CONSERVATION OF RESOURCES IN THE AUTOMOBILE INDUSTRY

1 Introduction

Following on from the previous year, 2021 saw a continuation of the transformation in the energy field. In particular, the global push for decarbonization was affected by the COVID-19 pandemic and the Russian invasion of Ukraine, causing massive disruption that spread across the world. According to the Japanese Energy White Paper, by the end of the United Nations Climate Change Conference in November 2021 (COP 26), 154 countries and 1 region had issued declarations about achieving carbon neutrality. These declarations account for 70% of global CO_2 emissions. This conference saw steady progress toward the formulation of international rules for decarbonization. For example, agreement was reached about the implementation policy for so-called market mechanisms, which had been under negotiation for several years, and the Paris Agreement rulebook was finalized. As a result, the achievement of carbon neutrality has become an even more important goal for Japan. This article summarizes recent energy trends, primarily in Japan. In addition to crude oil, natural gas, and other natural energy sources, it also presents recent trends related to automotive fuels, such as bioethanol, biodiesel, methanol, and dimethyl ether (DME).

2 Energy Trends in Japan

2. 1. Trend toward Carbon Neutrality and the Clean Energy Strategy

Alongside more widespread discussions about realizing a green recovery from the COVID-19 pandemic that mainly centered in Europe, concerns about energy and mineral resource supplies due to the Russian invasion of Ukraine have further accelerated actions toward carbon neutrality.

Such initiatives are also gaining traction in Japan with, for example, the government's declaration about achieving carbon neutrality by 2050 and reducing greenhouse gas emissions by 46% in 2030. A Clean Energy Strategy to realize these two objectives has been discussed and an Interim Report was issued in May 2022. Several important actions related to energy occurred in 2021. On October 22, the Sixth Strategic Energy Plan, the Plan for Global Warming Countermeasures, and Long-Term Strategy were all promulgated, demonstrating the importance given by Japan to achieving carbon neutrality. Of these initiatives, both the Strategic Energy Plan and the Plan for Global Warming Countermeasures were formulated factoring in the objective to reduce CO_2 by 46% in 2030. In addition, the Green Growth Strategy and Long-Term Strategy both factor in the 2050 carbon neutrality declaration. The role of the Clean Energy Strategy is to ensure that these efforts continue to be discussed.

Chapter 1 of the Interim Report (Ensuring Energy Security) lays out the policies for accelerating decarbonization considering the crisis in Ukraine and tightening electricity supply and demand conditions. Chapter 2 describes the necessary policies and the like for realizing a green transformation (GX). This chapter lays out a specific roadmap and initiatives toward realizing industrial GX in order to link economic growth and development with decarbonization, while also defining specific initiatives toward the decarbonization of local communities and daily living.

Technical items in this strategy include ammonia, hydrogen, offshore wind power, batteries, nuclear power, carbon recycling, cement, sustainable aviation fuel (SAF), E-methane, synthetic fuels, green LPG, chemicals, bio manufacturing technologies, steelmaking, automobiles, transport, houses, buildings, infrastructure, food/agriculture, forestry, and fisheries, carbon capture and storage (CCS), and negative emissions technologies (NETs). These items are defined in the report in terms of energy and are being discussed as part of industrial strategy.

2.2. Energy White Paper and Primary Automotive Energy Sources

According to the Energy White Paper 2021 (June 2021), final energy consumption in Japan increased at a higher rate than the country's gross domestic product (GDP) in the period of rapid economic growth extending up to 1970. However, prompted by the oil shocks, energy-saving measures primarily in the manufacturing industry have had an increasing effect and consumption started to decline in 2005. This trend further accelerated due to higher social awareness of energy-saving after the Great East Japan Earthquake in 2011. Moreover, the restrictions placed on the movement of people and the drop in industrial activity due to the effects of the COVID-19 pandemic in 2020 caused real GDP to decline by 4.5% compared to 2019. This resulted in final energy consumption decreasing by 6.7% on the same year-on-year basis. The amount of primary energy supplied per unit of GDP was 34 PJ/trillion yen in 2020, less than half the 70 PJ/trillion yen figure of 1973. This amount has decreased for ten consecutive years and the amount of primary energy supplied per unit of GDP in Japan is now substantially lower than the global average.

The amount of primary energy generated in Japan in 2020 was 17.96 EJ, with oil accounting for 36.4%, coal for 24.6%, natural gas for 23.8%, nuclear energy for 1.8%, hydroelectric power for 3.7%, and non-hydroelectric renewable energy sources for 9.7%. The proportion of energy consumed by the business/commercial, domestic, and transportation sectors was 61.9%, 15.8%, and 22.3%, respectively. Compared to 1973, these figures have grown by 0.9, 1.9, and 1.5 times, and total energy consumption has increased by 1.2 times.

The primary energy source for vehicles is mostly crude oil. In 2021, 148.9 billion kL of crude oil was imported from the following countries: Saudi Arabia (37.3%), the United Arab Emirates (UAE) (36.4%), Kuwait (8.4%), Qatar (7.8%), Russia (3.6%), Ecuador (1.6%), Bahrein (1.5%), Oman (0.7%), and other countries (2.7%).

3 International Energy Trends

3.1. Trends in Crude Oil

The total amount of crude oil produced around the world in 2020 was 4.17 billion tons. When this total amount is broken down according to the top ten producing nations, the U.S. accounted for 17.1% of production, followed by Russia at 12.6%, Saudi Arabia at 12.5%, Canada at 6.1%, Iraq at 4.9%, China at 4.7%, the UAE at 4.0%, Brazil at 3.8%, Iran at 3.4%, and Kuwait at 3.1%. Together, these ten countries accounted for 72.2% of global crude oil production.

Additionally, in 2020, worldwide petroleum consumption was 91.297 million barrels per day. Breaking this down by the top ten oil consuming nations reveals that petroleum consumption in the U.S. accounted for 19.9%, China 15.7%, India 5.2%, Saudi Arabia 3.9%, Japan 3.6%, Russia 3.6%, Brazil 3.3%, Korea 2.8%, Canada 2.6%, and Germany 2.3%. Together, these ten countries accounted for 62.9% of global crude oil consumption.

3.2. Trends in Natural Gas

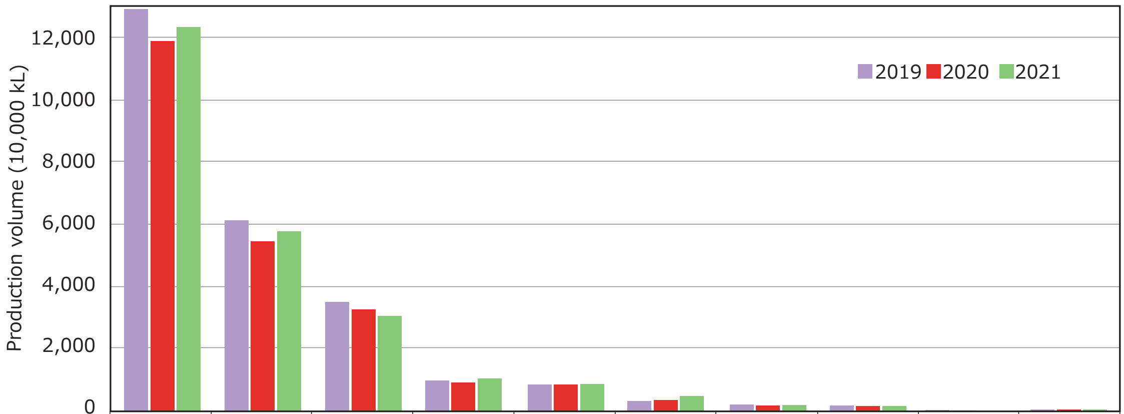
The total amount of natural gas produced around the world in 2020 was 3.85 billion m^3. Broken down according to the top ten producing nations, the U.S. was the leading producer, accounting for 23.7%, followed by Russia at 16.6%, Iran at 6.5%, China at 5.0%, Qatar at 4.4%, Canada at 4.3%, Australia at 3.7%, Saudi Arabia at 2.9%, Norway at 2.9%, and Algeria at 2.1%. Together, these ten countries accounted for 72.1% of global natural gas production.

Additionally, in 2020, worldwide natural gas consumption was 3.82 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 21.8%, Russia 10.8%, China 8.6%, Iran 6.1%, Canada 2.9%, Saudi Arabia 2.9%, Japan 2.7%, Germany 2.3%, Mexico 2.3%, and the U.K. 1.9%. Together, these ten countries accounted for 62.3% of global natural gas consumption.

4 Energy

4.1. Wind-Based Electric Power Generation

According to the Global Wind Energy Council (GWEC), newly installed onshore wind power capacity in 2021 amounted to 72.5 GW. When this is broken down by country, China accounted for 42.3% of this new capacity, followed by the U.S. at 17.6%, Brazil at 5.3%, Vietnam at 3.7%, Sweden at 2.9%, Germany at 2.7%, Australia at 2.4%, India at 2.0%, Turkey at 1.9%, and France at 1.6%. Japan accounted for 0.3% of new capacity. The total installed onshore wind power capacity around the world as of 2021 amounted to 780.3 GW. In terms of the country-by-country share of this global total, China again leads with 39.8%, followed by the U.S. with 17.2%, Germany with 7.3%, India with 5.1%, Brazil with 2.8%, France with 2.5%, Canada with 1.8%, the U.K. with 1.8%, Sweden with 1.5%,



	Total	U.S.	Brazil	China	Europe	India	Canada	Thailand	Australia	Pakistan
2019	12,907	6,133	3,517	980	861	323	211	185	33	63
2020	11,878	5,452	3,270	920	860	361	186	176	31	51
2021	12,321	5,780	3,069	1,055	882	489	197	173	31	59

Fig. 1 Changes in Annual Bioethanol Production Volume

and Turkey with 1.4%. Japan accounted for 0.6% of wind power capacity.

In contrast, newly installed offshore wind power capacity in 2021 amounted to 21.1 GW. According to the country-by-country breakdown, China accounted for 80.1% of this new capacity, followed by the U.K. at 11.0%, Denmark at 2.9%, and the Netherlands at 1.9%. The total installed offshore wind power capacity around the world as of 2021 amounted to 57.2 GW. China accounted for the highest proportion at 48.4%, followed by the U.K. at 21.9%, Germany at 13.5%, the Netherlands at 5.3%, and Denmark at 4.0%.

4. 2. Solar-Based Electric Power Generation

According to the Renewable Energy Policy Network for the 21st Century (REN21), the total capacity of newly installed solar-based electric power generation around the world in 2020 was approximately 139 GW. Breaking down this new capacity by country indicates that China accounted for 34.7%, followed by the U.S. at 13.8%, Vietnam at 8.0%, Japan at 5.9%, Germany at 3.5%, India at 3.2%, Australia at 2.9%, Korea at 2.9%, Brazil at 2.2%, and the Netherlands at 2.2%. The total installed solar-based electric power generation capacity around the world as of 2020 amounted to 759 GW. According to the country-by-country breakdown, China accounted for the highest proportion at 33.4%, followed by the U.S. at 12.6%, Japan at 9.4%, Germany at 7.1%, India at 6.2%, Australia at 2.7%, Vietnam at 2.2%, Korea at 2.1%, the Netherlands at 1.3%, and Brazil at 1.0%.

5 Bioethanol

According to statistics compiled by F.O. Licht GmbH, global ethanol production is forecast to increase by approximately 4% in 2021 to about 123.21 million kL, still below the level prior to the COVID-19 pandemic. 84% of this production is predicted to be for fuel, an increase of approximately 5%. Figure 1 shows the annual production trends for bioethanol in each country. Of the two major producing countries, production in the U.S. is forecast to increase by approximately 6% to 57.8 million kL, whereas production in Brazil is forecast to decrease by approximately 6% to 30.69 million kL as unfavorable weather conditions affect the sugar cane harvest. It should be noted that the production of ethanol from corn is forecast to increase by 40% in Brazil to 3.39 million kL, which is equivalent to 11% of total ethanol production. However, this production is geographically limited to areas at a distance from export centers, which means that this ethanol is mainly consumed domestically.

With respect to initiatives aiming to encourage the use of biofuels in Japan, in 2021, sales of gasoline blended with Ethyl tert-butyl ether (ETBE) again achieved the target defined in the Act on Sophisticated Methods of Energy Supply Structures (500,000 kL (crude oil equivalent) or 820,000 kL of bioethanol, and 1.94 million kL of bio-ETBE each year). (Sales were 850,000 kL of bioethanol.)

With respect to ethanol production technology, Toppan Printing Co., Ltd. and ENEOS Corporation agreed to study starting up a bioethanol business using both regu-

Table 1 Biodiesel-Related Quality Standards in Europe

Property	Unit	Limits	Diesel (EN 590)	B10 (EN 16734:2016)	B20 (EN 16709:2019-02)	B30 (EN 16709:2019-02)	B100 (EN 14214:2019)
Cetane number	—	Minimum	51.0	51.0	51.0	51.0	51.0
Cetane index	—	Minimum	46	46	—	—	—
Density at 15℃	kg/m^3	Minimum	820.0	820.0	820.0	825.0	860
		Maximum	845.0	845.0	860.0	865.0	900
Polycyclic aromatic hydrocarbons	% (m/m)	Maximum	8.0	8.0	8.0	8.0	—
Sulfur content	mg/kg	Minimum	—	—	—	—	—
		Maximum	10.0	10.0	10.0	10.0	10.0
Manganese content	mg/l	Maximum	2.0	2.0	2.0	2.0	—
Flash point	℃	Minimum	55.0	55.0	55.0	55.0	101
Carbon residue (on 10% distillation residue)	% (m/m)	Maximum	0 30	0.30	—	—	—
Ash content	% (m/m)	Maximum	0.010	0.010	0.010	0.010	—
Water content	mg/kg	Maximum	200	200	260	290	500
Total contamination	mg/kg	Maximum	24	24	24	24	24
Copper strip corrosion (3 h at 50℃)	rating	Minimum	Class 1	Class 1	—	—	Class 1
Fatty acid methyl ester (FAME) content	% (V/V)	Minimum	—	—	14.0	24.0	96.5%(m/m)
		Maximum	7.0	10.0	20.0	30.0	—
Oxidation stability	g/m^3	Maximum	25	25	—	—	—
	h	Minimum	20	20	20	20	8
Lubricity, corrected wear scar diameter (wsd 1, 4) at 60℃	mm	Maximum	460	460	—	—	—
Viscosity at 40℃	mm^2/s	Minimum	2.0	2.0	2.0	2.0	3.5
		Maximum	4.5	4.5	4.62	4.65	5.0
Distillation							
%(V/V) recovered at 250℃	%(V/V)	Maximum	65	65	65	65	—
%(V/V) recovered at 350℃	%(V/V)	Minimum	85	85	85	85	
95%(V/V) recovered at	℃	Maximum	360	360.0	360.0	360.0	

lar and difficult-to-recycle scrap paper (such as waterproofed paper and non-carbon paper) as a feedstock, and have started discussions toward that objective. In addition, in the 2021 season, Formula 1 cars used a fuel blended with 5.75% ethanol. With the introduction of new power unit regulations for the 2022 season, this percentage is to be increased to 10%, resulting in the introduction of new E10 fuel standards.

6 Biodiesel Fuel

Although countries in Europe are currently making progress toward eliminating the use of diesel in passenger vehicles, diesel engines are still the main powertrain used by heavy-duty trucks and other large vehicles. The use of biodiesel fuels such as fatty acid methyl ester (FAME) and plant-derived hydrotreated vegetable oil (HVO) is increasing as a carbon-neutral replacement for conventional diesel. Used cooking oil (UCO) is gradually replacing virgin oils such as palm oil and rapeseed oil as the raw material for these biodiesel fuels. This is because UCO generates lower greenhouse gas (GHG) emissions between the raw material and fuel production stages than virgin oil. In particular, the production costs and production GHG emissions of UCO methyl ester (UCOME) is only two-thirds that of UCO-derived HVO.

The scale of the UCO market is growing at an average annualized rate of 3.6%, led by demand for biodiesel. UCO accounts for approximately 80% of biodiesel production in the Netherlands, the U.K., and Ireland, and approximately 40% in Germany, the world's largest biodiesel producing nation. Germany imports around 60% of its UCO from Asian countries such as Indonesia, Malaysia, and China. This trend of importing from Asia is the same in other European countries as well.

UCOME must comply with the same fuel quality standards as FAME derived from virgin oil, such as rapeseed-oil methyl ester (RME). Table 1 lists the standards that apply to FAME and FAME-blended diesel in Europe. EN 14214 and EN 590 apply to B100 and 7% diesel blends by volume, respectively. In 2019, EN 16734 was established as a standard for B10 (diesel fuel blends containing up to 10% biodiesel). In the same year, EN 16709 was also established as a standard for B20 (diesel fuel blends containing between 14 and 20% biodiesel) and B30 (diesel fuel blends containing between 24 and 30% biodiesel). Since the release of these quality standards, automakers and agricultural machine manufacturers have started to disclose the FAME tolerances of engine types. For example, some manufacturers have announced engines compliant with the Euro VI Stage C emissions standards that are capable of running on B100. In the sixth edition of the Worldwide Fuel Charter (WWFC): Gasoline and Diesel Fuel, which was released in October 2019, vehicles that comply with the Euro 6/6b, Euro IV, or JP 2009 emissions standards are permitted to use fuels blended with up to 5% FAME by volume. However, vehicles that comply with the Euro 6d or Euro VI emissions standards are not permitted to use FAME blends and may only use HVO or biomass-to-liquid (BTL) components in fuel.

7 Methanol and Di-methyl Ether (DME)

Methanol is mainly produced from natural gas and coal. In 2021 the worldwide demand for methanol is estimated to be 87.7 million tons, with China forecast 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 methyl tertiary-butyl ether (MTBE), biodiesel, DME, and synthetic gasoline, and even developing methanol engine automobiles. In China, methanol is synthesized from cheap domestic coal sources, primarily at inland coal fields, and either used directly as vehicle fuel or converted into other substances before use. Also in China, gasoline blends are shifting to bioethanol. The use of direct methanol blends and MTBE raw materials is declining. In contrast, the demand for methanol as a raw material for biodiesel is expected to grow around the world as demand switches to more environmentally friendly energy sources.

Furthermore, DME, which can be produced easily from methanol, is mainly consumed in liquid petroleum gas (LPG)-blending applications, but can also be used as an alternative fuel to diesel. Companies and institutions possessing technology for DME diesel vehicles include Volvo, Ford, and Shanghai Jiao Tong University. In Japan, Isuzu Advanced Engineering Center, Ltd. has completed testing of this technology on public roads.

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. In North America, Oberon Fuels is cooperating with the State of California in a project to help realize a recycling-oriented society using renewable dimethyl ether (rDME). In Europe, the FLEDGED Project has been studying technologies capable of synthesizing methanol and rDME from biomass, and has already published results. In Japan, the New Energy and Industrial Technology Development Organization (NEDO) has commissioned a project aiming to develop technology to re-use carbon dioxide. This project is aiming to produce liquid fuels such as diesel and gaseous fuels such as methane. Methanol synthesized from carbon dioxide primarily uses chemical products such as plastics as feedstock. However, the growing trend toward rDME in North America and Europe has not received the backing of public sector agencies in Japan.

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