CONSERVATION OF RESOURCES IN THE AUTOMOBILE INDUSTRY

1 Introduction

This article introduces the Energy White Paper (June 8, 2018)[1] that summarizes energy trends both in and outside Japan, and also discusses the Japanese government's Fifth Basic Energy Plan (Draft) (May 16, 2018)[2] and Basic Hydrogen Strategy (December 26, 2017)[3]. In addition, it will present international energy trends concerning crude oil, natural gas, and natural energy sources.

Liquid hydrogen, ammonia, methylcyclohexane (MCH) and related substances have drawn attention as potential energy carriers for the transportation and storage of hydrogen. With research and development on this topic is underway at NEDO and other organizations, the international prices of ammonia, methanol, crude oil, and LNG, which are already circulating internationally, were compared to evaluate the possibilities of these different carriers, and the results are reported in this article.

Furthermore, the latest trends in alternative fuels, such as bioethanol, biodiesel fuel (FAME and BDF), methanol, and dimethyl ether (DME) will be presented. Please also refer to the article on "The Latest Trends in Alternative Fuels" in the November 2017 issue of the Journal of the Society of Automotive Engineers of Japan, which is entitled, "Forefront of technologies for Fuels and lubricants"[4].

2 Energy Trends in Japan

2. 1. Energy White Paper[1]

The Japanese Cabinet approved the Energy White Paper 2018 which describes the history of Japan's energy relations since the Meiji Restoration in honor of its 150th anniversary in 2018. In particular it focuses on (1) Japan's history concerning energy since the Meiji Restoration, (2) changes in the energy situation since the formulation of the previous Strategic Energy Plan, and (3) technological competition and the possibilities for Japanese companies with respect to decarbonization.

In 2016 the transportation sector accounted for 23.4% of the annual total final energy consumption, with consumption within that sector breaking down to 59.2% in the passenger sector (e.g., passenger vehicles and buses), and 40.8% by the cargo sector (land transportation, shipping, and air cargo).

In 1965 the amount of energy consumption by the transportation sector in Japan was about 800×10^{15} J (18% of the total final energy consumption) and the passenger sector accounted for 41.5% of that consumption, while the cargo sector accounted for 8.5%. Over the eight years from 1965 to 1973, energy consumption by the transportation sector as a whole increased 2.3 times (10.8% annually). Despite the growth rate slowing after the two oil crises in the 1970s, it still increased by 2.1 times (2.8% annually) in the 28 years from 1973 to 2001.

However, energy consumption in the transportation sector has begun to decline due to reduced transport volume and improved transport efficiency since the 2000s. The energy consumption in 2016 has increased 3.9 times over the 51 years since 1965 for an increase of 2.7% per year. By sector, the 5.6 times (3.4% per year) increase of the passenger sector exceeded that of the cargo sector, which stood at 2.7 times (2.0% per year).

With respect to crude oil supply trends, use of that fuel as a primary energy source in Japan had decreased due to the promotion of the energy conservation and alternative energy policies that followed the oil shocks of the 1970s, but rose again in the latter half of the 1980s, as the energy conservation policies made a round and crude oil prices fell. Since the mid-1990s, the use of crude oil has been declining again due to progress in the use of alternative energy sources to replace petroleum.

When the percentages of Japanese crude oil imports are ranked according to the supplying country, Saudi Arabia comes first at 37.4%, followed by the United Arab Emirates at 23.7%, Qatar at 8.7%, and then Iran at 7.0%.

2. 2. Basic Energy Plan (Draft)[2] and Basic Hydrogen Strategy[3]

In April 2014 the Japanese government created the Fourth Basic Energy Plan in response to the Great East Japan Earthquake and the TEPCO Fukushima Daiichi nuclear power plant accident in March 2011. The goal was to reduce dependence on nuclear power, reduce dependence on fossil fuel resources, and expand the use of renewable energy by the year 2030.

Now, four years after the Fourth Basic Energy Plan was drafted, Japan must not only review its plans for 2030, but also work in the context of the Paris Agreement with a view toward 2050. And beyond that, Japan needs to formulate an ultra-long-term response to eventual fossil fuel resource depletion as well as the changing energy situation. The time has come for Japan to replan its energy choices. Consequently, this latest review of the Basic Energy Plan consists of ways to realize the energy mix for 2030 (the long-term energy supply and demand forecast determined by the Ministry of Economy, Trade and Industry in July 2015) and designing a scenario focused on 2050.

This plan maintains the previous 2030 electrical power supply targets of 20 to 22% from nuclear power and 22 to 24% from renewable energy sources. In conjunction with renewable energy, hydrogen is attracting attention as a secondary energy source. The Basic Hydrogen Strategy provided a roadmap and other policies for a transition to a hydrogen-based society.

3 International Energy Trends

3. 1. Trends in Crude Oil[4]

The total amount of crude oil produced around the world in 2016 was 4.38 billion tons. When this total amount is broken down according to the top ten producing nations, Saudi Arabia is the leading producer, accounting for 13.4%, followed by Russia at 12.6%, the U.S. at 12.4%, Iraq at 5.0%, Canada at 5.0%, Iran at 4.9%, China at 4.6%, the UAE at 4.2%, Kuwait at 3.5%, and Brazil at 3.1%. These top ten countries account for 68.6% of all crude oil produced in the world.

In 2017, worldwide crude oil consumption was 4.42 billion tons. Breaking this down by the top ten oil consuming nations reveals that petroleum consumption in the U.S. accounted for 19.5%, China 13.1%, India 4.8%, Japan 4.2%, Saudi Arabia 3.8%, Russia 3.3%, Brazil 3.1%, South Korea 2.8%, Germany 2.6%, and Canada 2.3%. These top ten countries account for 59.6% of all crude oil consumption in the world.

3. 2. Trends in Natural Gas[5]

The total amount of natural gas produced around the world in 2016 was 3.55 billion m^3. Broken down according to the top ten producing nations, the U.S. is the leading producer, accounting for 21.1%, followed by Russia at 16.3%, Iran at 5.7%, Qatar at 5.1%, Canada at 4.3%, China at 3.9%, Norway at 3.3%, Saudi Arabia at 3.1%, Algeria at 2.6%, and Australia at 2.6%. The natural gas production of these ten top producers accounts for 67.9% or approximately two-thirds of all production throughout the world.

In 2016, worldwide natural gas consumption was 3.54 billion m^3. Breaking this down by the top ten natural gas consuming nations reveals that natural gas consumption in the U.S. accounted for 22.0%, Russia 11.0%, China 5.9%, Iran 5.7%, Japan 3.1%, Saudi Arabia 3.1%, Canada 2.8%, Mexico 2.5%, Germany 2.3%, and the U.K. 2.2%. These top ten countries account for 60.6% of all natural gas consumption in the world.

3. 3. Evaluating the Possibilities of Energy Carriers

Methanol and ammonia are already in wide circulation and perceived as energy carrier candidates for the transportation and storage of hydrogen. Figure 1 compares their prices to those of crude oil and LNG. The vertical axis shows the market price of each fuel converted to the calorific value per one liter of diesel oil in yen, with the exchange rate taken into consideration.

The price of crude oil rose to about 90 yen/L at the time of the 2008 global financial crisis, but then dropped to about 20 yen/L in 2016. It has been rising again due to destabilization of the world situation resulting from the United States pulling out of the Iranian nuclear agreement. The price of LNG generally tracks that of crude oil, but it is becoming more stable due, in part, to long-term contracts.

Worldwide demand for methanol has been rising for both industrial and automotive applications, and its production volume has therefore been increasing rapidly. Presently, the price of methanol is about twice that of crude oil and LNG on a calorific-value basis because it is manufactured from natural gas.

Ammonia is often used as a fertilizer and since, like methanol, it is also manufactured from natural gas, its price has risen to about double that of crude oil and LNG on a calorific-value basis.

The target price for hydrogen starting in the year

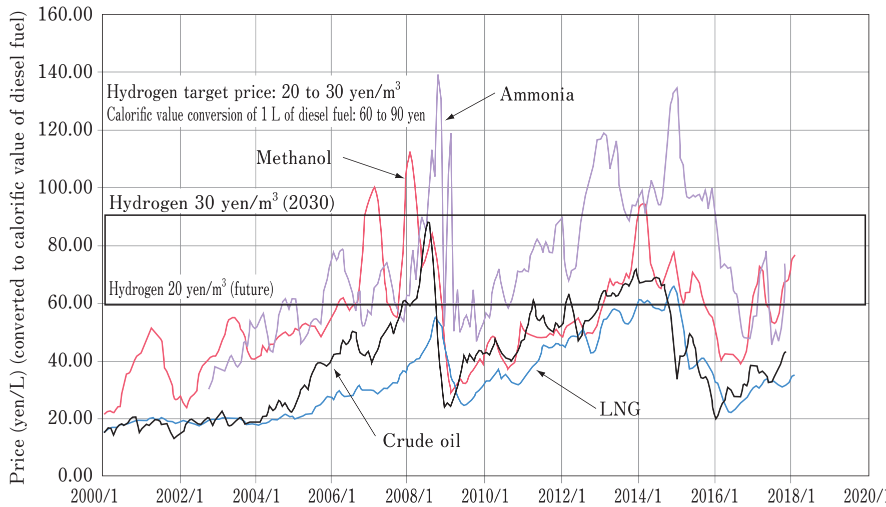


Fig. 1 Comparison of the international price by fuel type

2030 and beyond is 20 to 30 yen/m^3[6]. This corresponds to about 60 to 90 yen when converted to the equivalent calorific value of one liter of light oil (diesel). The hydrogen used for fuel cell vehicles is currently sold at 1,000 to 1,100 yen/kg, which is about 89 to 98 yen/m^3.

Vehicle fuels are subject to volatile oil taxes and other taxes that amount to 53.8 yen/L for gasoline, 32.1 yen/L for diesel, and 9.8 yen/L for LPG, but natural gas and other newer fuels are not being taxed yet. Taking taxation into consideration suggest that energy carriers such as hydrogen, ammonia, and methanol are sufficiently marketable as automobile fuels.

4 Trends in Natural Sources of Energy

4. 1. Wind-Based Electric Power Generation

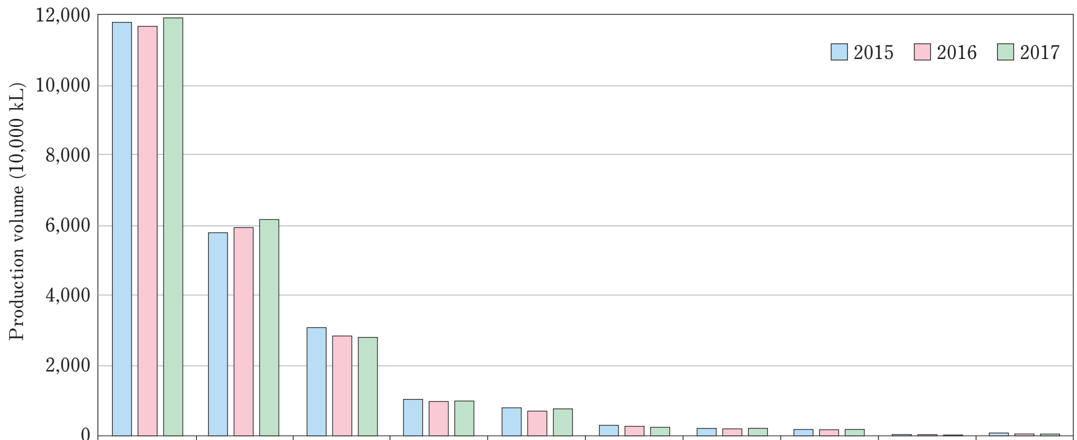
According to the Global Wind Energy Council (GWEC)[6], newly installed wind power in 2016 amounted to 46.94 GW. When this is broken down by country, China led the way and accounted for 41.5% of this new capacity, followed by the U.S. at 14.9%, Germany at 14.0%, the U.K. at 9.1%, India at 8.8%, Brazil at 4.3%, France at 3.6%, Turkey at 1.6%, Mexico at 1.0%, and Belgium at 1.0%. The total installed wind power capacity around the world is now 455.6 GW. Breaking this down by country share of this total, China again leads with 41.2%, followed by the U.S. with 19.5%, Germany with 12.3%, India with 7.2%, Spain with 5.1%, the U.K. with 4.1%, France with 3.0%, Brazil with 2.8%, Canada with 2.7%, and Italy with 2.1%.

4. 2. Solar-Based Electric Power Generation

In 2016 the total capacity of newly installed solar-based electric power generation around the world was approximately 75 GW. This statistic is from REN21, the Renewable Energy Policy Network for the 21st Century[7], whose breakdown of this new capacity by country indicates that China accounts for 46.0%, followed by the U.S. at 19.7%, Japan at 11.5%, India at 4.1%, the U.K. at 2.0%, Germany at 1.5%, South Korea at 0.9%, Australia at 0.9%, the Philippines at 0.8%, and Chile at 0.7%. A look at the cumulative amount of solar-based electric power generation introduced in 2017, shows that China ranks first at 77.4 GW, which accounts for 25.5%, while Japan has reached 42.8 GW to surpass Germany and rank second in the world.

5 Bioethanol

According to statistics compiled by F.O. Licht GmbH, global ethanol production increased once again in 2017 by approximately 2% to reach about 119.48 million kL[8]. Approximately 84% of this total was used for fuel, which is about the same proportion as in 2016. Figure 2 shows the annual production trends for bioethanol in each country. The two main bioethanol producing countries are the U.S. and Brazil (accounting for about 75% of total global production). The amount of bioethanol produced in the U.S. continues to increase, and the percentage of ethanol blended into all gasoline in 31 states across the U.S. exceeded 10% of volume (the nationwide average was 10.02%), breaking through the so called "blend wall". On the other hand, the amount bioethanol produced in Brazil continues to decrease. In December 2017 the government decided to introduce a new policy (the RenovaBio Project) aimed at reducing CO_2 emissions and expanding bio-



	Total	U.S.	Brazil	China	EU	India	Canada	Thailand	Australia	Pakistan
2015	11,761	5,753	3,030	967	733	242	189	147	32	48
2016	11,690	5,953	2,819	940	695	244	190	150	35	45
2017	11,948	6,153	2,774	950	752	219	194	163	34	62

Fig. 2 Changes in Annual Bioethanol Production Volume in Producing Countries

fuel consumption to prevent global warming. The plan aims to cover 18% of Brazil's domestic energy consumption using biofuels by the year 2030 by increasing sugarcane-based bioethanol production and expanding of use of second generation biofuel and biodiesel[9].

In Japan, one of the initiatives being used to promote the use of biofuels was a bioethanol demonstration project that had been carried out since 2012 in Miyakojima City, but this project came to an end in 2017[10]. At the same time, sales of gasoline blended with ETBE are also being promoted to achieve the target (500,000 kL (crude oil equivalent) of bioethanol in 2017) indicated in the Act on Sophisticated Methods of Energy Supply Structures and in 2016 sales of this blended gasoline reached a total 441,000 kL[11]. The "Expert Committee to Discuss the Future of Biofuel Introduction in Japan" has been established to examine the "criteria" for the bioethanol usage targets that have been set and they are now examining the form that these criteria should take from 2018 and on[12].

New technologies for manufacturing bioethanol include a NEDO project in Thailand (outsourced to Tsukishima Machinery and JFE Engineering) that has demonstrated the effectiveness of a bioethanol production technology using sugar cane bagasse (the dry fibrous residue that remains after juice extraction) as a raw material[13]. Likewise, NEDO has also announced that a bioethanol production demonstration project in China (outsourced to Hitachi Zosen and Sojitz Corporation) using potato starch residue had begun[14]. Sekisui Chemical Co., Ltd. and LanzaTech of the U.S. announced that they succeeded in developing a new ethanol production technology that makes ethanol from completely unsorted municipal solid waste. Incinerating this waste produces various gases, which are then fermented using a naturally occurring bacteria to convert them into ethanol and other chemicals[15].

6 Biodiesel Fuel (FAME and BDF)

Outside of Japan, the latest revision of the European Union's Renewable Energy Directive for the period of 2020 to 2030 proposes reducing the contribution of transport sector biofuels that compete with food down to 3.8% from the current energy target of 7%[16]. Conversely, Asian countries, which are petroleum importers, are promoting domestic biofuel production. For example, India, Thailand, Indonesia, and Malaysia are all expanding their markets for biodiesel fuel.

Total worldwide biodiesel fuel production amounts to about 34 million tons, approximately one third of which is produced in the 28 countries of the EU. Within the EU, Germany produces about 3.1 million tons of biodiesel, with about half of its raw oil material coming from waste cooking oil. This represents a major change from the previous use of virgin rapeseed oil for the majority of the raw material oil. On a pan-European scale as well, the main sources of raw material oil for biodiesel fuel are rapeseed oil and palm oil, waste cooking oil gaining ground and now accounting for 14% of the total source material[17].

In Japan, the volume of FAME production has already peaked. Nevertheless, last year a domestic engine manufacturer released a micro-cogeneration system consisting of a stationary, regular electric power generator that can coordinate with the electrical grid. The system is compatible with both FAME and straight vegetable oil (SVO), which relies only on a simplified filtration process to directly use waste cooking oil as a fuel, as well as FAME manufactured using waste cooking oil as its raw material. Although SVO, in particular, has limited use due to being about 10 times more viscous than diesel fuel at room temperature, the adoption methods such as warming up the fuel tank or switching to FAME fuel when starting and stopping the generator[18] made stable operation possible.

In March 2007 the mandatory standards for diesel fuel in the Japanese Act on the Quality Control of Gasoline and Other Fuels were amended, stipulating a 5% FAME by mass (B5) content for blended diesel fuel starting in February 2009. This led the National Council for Promotion of Biodiesel Fuel Utilization to establish the Council Monitoring Standard for its members, who often use unblended 100% FAME biodiesel[19]. This standard initially consisted of only five items: kinematic viscosity, moisture content, methanol content, triglyceride content, and free glycerin content. However, diglyceride content and monoglyceride content were added in 2016 and have been in effect since 2017. The purpose of adding these two items is to use the monitoring of the intermediate products in the FAME manufacturing process to determining whether that process is appropriate.

Hydrocarbon biofuel, the next-generation biofuel, is still at the research and development stage. Examining the country of origin of patent applications related to this biofuel reveals that applications from China account for approximately half of the total, followed by the U.S. at 16% and Japan at 10%. While the number of Chinese patents has been rising remarkably, the number of Japanese patents has gradually declined since 2008[20]. The main technological developments concern new processes for obtaining hydrocarbon biofuel that can be used as a substitute for diesel fuel. These processes include a process for extracting fats, oils, and hydrocarbons from microalgae and purifying them, as well as a process that manufactures bio-crude oil using a hydrothermal treatment and subsequently reforming, distilling, and separating it.

7 Methanol and DME (Di-methyl Ether)

Methanol is mainly produced from natural gas and coal. In 2017 the worldwide demand for methanol was estimated at 78 million tons, with China thought to account for about 60% of that total[21]. Possible applications for methanol in automotive fuels include blending it into gasoline, using it as a raw material for MTBE, biodiesel, DME, and synthetic gasoline, and even developing methanol engine automobiles. In China, local governments in major coal producing areas, such as Shanxi Province and Shaanxi Province, are planning to introduce policies to promote the use of methanol-blended gasoline[22], and construction of an MTG plant that synthesizes gasoline from methanol is also underway[23].

Furthermore, DME is attracting attention as an alternative fuel to diesel that can be produced easily from methanol. In North America, Oberon Co., Ltd. and Mack Trucks, Inc. are carrying out demonstrations using DME trucks with technology from Volvo Truck Corporation. Ford Motor Company in Germany, and the Shanghai Jiao Tong University in China, are both developing engines that run on DME, while in Japan the Isuzu Advanced Engineering Center, Ltd., is developing DME automobiles.

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