CONSERVATION OF RESOURCES IN THE AUTOMOBILE INDUSTRY

1 Introduction

The Fifth Strategic Energy Plan (July 3, 2018) has been revised, and a long-term plan presented that looks ahead to 2030 and 2050. Based on this plan, the Basic Hydrogen Strategy, the Tokyo Statement, and the Strategic Road Map for Hydrogen and Fuel Cells, which concern the hydrogen energy that is key to a low-carbon society, were announced in succession. In addition to these items, this article introduces the Energy White Paper 2020 (June 5, 2020) that summarizes energy trends both inside and outside Japan. It also presents recent trends related to automotive fuels, such as crude oil, hydrogen, biodiesel (FAME and BDF), methanol, and dimethyl ether (DME).

2 Energy Trends in Japan

2. 1. Energy White Paper and Primary Energy Sources

According to the Energy White Paper 2020[1] (June 5, 2020), final energy consumption in Japan has been declining since its peak in 2005. This trend has accelerated due to higher social awareness of energy-saving after the Great East Japan Earthquake in 2011. In 2018, real GDP increased by 0.3% from 2017, but warm winter weather resulted in a 2.7% drop in final energy consumption. The amount of primary energy supplied per unit of gross domestic product (GDP) was 37 PJ/trillion yen in 2018, little more than half the 73 PJ/trillion-yen figure of 1973.

The proportion of energy consumed by the business/commercial, domestic, and transportation sectors has changed from 74.7%/8.9%/16.4% in 1973 when the first oil shock occurred to 62.7%/14.0%/23.4% in 2018. In the transportation sector, the passenger segment accounted for 59.3% of this energy consumption, while the freight segment accounted for 40.7%.

The primary energy source for vehicles is mostly crude oil. In 2019, 175.49 billion kL of crude oil was imported from the following countries[2]: Saudi Arabia (35.3%), the United Arab Emirates (UAE) (29.8%), Qatar (8.9%), Kuwait (8.4%), Russia (5.1%), the U.S. (2.1%), Oman (1.9%), Bahrein (1.7%), Iran (1.5%), Iraq (1.4%), Ecuador (1.3%), Kazakhstan (0.6%), Malaysia (0.4%), Vietnam (0.3%), and other countries (1.3%).

2. 2. Trends Related to Hydrogen Energy

Technological development and demonstration projects related to hydrogen in Japan are being driven following the world-leading Strategic Road Map for Hydrogen and Fuel Cells[4] (announced on March 12, 2019) based on the Basic Hydrogen Strategy[3] (December 26, 2017). Globally, hydrogen is being promoted from the standpoint of lowering greenhouse gas emissions under the Paris Agreement. As a result, various countries and regions have produced hydrogen-related roadmaps. The Hydrogen Roadmap Europe[5] was released in January 2019 under the auspices of the European Commission, and a coalition called the Fuel Cells and Hydrogen Joint Undertaking (FCH JU). In the U.S., California has announced its own vision for hydrogen[6] to stand beside the private sector Road Map to a US Hydrogen Economy. Korea and Australia have also announced hydrogen roadmaps with governmental backing.

In Japan, 2019 was a very active year for initiatives related to hydrogen energy. In September 2019, continuing on from the previous year, the second Hydrogen Energy Ministerial Meeting[7] was held with participants from 35 countries, regions, and organizations. This meeting went onto adopt a global action agenda.

On December 11, 2019, the CO_2-free Hydrogen Energy Supply-chain Technology Research Association (HySTRA) announced the construction of the world's first liquefied hydrogen marine carrier and held a launching ceremony. This is a major step forward toward the construction of a hydrogen supply chain in 2020.

The Advanced Hydrogen Energy Chain Association for Technology Development (AHEAD) is aiming to construct a hydrogen supply chain using an organic hydride

Source: Toshiba Energy Systems & Solutions Corporation

Fig. 1 Panoramic View of FH2R Hydrogen Production Unit

(methylcyclohexane (MCH)). It has reported the following definite progress toward this objective. In April 24, 2020, it announced that the dehydrogenation plant at the Keihin Refinery of Toa Oil Co., Ltd. in Kawasaki City waterfront had entered stable operation, and had started to separate hydrogen and toluene from MCH produced in Brunei Darussalam. Subsequently, on May 26, 2020, it also announced the start of hydrogen supply to gas turbines at a power station.

In addition, on February 10, 2020, the New Energy and Industrial Technology Development Organization (NEDO), in partnership with Toshiba Energy Systems & Solutions Corporation, Tohoku Electric Power Co., Inc., and Iwatani Corporation, announced the opening of F2HR, the world's largest 10 MW-class hydrogen production unit in Namie, Fukushima Prefecture (Fig. 1)[8]. This project has an hourly hydrogen production capacity of 1,200 Nm^3 under rated operation using renewable energy and other sources. As renewable energy sources are subject to large fluctuations, F2HR intends to adjust to supply and demand in the power grid to maximize usage of these sources while establishing the feasibility of clean, low-cost hydrogen production technology.

3 International Energy Trends

3. 1. Trends in Crude Oil[2]

The total amount of crude oil produced around the world in 2018 was 4.47 billion tons. When this total amount is broken down according to the top ten producing nations, the U.S. accounted for 15.0% of production, followed by Saudi Arabia at 12.9%, Russia at 12.6%, Canada at 5.7%, Iran at 5.1%, Iraq at 4.9%, China at 4.2%, the UAE at 4.0%, Kuwait at 3.3%, and Brazil at 3.1%. Together, these ten countries accounted for 70.8% of global crude oil production.

In 2017, worldwide crude oil consumption was 4.66 billion tons. Breaking this down by the top ten oil consuming nations reveals that petroleum consumption in the U.S. accounted for 19.7%, China 13.8%, India 5.1%, Japan 3.9%, Saudi Arabia 3.5%, Russia 3.2%, Brazil 2.9%, South Korea 2.8%, Germany 2.4%, and Canada 2.4%. Together, these ten countries accounted for 59.7% of global crude oil consumption.

3. 2. Trends in Natural Gas[9]

The total amount of natural gas produced around the world in 2018 was 3.87 billion m^3. Broken down according to the top ten producing nations, the U.S. was the leading producer, accounting for 21.5%, followed by Russia at 17.3%, Iran at 6.2%, Canada at 4.8%, Qatar at 4.8%, China at 4.2%, Australia at 3.4%, Norway at 3.1%, Saudi Arabia at 2.9%, and Algeria at 2.4%. Together, these ten countries accounted for 70.3%, or approximately two-thirds, of global natural gas production.

In 2018, worldwide natural gas consumption was 3.85 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 21.2%, Russia 11.8%, China 7.4%, Iran 5.9%, Canada 3.0%, Japan 3.0%, Saudi Arabia 2.9%, Mexico 2.3%, Germany 2.3%, and the U.K. 2.0%. Together, these ten countries accounted for 61.8% of global natural gas consumption.

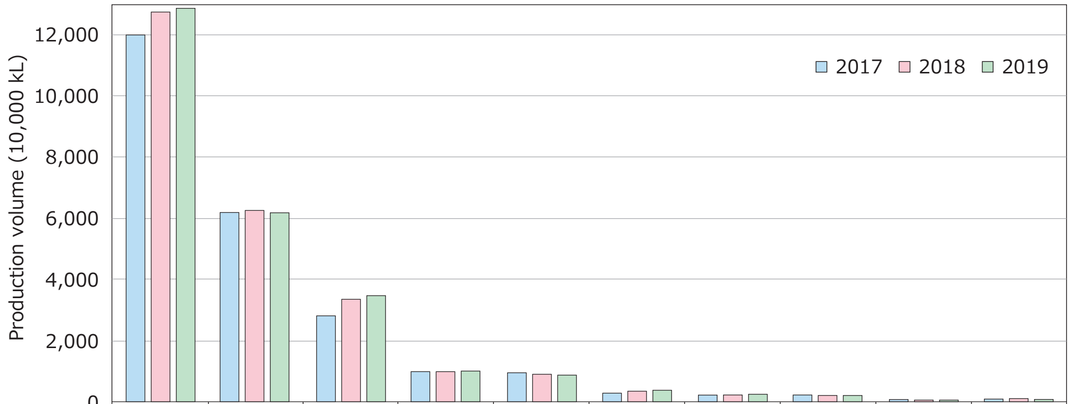
4 Trends in Natural Sources of Energy

4. 1. Wind-Based Electric Power Generation

According to the Global Wind Energy Council (GWEC)[10], the newly installed wind power capacity in 2019 amounted to 61.45 GW. When this is broken down by country, China led the way and accounted for 43.3% of this new capacity, followed by the U.S. at 15.1%, the U.K. at 4.0%, India at 3.9%, Germany at 3.6%, Sweden at 2.6%, France at 2.2%, Mexico at 2.1%, Argentina at 1.5%, and Australia at 1.4%. The total installed wind power capacity around the world as of 2019 amounted to 650.56 GW. In terms of the country-by-country share of this global total, China again leads with 36.3%, followed by the U.S. with 16.2%, Germany with 9.4%, India with 5.8%, the U.K. with 3.6%, France with 2.6%, Brazil with 2.4%, Canada with 2.1%, Sweden with 1.4%, and Turkey with 1.2%.

4. 2. Solar-Based Electric Power Generation

According to the Renewable Energy Policy Network



	Total	U.S.	Brazil	China	Europe	India	Canada	Thailand	Australia	Pakistan
2017	11,985	6,153	2,775	930	887	229	194	166	34	62
2018	12,739	6,238	3,309	955	881	308	203	169	35	71
2019	12,840	6,160	3,429	980	839	349	219	182	35	54

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

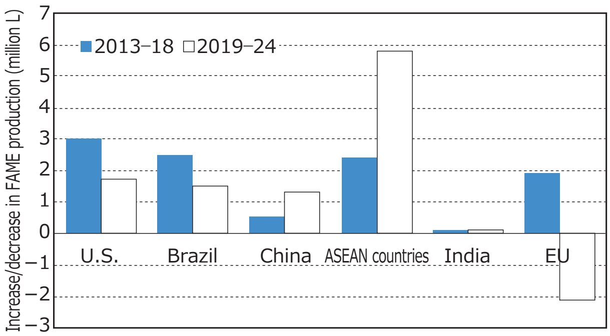
for the 21st Century (REN21)[11], the total capacity of newly installed solar-based electric power generation around the world in 2018 was approximately 100 GW. Breaking down this new capacity by country indicates that China accounted for 45.0%, followed by India at 10.8%, the U.S. at 10.6%, Japan at 6.5%, Australia at 3.8%, Germany at 3%, Mexico at 2.7%, South Korea at 2.0%, Turkey at 1.6%, and the Netherlands at 1.4%. A look at the cumulative amount of solar-based electric power generation introduced in 2018, shows that China ranked first at 176.1 GW, which accounts for 34.9%, while Japan has reached 56 GW and ranked third in the world, following the U.S., which ranked second at 62.4 GW.

5 Bioethanol

According to statistics compiled by F.O. Licht GmbH, global ethanol production increased slightly in 2019 by approximately 0.8% to reach about 128.40 million kL[12]. Figure 2 shows the annual production trends for bioethanol in each country. Approximately 85% of this total was used for fuel, which is about the same proportion as in 2018. The two main bioethanol producing countries are the U.S. and Brazil. The amount of bioethanol produced in the U.S was 61.60 million kL, a slight decrease of approximately 1.3%. This was due to issues such as uncertain government policies toward biofuels, such as exempting small-scale crude oil refinery businesses from mandates introducing biofuels, and the ongoing debate around the so-called blend wall In contrast, the amount of bioethanol produced in Brazil increased by approximately 3.6% to 34.29 million kL, a record high, due to a good sugar cane harvest and the continuing shift from sugar to ethanol production. In addition, the RenovaBio project began full-scale operations in 2020, with laws and regulations being established[12]. In addition, it was also reported that the government of China decided to halt plans for the mandatory nationwide adoption of gasoline blended with 10% ethanol due to a sharp decline in national corn stocks and biofuel production capacity restrictions[13].

With respect to initiatives aiming to encourage the use of biofuels in Japan, in 2019, sales of gasoline blended with Ethyl *tert*-butyl ether (ETBE) again achieved the target stipulated detailed in the Act on Sophisticated Methods of Energy Supply Structures (500,000 kL (crude oil equivalent) of bioethanol and 1.94 million kL of bio-ETBE each year from 2018 to 2020), which was announced in April 2018[14]. This bio-ETBE is either imported as ETBE or manufactured from bioethanol in Japan. According to trade statistics, approximately 66,000 tons of ethanol was imported, mainly from Brazil, in 2019 as raw material for ETBE (equivalent to roughly 153,000 kL of ETBE)[15].

With regard to bioethanol production technology, at the 12th China-Japan-Korea Petroleum Technology Congress held in Seoul, JXTG Nippon Oil & Energy Corporation (the current ENEOS Corporation) and Oji Holdings Corporation announced the joint development of an efficient technique that produces ethanol from woody biomass, the raw material of paper. The two companies opened a demonstration plant with an annual production capacity of 100 kL, and successfully achieved at least



Created by the authors of this article based on the data presented in reference (16).

Fig. 3 Volume of Increase/Decrease in FAME and HVO Production in Main Countries and Regions

twenty days of continuous production, a world-first[16].

6 Biodiesel (FAME and BDF)

According to the International Energy Agency (IEA), the production of fatty acid methyl ester (FAME), biodiesel, is predicted to increase in most regions around the world between 2019 and 2024, apart from Europe (Fig. 3). Although this increase is likely to be particularly pronounced in ASEAN countries, Europe is likely to see a drop in production. In contrast, the production of hydro-treated vegetable oil (HVO) is forecasted to increase in the same period in the U.S., ASEAN, and the EU. This future decline in FAME production in Europe is because existing clean diesel engines can only use low concentration biodiesel-diesel fuel blends. However, since HVO is the same type of hydrocarbon (HC) as diesel, it can be handled in the same way as diesel and used without modification in clean diesel engines. Therefore, it is likely that production will shift in the future from first-generation biodiesel to second-generation biomass-to-liquids (BTL) such as HVO[17].

In Japan, the Guidelines for Biodiesel Usage in the Construction Industry were partially revised in April 2019[18]. According to these guidelines, most machinery in the industry complies with the level of the 1st or 2nd emissions standards. Although there are cases of machinery complying with the 3rd emissions standards, the use of such machinery is far from expanding. It appears that there are issues to be resolved for the use of neat 100% biodiesel (B100), which has a different combustion temperature, can be used under advanced emissions standards from the 3rd level and beyond that require special devices for diesel to boost emissions treatment performance, such as diesel particulate filters (DPFs) and electronic controls. However, distilling technology is helping to increase supplies of higher quality B100 that complies with the JIS K 2204 diesel fuel standard. It has been reported that this higher quality B100 fuel (distilled fuel or non-distilled fuel with the equivalent quality) is appropriate for machinery compliant with emissions standards from the 3rd level and beyond.

However, if biodiesel is distilled at close to normal pressures to raise the methyl ester concentration, this has the adverse effect of causing a major drop in oxidation stability. For this reason, this fuel must be used with care[19]. It should be noted that, in Europe, distillation is generally carried out at reduced pressures, and is simply used to eliminate residual methanol and water, or is only used for single cut methyl ester solvent production.

In addition, bio-jet fuel, has recently reached the practical adoption phase as a biofuel derived from the same fatty sources as biodiesel. On February 3, 2020, a communique from the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) announced a partial revision to how the standard specifications for alternative jet fuels for aircraft (ASTM D7566) should be handled[20]. This communique included annexes detailing fuel standards in accordance with the refinement methods of synthetic fuels and limits for the blending of conventional jet fuels. For example, Annex 2 described paraffin kerosene (Bio-SPK or HEFA) synthesized by hydroprocessing vegetable oils or the like, and stated that, providing the properties of a blended fuel containing a mix of this fuel and conventional jet fuel complies with existing jet fuel standards, such a blended fuel may be handled in the same way as conventional jet fuel. Revisions like this are major step forward to the realization of flight using domestically produced bio-jet fuel using algal oil obtained from microalgae[21].

7 Methanol and Di-methyl Ether (DME)

Methanol is mainly produced from natural gas and coal. In 2019 the worldwide demand for methanol was estimated at 82 million tons, with China thought to account for about 60% of that total. 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 the 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 underway[23].

Furthermore, DME, which can be produced easily from methanol, is mainly consumed in LPG-blending applications, but is also attracting attention as an alternative fuel to diesel. In North America, Oberon Co., Ltd. and Mack Trucks, Inc. carried out demonstrations using DME trucks with technology from Volvo Truck Corporation. Ford Motor Company in Germany is developing passenger cars with DME fuel, and the Shanghai Jiao Tong University in China is developing engines that run on DME. In Japan, the Isuzu Advanced Engineering Center, Ltd., is developing DME trucks.

With environmental awareness continuing to increase, methanol or DME, which can be produced from carbon dioxide and hydrogen have been suggested as feasible renewable energy sources. In North America and Europe, projects are under way involving the production of methanol, DME, and derivatives from carbon dioxide and waste[24]. Similarly, in Japan, NEDO has commissioned a project aiming to develop technology to re-use carbon dioxide[25].

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