IEA-Advanced Motor Fuels

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Japan

Introduction

The transportation sector accounts for 23.1% of total energy consumption in Japan. Of this transportation sector energy consumption, passenger transport was responsible for 61.1%, and freight transport was responsible for the other 38.9% in 2013. Energy for transport in Japan depends mostly on imported oil (Figure 1).

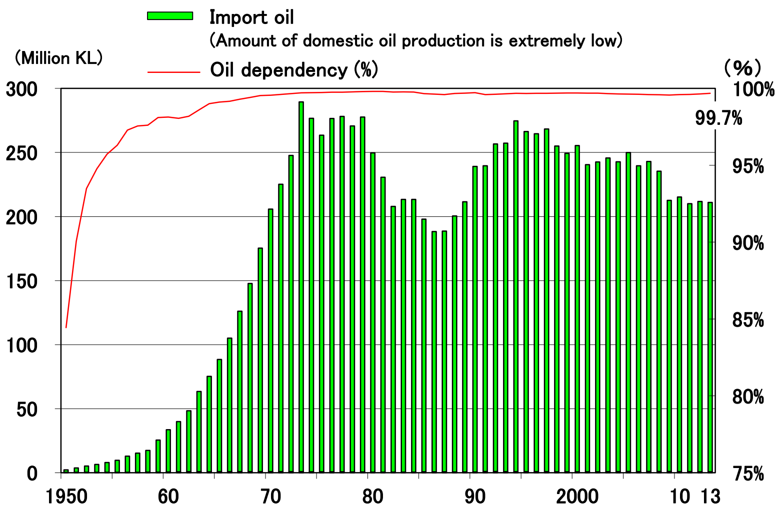

Fig. 1 Transition of Crude Oil Imports and Oil Dependency in Japan, 1950–2013 [1]

Figure 2 shows the energy sources used in the transportation sector [2]. Oil-related energy accounts for 97.9% of the total usage. The market for alternative fuels is very small in Japan, and the number of alternative fuel vehicles is small (Table 1). Methanol, compressed natural gas (CNG), hybrid, and electric vehicles currently constitute the low-emission vehicles. The number of hybrid vehicles is rather large, and the number of passenger hybrid vehicles contributes to this. CNG vehicles currently account for the largest number of vehicles in the low-emission truck category.

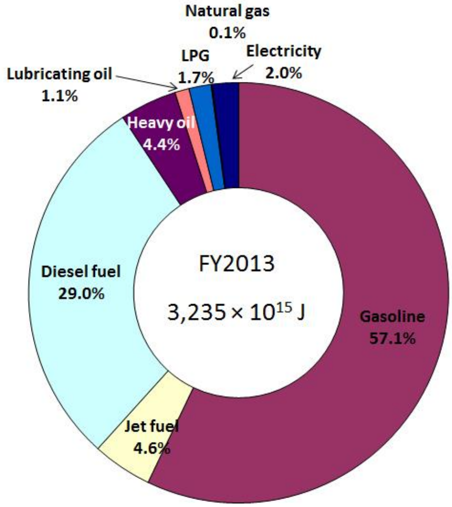

Fig. 2 Energy Sources Used in the Transportation Sector in Japan in 2013

Table 1 Current Penetration of Low-Emission Vehicles in Japan

Vehicle Type	Methanol [3]	CNG [4]	Hybrid [5])	EV [6]	Vehicle Registration [7]
Passenger vehicles	0	1,579	3,948,371	39,650	39,689,646
Light, mid, and heavy-duty trucks	576	5,784 19,367	13,470	24	5,877,354
Buses	0	1,575	978	34	226,944
Special vehicles	0	3,965	6,418	38	1,682,582
Small vehicles	0	12,406	435	15,974	Not available
Total	576	44,676	3,969,672	55,720	Not available

Policies and Legislation

In terms of primary energy, the new Strategic Energy Plan (the fourth plan) approved in April 2014 discusses the use of nuclear power and ensuring safety, improving the efficiency of electricity generation (such as through the application of an integrated gasification combined cycle for coal), expanding the use of liquefied natural gas (LNG) and liquefied petroleum gas (LPG), and places an emphasis on reducing the cost of renewable energy [8].

Regarding secondary energy, the plan cites the need to reform the structure of electricity generation. Consequently, on April 30, 2015, the Ministry of the Environment (MOE) and the Ministry of Economy, Trade and Industry (METI) presented a government proposal that targets reducing the level of greenhouse gases in 2030 by 26% compared to the level in 2013. The use of hydrogen as a fuel source was also widely discussed in the plan, which promoted the creation of a roadmap for the production, storage, transport, and use of hydrogen, as well as the strategic development of supply systems and infrastructure. As a result, the Strategic Roadmap for Hydrogen and Fuel Cells, which looks at the way that hydrogen fuel will be used in the future, was compiled in June 2014 [9].

Implementation: Use of Advanced Motor Fuels

Bioethanol

In Japan, the main activities promoting the use of biofuels are the three biofuel production site establishment projects between 2012 and 2016 managed by the Ministry of Agriculture, Forestry and Fisheries (MAFF). However, since it was determined that it would be too difficult to achieve the secondary objective of self-reliance and commercialization of these projects by Fiscal Year (FY) 2017, budgetary support as auxiliary projects of the MAFF was only provided up to FY 2014. The project to popularize the use of biofuels in Okinawa supplied roughly 70,000 kiloliters (kL) of E3 and E10 fuel in FY 2014. As of April 2015, it has established 57 service stations supplying E3 fuel and 29 service stations supplying E10 fuel [10]. In contrast, the number of service stations in Japan selling bio-gasoline blended with ethyl tertiary-butyl ether (ETBE) decreased by approximately 2% from April 2014 to 3,300, as of May 10, 2015 [11].

In Thailand, the New Energy and Industrial Technology Development Organization (NEDO) (outsourcing contractors: Sapporo Breweries Ltd. and Iwata Chemical Industry Co., Ltd.) has started demonstration operation of a plant to produce bioethanol from tapioca residue (production capacity of 80 kL/year) as a new bioethanol production technology). In addition, Iogen

Corporation and Raizen, Inc. announced the start of continuous commercial production of ethanol from cellulose in Brazil beginning with the harvest in 2015.

Biodiesel

Over the past year, the main trend in Japan concerning biodiesel was the provision of subsidies by METI in cooperation with MAFF for regional biodiesel distribution system technology demonstration projects as a measure to help encourage the use and popularization of biomass-derived fuels. These subsidies will be used to support the main operators in each region in addressing technical issues surrounding an integrated and advanced distribution system for biodiesel. This is being done in an effort to promote and stabilize the supply, production, distribution, and production volume of biodiesel. The subsidies provided by METI will help the operators cover business expenses, giving METI and the operators the opportunity to identify and resolve issues blocking the wider use of biodiesel. This project and the subsidies began in FY 2013, and in FY 2014, 16 operators were adopted.

In terms of fuel properties, the JIS (Japan Industrial Standard) K 2390 standard has been aligned with the guidelines determined by EAS-ERIA (the Economic Research Institute for ASEAN (Association of Southeast Asian Nations) and East Asia at East Asia Summits), which is the unified standard for Southeast Asian countries. This was accomplished in four ways: (1) the provisions concerning kinematic viscosity, flash point, and iodine value were loosened to accommodate the diversity of oils derived from raw materials; (2) the provisions for monoglycerides related to vehicle cold startability were made stricter and the items in the test method (cloud point and cold filter plugging point) for cold startability were clearly specified; (3) the provisions concerning phosphorus related to catalyst poisoning in after-treatment devices were made stricter; and (4) a subcommittee of the Society of Automotive Engineers of Japan (JSAE) discussed how to clearly specify a standard value for oxidation stability. With regard to number 2, the European standard that concerns the low-temperature fluidity requirements for biodiesel fuels is EN14214:2012. It divides fuels into six classes through a complicated method that combines the cloud point, cold filter plugging point, and monoglyceride content. However, in Japan, the distribution of biodiesel fuel has not progressed very far, and Japanese manufacturers would likely be unable to adequately follow complicated standards. Therefore, the JSAE committee agreed to stop at the specification of two grades based on the monoglyceride content. However, this has not yet been reflected in the JIS standard.

Natural Gas

According to statistics published by the Japanese Ministry of Finance (MOF), Japan imports most of its LNG from Qatar, Australia, Malaysia, and Russia. In 2013, the import price into Japan was 16.2 U.S. dollars per MMBtu. (MMBtu is an abbreviation for one million British thermal units and is roughly equivalent to 25 cubic meters [m^3] of natural gas.) This indicates that Japan was forced to pay a higher price in comparison to the import price into the United Kingdom (10.7 U.S. dollars/MMBtu) and the United States (3.7 U.S. dollars/MMBtu). Currently, light-duty and medium-duty CNG trucks have been disseminated in Japan. However the latest news is that Isuzu Motors Limited launched a CNG heavy-duty truck in December 2015.

Natural Energy and Hydrogen

In Japan, the most common use of natural energy (renewable energy) in the form of automotive fuel is hydrogen obtained via water electrolysis. In anticipation of the eventual realization of a hydrogen-fuel-based society, NEDO, a national research and development institute, has compiled a Hydrogen Energy White Paper that outlines the current state of research and development into hydrogen-based fuels. This white paper contains information concerning the use of hydrogen as an energy source, both inside and outside Japan, in a systematic manner. Starting with the characteristics of hydrogen itself, the white paper discusses the significance of using hydrogen as an energy source, the technology trends concerning hydrogen manufacturing, transportation, storage, and use, as well as the policy trends toward developing a hydrogen-fuel-based society, current issues, and future directions. The white paper also contains a section that provides the basics of hydrogen energy.

The Toyota Mirai hydrogen fuel cell vehicle (FCV) went on sale in December 2014. In conjunction with this event, Iwatani Corporation and JX Nippon Oil & Energy Corporation started selling hydrogen fuel at 1,100 yen/kilograms (kg) and 1,000 yen/kg, respectively. Therefore, it is now possible to compare the fuel costs of FCVs to existing gasoline engine and hybrid vehicles. Figure 3 compares the fuel cost in yen per kilometer (km) of driving distance at a gasoline price of 120 yen/liter. The fuel economy values for the gasoline engine vehicles and hybrid vehicles are the catalog values provided by each manufacturer. While the test cycle fuel economy of the Toyota FCV-ADV has been published, this information has yet to be published for the Mirai. Therefore, the values shown in Figure 3 were calculated based on the volume of the hydrogen fuel tank and travel distance.

Although it is difficult to make a direct comparison because the vehicle sizes are different, the Mirai has approximately the same fuel cost as a hybrid vehicle in the same vehicle class. Furthermore, according to the NEDO

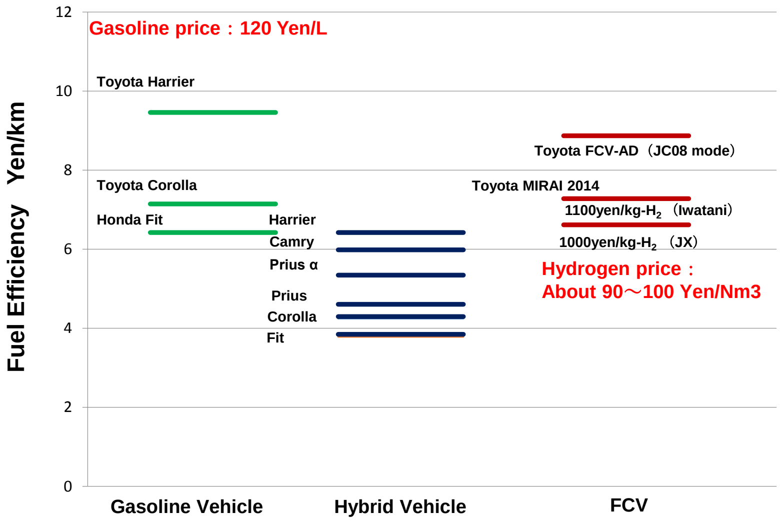

Fig. 3 Fuel Efficiency of FCVs Compared to Gasoline and Hybrid Vehicles [12]

project and other sources, the cost of supplying hydrogen around the year 2030 is predicted to be 20 to 40 yen/normal cubic meter (Nm^3) (approximately 230 to 450 yen/kg). Depending on the price of crude oil, there is a strong possibility that the market will accept this price range.

Dimethyl Ester (DME)

DME is attracting attention as an alternative fuel to diesel that can be produced easily from methanol. In North America, Oberon Co., Ltd. and Volvo Truck Corporation are planning to produce DME and run some vehicles on DME. Mitsubishi Gas Chemical Company Inc. and Mitsubishi Corporation have similar plans under way in Trinidad and Tobago, and Isuzu Motors, Ltd. is also producing low-pollution vehicles with DME engines.

Engines for Alternative Fuels

LPG Engines

The number of registered vehicles in Japan that run on LPG has been decreasing steadily after reaching a peak of 319,000 in 1991. There were 223,630 registered vehicles at the end of 2014 (including 4,619 bi-fuel vehicles and 5,093 mini-vehicles), a decrease of approximately 8,000 vehicles from 2013. The reasons for this decline are the long-term rise in LPG prices and the erosion of the relative cost merit of LPG vehicles as gasoline vehicles become more fuel efficient. A significant impact is also attributed to the policy of reducing the number of taxis, which represented 80% or more of registered vehicles. LPG stations can be found at approximately 1,600 locations in Japan.

Natural Gas Engines

Basic research on natural gas engines is focusing on dual fuel engines where a small amount of diesel is injected directly into the cylinder as an ignition source. Waseda University used a rapid compression machine to study combustion improvements in natural gas engines with diesel ignition and confirmed that under exhaust gas recirculation (EGR) conditions, the higher dispersion of the premixed gas resulting from the multi-injection of the diesel pilot stimulates flame propagation during the main injection and improves thermal efficiency [13]. Using a natural gas and diesel dual fuel (DDF) engine based on a 4-cylinder diesel engine, intake control indicators when supercharging and EGR were studied by the National Institute of Advanced Industrial Science and Technology and Denso Corporation for three load conditions ranging from light to heavy [14].

Hydrogen Engines

In Japan, a group consisting of Tokyo City University, the National Traffic Safety and Environment Laboratory, and Okayama University has issued reports on improving thermal efficiency through stratification in the axial direction in hydrogen engines with high-pressure direct injection in the cylinder [15] and measuring the local excess air ratio around the spark plug [16]. Nissan Motor Co., Ltd. demonstrated the possibility of ensuring stable combustion even at high EGR ratios by adding hydrogen obtained through gasoline reforming [17].

Dimethyl Ether (DME) Engines

Work on DME fuel standardization started at International Organization for Standardization (ISO) TC 28/SC 4 in 2007 and has led to the publication of the following standards:

ISO 16861:2015, Petroleum products — Fuels (class F) – Specifications of dimethyl ether (DME), 2015-05-15

ISO 17196:2014, Dimethyl ether (DME) for fuels – Determination of impurities – Gas chromatographic method, 2014-11-15

ISO 17197:2014, Dimethyl ether (DME) for fuels – Determination of water content – Karl Fischer titration method, 2014-11-15
ISO 17198:2014, Dimethyl ether (DME) for fuels – Determination of total sulfur, ultraviolet fluorescence method, 2014-11-15
ISO 17786:2015, Dimethyl ether (DME) for fuels – Determination of high temperature (105°C) evaporation residues, mass analysis method, 2015-05-01

Stirling Engines

Examples of units originally developed in Japan include 0.2-kilowatt (kW) to 10-kW-class engines for relatively low-temperature waste heat and biomass combustion power generation using waste heat from marine diesel engines and factories. These are either still under development or only available on a made-to-order basis. However, with the revision of the Electricity Business Act, Stirling engine generation facilities of 10 kW or less have been designated as electric facilities for general use, removing legal restrictions other than technical standards and facilitating the installation of such engines. The regional exchange center in the Omachi District of Minamisoma, which installed and operates a 10-kW-class Stirling engine power generation system that burns woody biomass produced by Suction Gas Engine Mfg. Co., Ltd., is an example.

Outlook

In April 2014, the Japanese government approved the new Strategic Energy Plan (the fourth plan) [18], which forms the basis for Japan's energy policies for the immediate future. The basic concepts behind this plan are ensuring stable energy supplies, economic efficiency, and environmental suitability. With the addition of safety to these concepts, the plan is now summed up as "3E+S."

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