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.

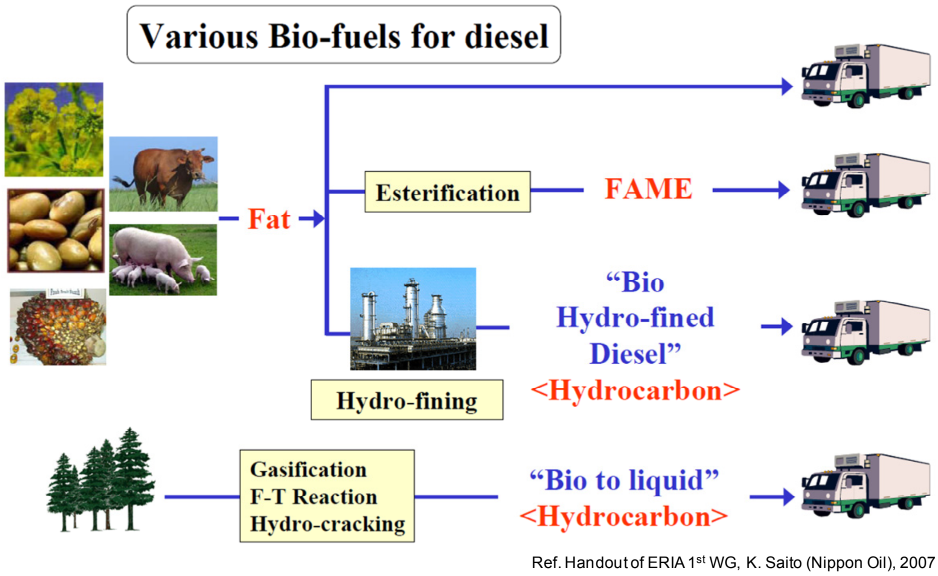

Figure 75 Various bio-fuel production processes

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.

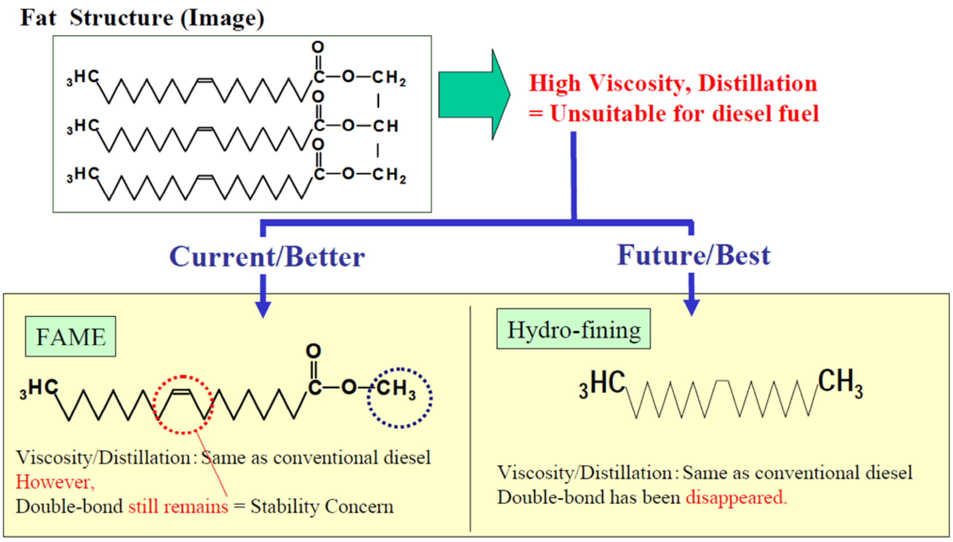

Figure 76 Production processes of FAME and hydrogenated biofuels

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.

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.