 Biodiesel production capacity in Asia Pacific by Country (million liters per year)

Country	Existing	Under Construction
China	3,526	3,358
Indonesia	3,488	909.09
Japan	4.72	-
Malaysia	3,120	2,205
New Zealand	33.61	95
Philippines	447.14	34.09
Singapore	986.36	-
South Korea	653.64	-
Thailand	1,770	406.82
Vietnam		11
Total :		

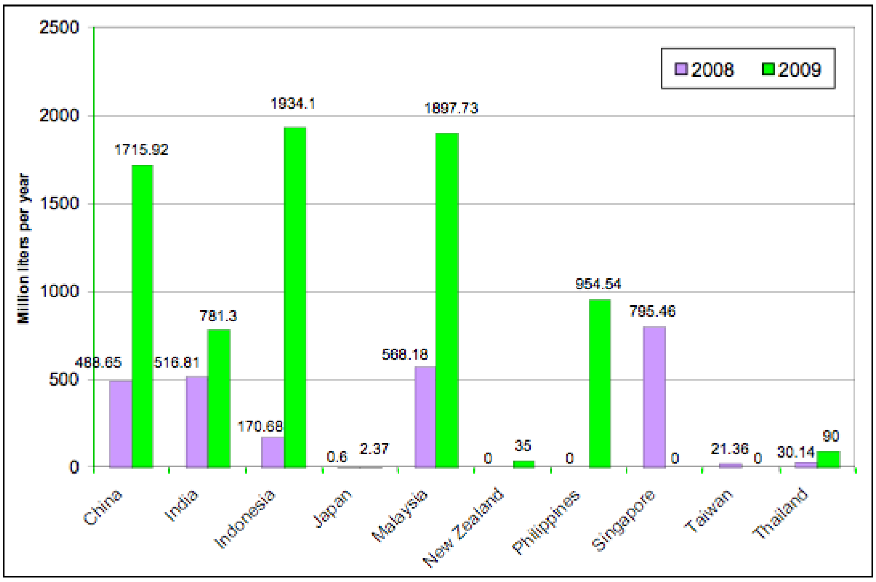
(Adapted from [58])

Million liters

Country	Present Capacity	Sale/Production		
		2007	2008	2009
Australia[a]	273			
China				
Indonesia	3,488	40	125	398
Japan	7			
Malaysia	3,120	108	207	258
New Zealand				
Philippines	396	49	65	131
Singapore	1,136			
South Korea	1,120	109	196	292
Thailand	1,770	392	460	607
Vietnam[*]		-	6	6
Total :				

[a] Department of Resources, Energy and Tourism.
[*] MINH TU company and Vietnam Institute of Industrial Chemistry (VIIC)

In 2008 the Asian biodiesel industry saw a capacity increase of 2.59 billion litres (648.2 million gallons) coming mainly from Singapore, Malaysia, India and China, with a further 7.41 billion litres (1.96 billion gallons) of new capacity expected to start operations in 2009 in several Asian countries. Figure 70 shows new and expanded biodiesel capacity in 2008 and outlook for 2009 in the Asia Pacific, which clearly shows China, Indonesia and Malaysia as the major growth areas in new biodiesel capacity in the region [58].



(Source data from [58])

Figure 70 New and Expanded Biodiesel Capacity in 2008 and Outlook for 2009 in Asia Pacific

China is one of the biggest diesel oil consumers in the world. About 60-70 million tons of diesel oil are used annually with approximately one third of it being imported to balance the market. China's government emphasized its support of biofuels sometime ago, but it seems that ethanol development is much faster than biodiesel. The potential markets are expected to grow rapidly: the vehicle ownership rate in China is 8.5 vehicles/1,000 persons and the number is projected to grow six fold by 2020 (52 vehicles/1,000 persons). Corresponding to these figures, transportation energy demand in China is projected to grow by 6.4%/year from 1999 to 2020, increasing its share of world energy use for transportation from 4.1% in 1999 to 9.1% in 2020. This indicates that China will become the world's second largest consumer of transportation fuels [59]. Although China has a target to replace from 5% to 20% of total petrodiesel consumption with biodiesel, there is no clear implementation plan of mandate of biodiesel blend. However, biodiesel production is expected to expand rapidly as China now consumes twice as much diesel as gasoline.

There is currently no national policy to use biodiesel in China. Local plants are only supplying captive fleets with biodiesel produced from waste cooking oil, which is limited in supply. Many plants have been proposed and a number of them are based on jatropha as China moves away from food-based feedstocks [58].

In countries such as Indonesia, Malaysia, Thailand and India, the aim of respective Government policy is for domestic biodiesel production to substitute diesel imports and be a support mechanism for the agricultural sector.

Mandates in the region include B1 mandates in Taiwan and Indonesia and B2 mandates in Thailand (2008), the Philippines (Feb 2009) and South Korea (2010). In Malaysia a B5 mandate was set in February 2009, for B2 use in Government agencies own depots. In June 2009 the mandate extends to industrial sectors and the to the transport sector in January 2010.

In Thailand, the production capacity is about 365 million litres (0.32 million tonnes) in 2007. The target of the Government is to mandate B2 by 2008 and to increase to 4.5 ML/D by 2022. In 2008, no new plants were known to come online in Australia, New Zealand or the Philippines. High tallow prices had a negative impact on the Australian and New Zealand markets. The repeal of the Biofuel Bill at the end of December 2006 in New Zealand has meant that biodiesel plants expected to come online in 2009 would most likely wait until financial support from the government is granted [58]. ExxonMobil announced a B5 trial in April 2009, becoming the first company to market biodiesel in the country. The biodiesel will be produced from tallow and the B5 product will be available in a trial marketing test in the Bay of Plenty.

In Australia a number of Government reviews relating to biofuels policy, including taxation treatment of fuels and broader energy policy, as well as the development of an emissions trading scheme, once completed, will have an impact on the biodiesel industry. A B2 mandate was announced by the NSW Government in December 2008 and is expected to be in place by January 2010. The current consumption of diesel transport fuel in NSW is 4,000ML p.a. and a B2 mandate would equate to 80ML of biodiesel. This is approximately equal to the current production volume nationwide. The NSW Government has indicated an increase to 5% (B5) in 2012 or as supply is available. At this stage it is planned that there will be sustainability criteria provisions linked to this mandate.

Public transportation and captive fleets are being supplied with biodiesel in India. Also, a number of producers have been exporting to the EU and the US. The industry is expected to grow in the next year, although not as rapidly as Malaysia and Indonesia, in the absence of a biodiesel blending requirements and maturity of large-scale jatropha plantations at this stage [58].

Despite high palm oil prices in early 2008 170 million liters (44.91 million gallons) of biodiesel capacity came online in Indonesia. With a subsequent drop in palm oil prices a number of producers are expected to start operating during 2009 to help meet the demand for the B1 blending requirement, which was expanded nationwide in January 2009 [58].

In the Philippines the Biofuels Act came into effect in May 2007 requiring a minimum biodiesel blend of 1 vol% increasing to 2 vol% in February 2009.

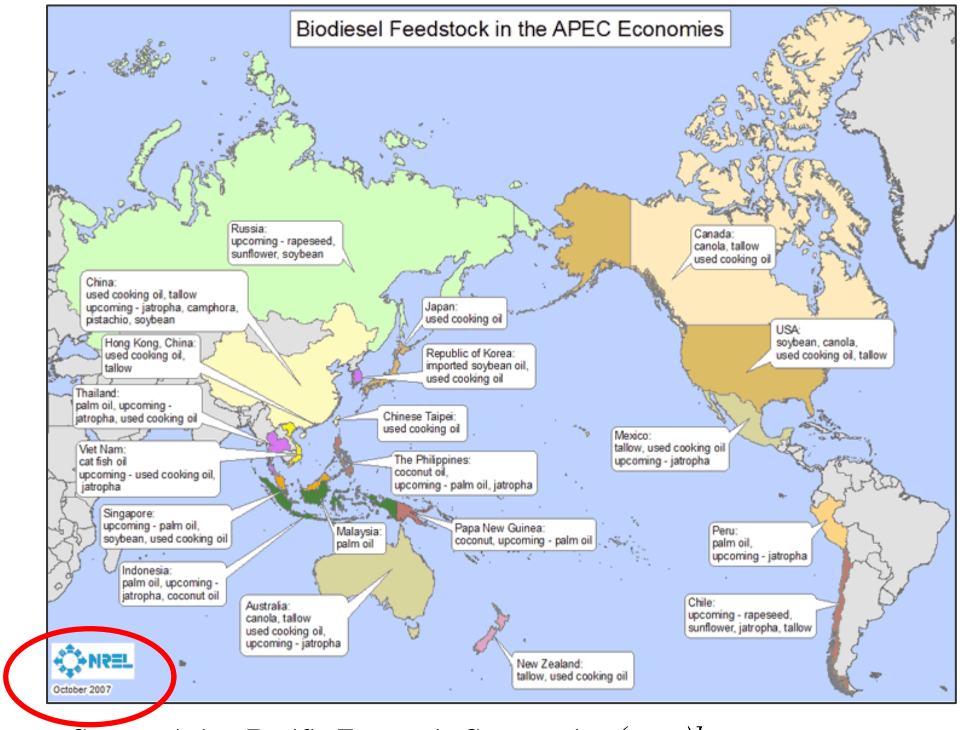
8.1.4 Brazil

Brazil has been a leader in biofuel production for many years starting with its production of ethanol after the fuel crisis in the 1970s. Brazil's biodiesel law developed in 2004 created the National Biodiesel Production and Use Program, which established a mandate of a minimum blend of 2% biodiesel blend from January to June 2008. Production capacity was estimated at five times that needed to meet the demand established by the blending mandate. Hence, in 2008, the mandatory blend was increased to 3% in order to offset the excess production capacity. Brazil has 56 biodiesel plants authorized by the government to produce biodiesel, with new projects awaiting approval. 80% of the feedstock used for biodiesel is soybean oil and 15% is animal fats. Current capacity is approximately 1.1 billion gallons (3.8 million tonnes). Production in 2007 was estimated to be 106.2 million gallons (0.36 million tonnes) while 2008 production is estimated at 290.6 million gallons (0.97 million tonnes). Unlike other countries in the region, it appears that Brazil could meet their minimum blending requirements for 2008 [60].

8.2 Biodiesel Price vs Diesel Price

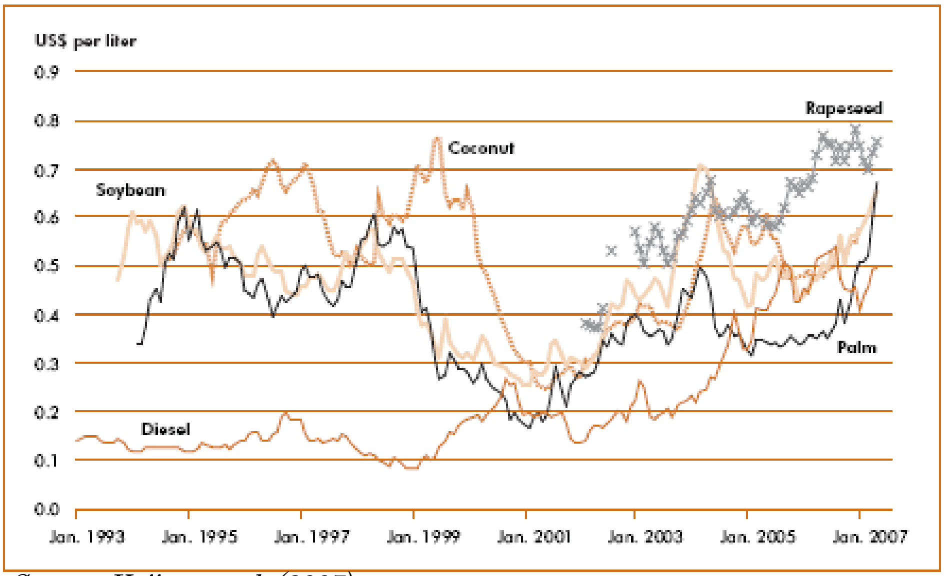
It is evident that the feedstock is the single largest component of biodiesel production cost [61] and it can account for up to 70% of the production cost. The feedstock cost can vary significantly from region to region due to types and availability of the feedstock. Figure 71 shows the biodiesel feedstocks used in the APEC region and these include palm oil, canola oil, rapeseed oil, Jatropha oil, used cooking oil and tallow. As for the EU countries, the biodiesel feedstock is focused on rapeseed and canola oil.

Figure 72 shows historical prices of coconut, soybean, palm and rapeseeds oil versus diesel and it shows that biodiesel has remained relatively expensive: biodiesel feedstock costs have generally been higher than petroleum diesel prices [62]. Since the feedstock is the most costly part of biodiesel production and the feedstock cost has risen very much in the last few years with the result that many biodiesel plants are being under-used or not used at all, awaiting a cheaper feedstock. The graph below also provides an indication of the production costs of biodiesel from various feedstocks, illustrating the cost advantage fossil diesel has over biodiesel. It also demonstrates that palm oil-based biodiesel is less expensive than rapeseed-oil based biodiesel, produced domestically in the EU countries [63].



Source: Asian Pacific Economic Cooperation (2008)].

Figure 71 Biodiesel Feedstock around the world

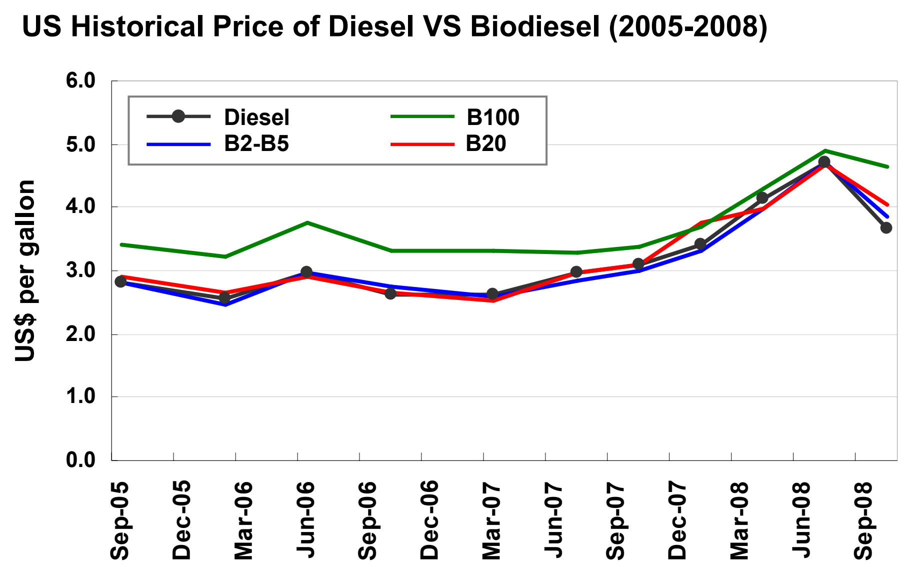


Source: Kojima et al. (2007).

Figure 72 Historical prices of coconut, soybean, palm and rapeseeds Oil versus diesel

8.2.1 The United States

For the USA, the biodiesel price also varies from area to area with a national B100 average price of US$ 4.64 per gallon or US$1.22 per litre in October 2008 while a national average petrol diesel price was US$ 3.65 per gallon or US$ 0.96 per gallon. Figure 73 shows the historical price of diesel versus biodiesel in the USA from 2005 to 2008 [64]-[66]. From September 2005 through July 2008, petroleum diesel has typically been less expensive than biodiesel. The greater amount of biodiesel in the biodiesel blend, the higher the cost, with B100 being the most expensive. However, the price gap has been narrowing between 2007 and 2008. This was probably due to the rising price of petroleum oil during that period. It should be noted that there are tax incentives for blenders of US$ 1.00/gallon (27 cents/litre) for biodiesel and US$ 0.51/gallon (13.5 cents/litre) for ethanol according to The Energy Policy Act of 2005. According to the information reported by Asian Pacific Economic Cooperation (2008) provided by EarthFirst Americas Incorporated (EFA), the palm oil-based biodiesel was imported twice from Ecuador at the end of 2005 and early 2006. The second shipment totals 3 million litres, a substantial increase from the first shipment of 1 million litres. The announcement was received with a negative reaction be the American Soybean Association (ASA) and called on the Congress to establish protectionist measures to block imported biodiesel from competing with the domestic soy-based product. The US biofuels market will unlikely grow substantially in the next few years given the increased domestic production. In fact, some analysts predict that the US biofuels market could become independent of imports in the next 1 to 2 years [67].

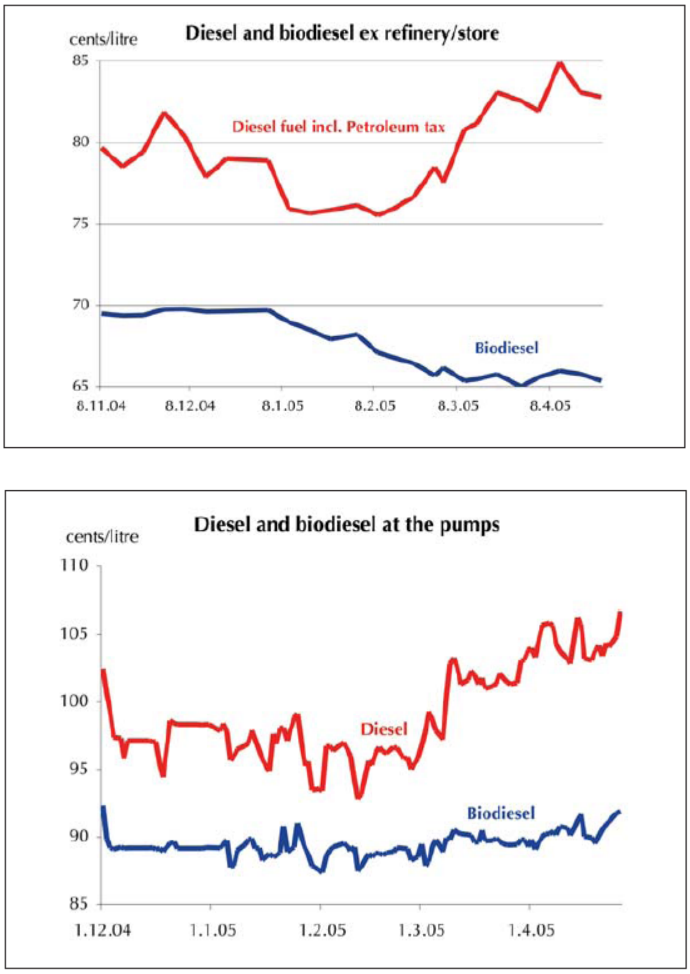


Source: U.S. Department of Energy (2008).

Figure 73 US historical price of diesel versus biodiesel from 2005 to 2008

8.2.2 The EU

Although the rapeseed oil is the most commonly used feedstock in EU countries, the *net production cost* of biodiesel still varies slightly from 0.8 Euro per litre in one region to 1.25 Euros per litre in another [47]. Figure 74 shows historical prices of biodiesel versus diesel during 2004 to 2005 in Germany, the largest biodiesel producer and consumer. Over the mentioned period, the price differences between diesel and biodiesel at the petrol stations were around 11 euro cents per litre with a price of diesel on gas-station of around 1.11 Euro (1.44 USD) per litre inclusive petroleum tax, compared with 1 Euro (1.3 USD)/litre for biodiesel [68]. The biodiesel production seems to be profitable for many companies. However, biodiesel can be profitable when it is subsidized, usually by a reduction in fuel tax. But subsidies can be given and subsidies can be taken away, making for uncertainty.



Source: Bockey, D (2005).

Figure 74 German historical price of diesel versus biodiesel

For example in Germany there have been significant impacts on biodiesel production and consumption with changes to taxation regimes. The German Union for the Promotion of Oil and Protein Plants (UFOP) reported that for the first two months of 2009 the price difference in Germany between biodiesel and diesel was €0.20 (US$0.27) per litre in favour of diesel, the highest negative difference for biodiesel since July 2006 following the introduction of the biodiesel tax in August 2006. This leads the association to predict that biodiesel consumption is likely to fall even further in 2009. This situation will be further aggravated if the Bundestag ratifies the proposed reduction of biofuels quotas this spring, to which UFOP is opposed [53].

9. FUTURE VISION

In this handbook, Fatty Acid Methyl Ester (FAME) which is called "First-generation biodiesel fuel" was mainly focused as biodiesel fuels. At this moment, FAME is one of better countermeasures against global warming in automobile section because of an ease to produce (low-technology and low-cost of equipment compared to petroleum refinery). However, FAME has some problems of the fuel properties, impingement on food prices, water resources, and so on. Especially, fuel properties are serious matter for automobile utilization. In this chapter, R&D trend/challenge of "Feedstock", "Next Generation Biodiesel Fuels" and "Sustainability of Biodiesel Fuel" are discussed as a helpful consideration of the future vision, namely, what should we do to prevent global warming in automobile section.

9.1 Feedstock challenge

The very dominant role of crude oil and petroleum fuels in the energy economy has a root in the fact that, among all the forms of final commercial energy (electricity and various kinds of traded fuels), liquid fuels are the most valuable and most strategic. Nowadays, crude petroleum oil is continually becoming scarcer, whereas due to the economic development of all countries in this world, its demand and consumption keep on increasing. Consequently,

(1) our Earth planet is becoming uncomfortably warmer and,

(2) crude oil is becoming more & more expensive and thus jeopardizing energy security of those petroleum-importing developing countries having unfavorable financial position.

These clearly indicate that clean domestically-producible alternative liquid fuels are urgently needed.

Renewable, and thus conceivably clean, energy resources include solar radiation, hydropower, biomass, geothermal energy, wind energy, tidal current, wave energy, ocean thermal energy, and nuclear energy. Among all these primary energy sources, biomass is the only resource that could be easily converted to liquid fuels, namely biofuels; the other resources (which totally amount to a very much larger potential) are directly convertible only to electricity. At least for the short and medium terms future; therefore, the utilization of biomass resource to produce liquid biofuels is unavoidable. This is the reason why biofuel industry development has been becoming the mainstream activity in the energy sector of the whole world.

The emerging 2nd generation biofuel technologies will enable us to utilize non-edible raw material, namely lignocellulosic biomass. These, together with the presently established 1st generation biofuels technologies that later on should utilize surplus of edible feedstocks (sugar, starch, fatty oils), would allow the provision of biofuels (principally biodiesel and bioethanol) to be mutually supporting with the production/provision of food. Further to this encouraging development, however, we should also recognize that the increasing scarcity and price of crude oil, plus the increasing awareness of environment protection, will lead to a growing demand of not only biofuel, but also other plant-based (or bio-based) products that all this time compete less favorably with petrochemicals. Among these are natural elastomer, natural fibers, natural medicines and herbal products, bio-fertilizer, bio-pesticide, and bio-insecticide. Therefore, in order to minimize land requirement, the future choices of energy crops are the so called *multipurpose energy crops*. These are crops that would allow the production of biofuels to be mutually supporting with the production/provision of either food or other important bio-based products. Research and development priorities should thus be devoted to identification, cultivation and utilization of these crops.

As previously mentioned in Chapter 5, microalgae has received much attention in the recent years. Nonetheless, to make the production of biodiesel production from microalgae feasible, R&D needs have been identified as follows:

- Selection of strain: screening of strain should be done using target waste (wastewater, CO_2 etc.) incorporate with the focus on useful products from the beginning.
- Stress response: to obtain the most suitable strain, screenings of strain under the real out-door cultivation conditions should be considered.
- Culture stability: under the co-process with wastewater, C:N ratio of wastewater and microalgal biomass should be analyzed to develop proper (highly selective) cultivation medium for the selected strain.

9.2 Next Generation Biodiesel Fuels

9.2.1 Introduction

Fatty acid methyl ester (FAME) is produced by transforming raw oils and fats into methyl esters. However, FAME that is produced via the alkaline catalyst method easily picks up impurities. Then, not only are fuel properties different, depending on the type of raw oil/fat used, but there is also a high possibility to cause fuel deterioration due to lower oxidation stability, compared to conventional petroleum based fuel oil. These problems cause serious troubles when FAME is used in vehicles; therefore it is necessary to incorporate countermeasures in the production process. This can be done by upgrading the biofuel production and refining process, and by addition of antioxidants. Alternatively, a new biodiesel production method has been developed, and can be used instead of the alkaline catalyst method. As shown in Figure 75 [69], there are various bio-fuel production processes. One of them is the methyl-esterification process that transforms raw oil and fat feedstock into FAME. The second is the bio-fuel hydrogenation process that generates saturated hydrocarbons from raw oil and fat feedstock using a direct hydrogenation process. The third is a bio-Fisher-Tropsch [69] (bio-FT) process that generates saturated hydrocarbons using Fisher-Tropsch synthesis, with hydrogenated decomposition after gasification of wood products and waste materials.

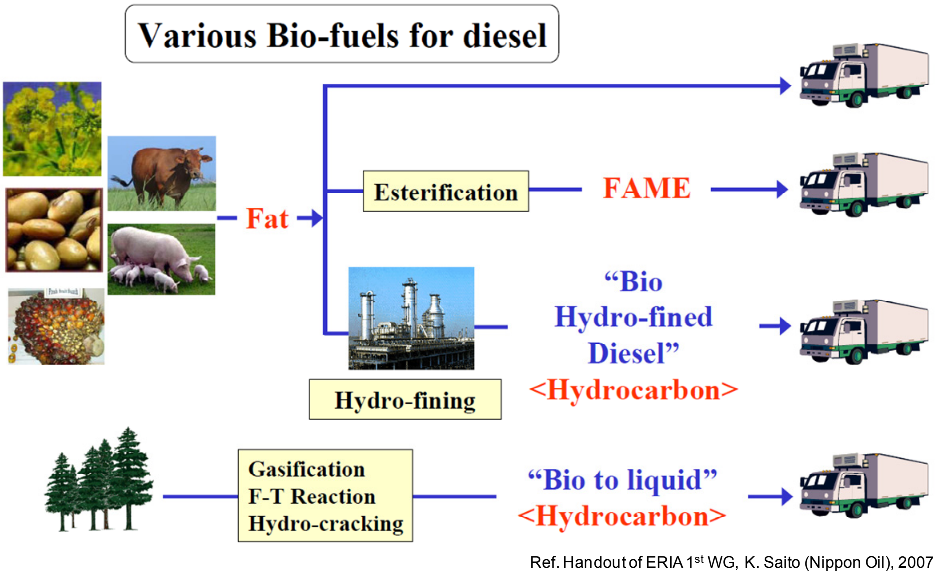


Figure 75 Various bio-fuel production processes

This section will discuss recent trends of hydrogenated biofuel production processes that are expected to be contenders for production of the next generation biodiesel fuel.

9.2.2 Hydrogenated bio-fuel

Since raw oils and fats contain high levels of glycerin, they tend to have a high viscosity and a high boiling point, which generally prevents direct use as motor fuels. As shown in Figure 76 [69], it is possible to remove glycerin through a conventional esterification process; however the molecular structure tends to develop a number of double-bonds, depending on the specific raw material. Thus its stability is inferior to conventional petroleum based fuel (diesel fuel). In the hydrogenated bio-fuels production method, on the other hand, the incoming glycerin-rich raw oils and fats are processed with hydrogenation and deoxygenation treatments. What results is a saturated straight chain hydrocarbon fuel, i.e. one that does not contain double-bonds. Hence, problems of oxidation stability that plague FAME are solved, and a high-quality hydrocarbon fuel can be produced from biomass, that does not contain sulfur or aromatic hydrocarbons.

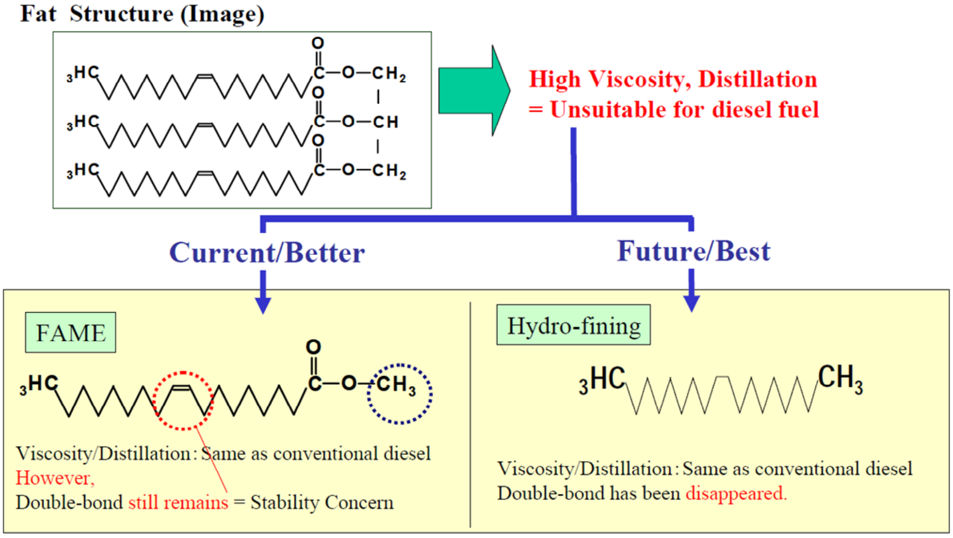
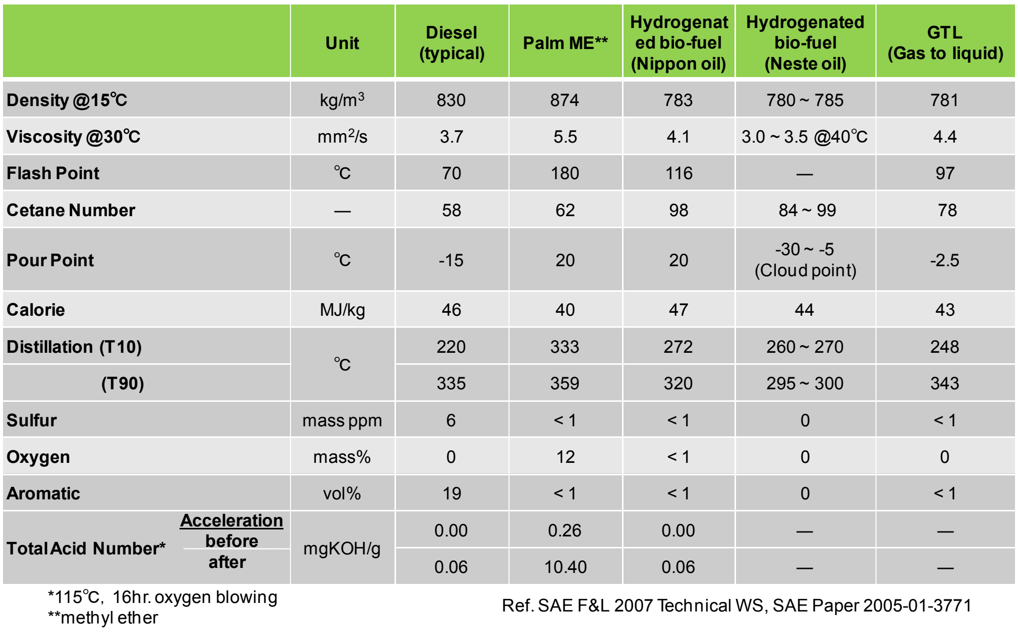


Figure 76 Production processes of FAME and hydrogenated biofuels

As shown in Table 53, specifications of conventional petroleum based fuel along with bio-fuels produced by various production processes [69], [70] include hydrogenated bio-fuels made by the New Japan Petroleum Co. Ltd. and Neste Oil Co. Ltd. Moreover, Gas To Liquid (GTL) specifications [71] are shown for fuel produced via FT synthesis of natural gas feedstock. We note that palm oil methyl ester's dynamic-viscosity is higher than that of conventional petroleum based fuel and also the distillation temperatures indicate a high boiling point. The oxidation stability, indicated by the total acid number, is higher than that of conventional petroleum based fuel. The acid number becomes remarkably high after high-temperature oxygenation. On the other hand, for the hydrogenated bio-fuels, their distillation characteristics show a tighter curve compared to conventional petroleum based fuel, and their total acid number has excellent characteristics as well. It is thought that unsaturated bonds in the incoming feedstock oils and fats are eliminated by the hydrogenation treatment. The cetane number (which indicates ignitability) of palm oil methyl ester is equivalent to conventional petroleum based fuel, while the cetane number of hydrogenated bio-fuels is extremely high. Note that these are mainly composed of saturated hydrocarbons. It has better ignitability than GTL, which is generally said to be a high cetane number fuel. However, without adding low-temperature flowability improver the hydrogenated bio-fuel made by New Japan Petroleum Co. Ltd. has a relatively high pour point, which leads to difficulties in winter and in cold climates.

Table 53 Specifications of bio-fuels produced by various production processes



	Unit	Diesel (typical)	Palm ME**	Hydrogenated bio-fuel (Nippon oil)	Hydrogenated bio-fuel (Neste oil)	GTL (Gas to liquid)
Density @15℃	kg/m³	830	874	783	780 ~ 785	781
Viscosity @30℃	mm²/s	3.7	5.5	4.1	3.0 ~ 3.5 @40℃	4.4
Flash Point	℃	70	180	116	—	97
Cetane Number	—	58	62	98	84 ~ 99	78
Pour Point	℃	-15	20	20	-30 ~ -5 (Cloud point)	-2.5
Calorie	MJ/kg	46	40	47	44	43
Distillation (T10)	℃	220	333	272	260 ~ 270	248
(T90)		335	359	320	295 ~ 300	343
Sulfur	mass ppm	6	< 1	< 1	0	< 1
Oxygen	mass%	0	12	< 1	0	0
Aromatic	vol%	19	< 1	< 1	0	< 1
Total Acid Number* **Acceleration before**	mgKOH/g	0.00	0.26	0.00	—	—
after		0.06	10.40	0.06	—	—

*115℃, 16hr. oxygen blowing
**methyl ether

Ref. SAE F&L 2007 Technical WS, SAE Paper 2005-01-3771

As referenced above, it is thought that the blend rate of hydrogenated bio-fuel (with petroleum base fuel) determines the low temperature flowability. However, it can be said that the stability and overall fuel quality characteristics of hydrogenated bio-fuels are excellent, compared to FAME. For practical use of hydrogenated bio-fuels, the New Japan Petroleum Co. Ltd, Toyota Motor Corporation, and Hino Automotive Corporation have performed validation testing in Tokyo since 2007, on blending hydrogenated bio-fuels at a rate of 10% to conventional petroleum based fuel [72], [73]. As shown in Figure 77, testing was done with a biofuel-hybrid bus.

This hybrid bus runs on bio hydrofined diesel (BHD)

Development of BHD with Toyota Motor Corporation

Figure 77 On-road testing of hydrogenated bio-fuels using a hybrid bus

9.3 Sustainability of Biodiesel Fuel

9.3.1 Sustainable Biomass Utilization Vision in East Asia

In East Asia and ASEAN region, a working group (WG) on "Sustainable Biomass Utilization Vision in East Asia" was established in 2007 as one of the WG of ERIA (Economic Research Institute for ASEAN and East Asia) Research Project. The WG developed the following policy recommendations as the results in 2007 [74]

- Addressing Macro and Micro Levels Needs to Reap Maximum Economic Benefits
- Mitigating Negative & Enhancing Positive Environmental Impacts
- Realizing Direct & Indirect Monetary Returns for Societal Benefit
- Developing Sustainability Indicators to Enhance the Decision Making Process
- Standardizing Tools to Generate Quantifiable & Verifiable Information
- Considering Country-Specific Needs & Available Biomass Resources
- Promoting Regional & International Cooperation

The details can be referred to the WG report [74].

9.3.2 Other Research Trends on Sustainability of Biofuels

Australia is considering options for ensuring sustainability in biofuels production, but currently has no specific environmental protection policies or regulations relating to biofuel production beyond the broad rules and regulations governing land and water use. The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) limits potential feedstock expansion into areas where a significant impact on matters of National Environmental Significance, such as listed threatened species and communities, are likely to occur. However, this would not prevent impacts on biodiversity not protected under the EPBC Act. In addition, proposals to import exotic species into Australia, for use in biofuel production are subjected, *inter alia*, to an assessment of their bio-security risk, including the potential for weediness.

9.4 Future Vision of the Handbook

In this handbook, the three yeas discussions of the ERIA's WG on "Benchmarking of Biodiesel Fuel Standardization in East Asia", the results and the findings are summarized as well. For the achievements were consistently aimed at the "secure use" of the first generation of biodiesel fuel (FAME). This is just an intermediate report of the WG's goal such as "Definition appropriate utilization of biodiesel fuel, by establishing quality standard and quality control/management method required in the actual market of East Asia and ASEAN regions".

The WG will be operated and discuss what should we do for the goal continuously. Especially, quality control/management method will be investigated in real market for EAS countries. Further discussions, for the goal of the WG, will be expanded from 1st generation biodiesel (FAME) to other biofuels (1st as well as 2nd generation such as ethanol, BHD, BTL, BioDME etc.) for updating the handbook.

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Chapter 2.

[1] BP Statistical Review (2009)

[2] At a company level, national oil companies hold 76% of reserves, while the Russian oil companies hold 17% of the reserves. An area of improvement is in major International Oil Companies (IOC), which have access to advanced technology and funds but the amount of accessible reserves they hold is only 7%.

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