CONSERVATION OF RESOURCES IN THE AUTOMOBILE INDUSTRY

1 Introduction

In 2022, the world faced energy supply constraints and rising prices. Since Japan relies heavily on imported energy, this was a year that highlighted the issues that the country is facing. With the global fuel supply capacity falling in response to low crude oil prices in the past and sluggish investment in fossil fuels as societies moves toward decarbonization, economic recovery around the world after the COVID-19 pandemic coincided with efforts to drop Russia as an energy supplier after it invaded Ukraine in February 2022. This created a highly unstable energy supply and demand situation and prompted record-breaking high energy prices, particularly of natural gas. Japan was less affected by these price rises than other countries since it procures most of its natural gas using long-term contracts that prioritize price stability. However, the effects of power supply constraints and high energy prices pushed Japan's trade balance into the red and underlined the issues facing the country related to energy security.

At the same time, the global trend toward carbon neutrality accelerated further. By October 2022, more than 150 countries and regions had issued declarations about achieving carbon neutrality by 2050 or similar deadlines. The gross domestic product (GDP) of these countries and regions accounts for approximately 94% of global GDP. In November 2022, Egypt hosted the 27th United Nations Climate Change Conference (COP 27). Based on the implementation guidelines agreed at COP 26, this conference made concrete progress toward the creation of carbon neutrality rules by making decisions on methods of reporting international transactions related to reductions and sequestration quantities of emissions, procedures for expert audits, detailed operational rules for market mechanisms managed by the United Nations, and the like.

In this way, as global trends surrounding vehicle energy sources become more difficult to navigate, the outlook with regard to natural resources is becoming increasingly important. 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

Japan has demonstrated its intention to address the issue of climate change by making international commitments to reduce greenhouse gas emissions by 46% in 2030 and to achieve carbon neutrality by 2050. To help realize these objectives, preparations were made to set up the Green Transformation (GX) League. The term GX is used to describe the conversion of industrial and social systems centered on fossil fuel energy, which has dominated since the advent of the industrial revolution, to industrial and social systems centered on clean energy. This represents a revolution unprecedented in Japan in the post-war period.

The policy of the League was defined in the basic guidelines for achieving GX that were announced in February 2023. The main direction of the GX League is to maximize utilization of Japan's technological expertise related to decarbonization to accelerate GX. By doing so, the intention is to help stabilize energy supplies and provide the impetus to return Japan's economy onto a growth track.

This will entail decarbonization initiatives for GX based on the main assumption of securing stable energy supplies through discussions related to energy saving technologies, the adoption of renewable energy as primary power sources, the utilization of nuclear energy, promotion of the adoption of hydrogen and ammonia, and resource recycling. Related to vehicles, the guidelines describe next-generation vehicles, carbon recycling fuel, and other items as relevant to GX in the storage battery industry and transportation sector.

The guidelines also include language covering the realization and implementation of a carbon pricing concept intended to encourage growth, a strategy for adopting measures internationally, promotion of GX throughout the whole of society, as well as progress evaluations of the status of new political initiatives for realizing GX and revisions as necessary.

Additionally, with respect to hydrogen energy, the Japanese government revised its Basic Hydrogen Strategy in June 2023. To accelerate realization of a hydrogen and ammonia energy-based society, Japan established annual usage targets of around 3 million tons in 2030 and 20 million tons in 2050. However, based on forecasts for potential hydrogen demand, a new annual target of around 12 million tons of hydrogen usage (including ammonia) was announced for 2040. On the demand side, the document also included strategies for various sectors including power generation, fuel cells, and heat and raw material utilization based on expectations for future demand growth due to the potential of hydrogen for decarbonizing heat use in sectors that are difficult to electrify as well as in the transport and industrial sectors through the adoption of fuel cells, and for the production of synthetic fuels and synthetic methane.

With respect to synthetic fuels, research and development is making progress as part of the Green Innovation (GI) Fund and projects organized by the New Energy and Industrial Technology Development Organization (NEDO). In September 2022, the Public-Private Council for Promoting the Introduction of Synthetic Fuels (e-Fuel) was established to provide a forum for discussions about the commercialization of synthetic fuels. These discussions were brought together in an interim report in June 2023. It was decided to bring forward the start of synthetic fuel usage from 2040 as originally planned to 2030 and calls were made for further acceleration of technological development toward commercialization.

2. 2. Energy White Paper and Primary Energy Sources

According to the Energy White Paper 2022 (June 2022), final energy consumption in Japan in 2021 increased by 1.6% from 2020 compared to a 2.6% rise in real GDP, which was prompted by factors such as economic recovery after the COVID-19 pandemic. In addition, the amount of primary energy supplied per unit of GDP was 35 PJ/trillion yen in 2021, substantially lower than the global average.

The amount of primary energy generated in Japan in 2021 was 18.67 EJ, with oil accounting for 36.0%, coal for 25.8%, natural gas for 21.4%, nuclear energy for 3.2%, hydroelectric power for 3.6%, and non-hydroelectric renewable energy sources for 10.0%. The proportion of energy consumed by the business/commercial, domestic, and transportation sectors was 63.5%, 14.6%, and 21.9%, respectively. Compared to 1973, these figures have grown by 0.9, 1.8, and 1.5 times.

The primary energy source for vehicles is mostly crude oil. In 2022, 156.56 billion kL of crude oil was imported from the following countries: Saudi Arabia (39.2%), the United Arab Emirates (UAE) (38.5%), Kuwait (8.5%), Qatar (6.5%), Ecuador (1.7%), the U.S. (1.5%), Oman (1.1%), Bahrein (1.0%), Russia (0.4%), and other countries (1.6%).

3 International Energy Trends

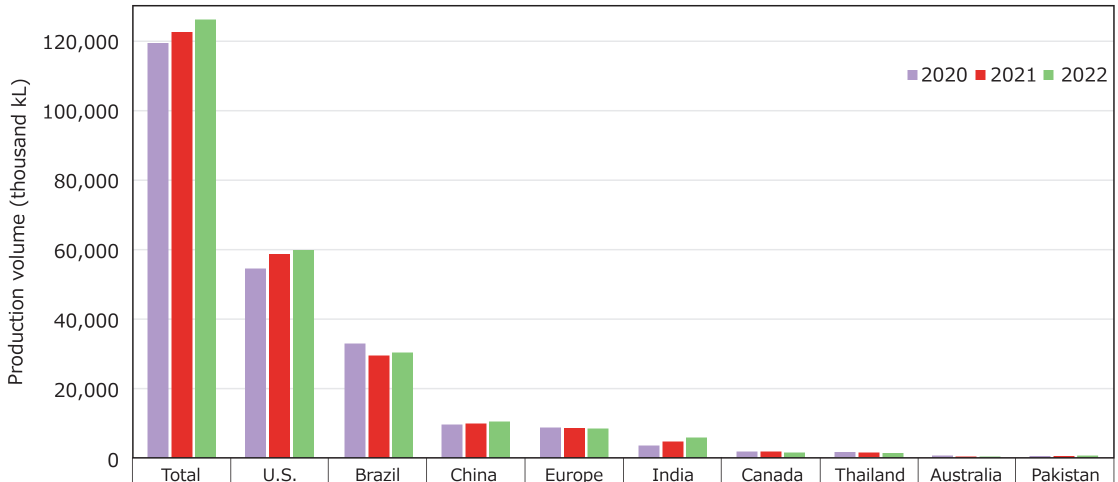
3. 1. Trends in Crude Oil

The total amount of crude oil produced around the world in 2021 was 4.22 billion tons. When this total amount is broken down according to the top ten producing nations, the U.S. accounted for 16.8% of production, followed by Russia at 12.7%, Saudi Arabia at 12.2%, Canada at 6.3%, Iraq at 4.8%, China at 4.7%, Iran at 4.0%, the UAE at 3.9%, Brazil at 3.7%, and Kuwait at 3.1%. Together, these ten countries accounted for 72.2% of global crude oil production.

Additionally, in 2021, worldwide petroleum consumption was 96.908 million barrels per day. Breaking this down by the top ten oil consuming nations reveals that petroleum consumption in the U.S. accounted for 20.4%, China 16.0%, India 5.1%, Saudi Arabia 3.7%, Russia 3.5%, Japan 3.5%, Brazil 3.0%, South Korea 2.9%, Canada 2.4%, and Germany 2.2%. Together, these top ten countries accounted for 62.7% of global crude oil consumption.

3. 2. Trends in Natural Gas

The total amount of natural gas produced around the world in 2021 was 4.04 billion m^3. Broken down according to the top ten producing nations, the U.S. was the leading producer, accounting for 23.1%, followed by Russia at 17.4%, Iran at 6.4%, China at 5.2%, Qatar at 4.4%, Canada at 4.3%, Australia at 3.6%, Saudi Arabia at 2.9%, Norway at 2.8%, and Algeria at 2.5%. Together, these ten countries accounted for 72.6% of global natural gas production.



	Total	U.S.	Brazil	China	Europe	India	Canada	Thailand	Australia	Pakistan
2020	119,180	54,520	32,700	9,450	8,690	3,590	1,900	1,730	320	510
2021	122,860	58,640	29,810	10,150	8,800	4,920	1,920	1,570	330	640
2022	126,110	60,010	30,540	10,600	8,710	5,900	1,960	1,640	350	780

Fig. 1 Changes in Annual Bioethanol Production Volume

Additionally, in 2021, worldwide natural gas consumption was 4.04 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 20.5%, Russia 11.8%, China 9.4%, Iran 6.0%, Canada 3.0%, Saudi Arabia 2.9%, Japan 2.6%, Germany 2.2%, Mexico 2.2%, and the U.K. 1.9%. Together, these ten countries accounted for 62.3% 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), newly installed onshore wind power capacity in 2022 amounted to 68.8 GW. When this is broken down by country, China accounted for 47.3% of this new capacity, followed by the U.S. at 12.5%, Brazil at 5.9%, Sweden at 3.5%, Finland at 3.5%, Germany at 3.5%, India at 2.7%, Spain at 2.4%, France at 2.3%, and Australia at 2.1%. Japan accounted for 0.2% of new capacity. The total installed onshore wind power capacity around the world amounts to 841.9 GW. In terms of the country-by-country share of this global total, China leads with 39.7%, followed by the U.S. with 17.1%, Germany with 7.0%, India with 5.0%, Spain with 3.5%, Brazil with 3.0%, France with 2.5%, Canada with 1.8%, the U.K. with 1.7%, and Sweden with 1.7%. Japan accounts for 0.6% of wind power capacity.

In contrast, newly installed offshore wind power capacity in 2022 amounted to 8.8 GW, substantially lower than 2021. According to the country-by-country breakdown, China accounted for 57.6% of this new capacity, followed by the U.K. at 13.4%, Taiwan at 13.4%, France at 5.5%, and the Netherlands at 4.2%. The total installed offshore wind power capacity around the world amounts to 64.3 GW. China accounts for the highest proportion at 48.9%, followed by the U.K. at 21.6%, Germany at 12.5%, the Netherlands at 4.4%, and Denmark at 3.6%.

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 2021 was approximately 175 GW. Breaking down this new capacity by country indicates that China accounted for 31.4%, followed by the U.S. at 15.4%, India at 7.4%, Japan at 3.7%, Brazil at 3.1%, Germany at 3.0%, Spain at 2.8%, Australia at 2.6%, South Korea at 2.4%, and France at 1.9%. The total installed solar-based electric power generation capacity around the world as of 2021 amounted to 942 GW. According to the country-by-country breakdown, China accounted for the highest proportion at 32.7%, followed by the U.S. at 13.0%, Japan at 8.3%, India at 6.4%, Germany at 6.3%, Australia at 2.7%, South Korea at 2.1%, Spain at 2.0%, France at 1.5%, and Brazil at 1.0%.

(1) Bioethanol

According to statistics compiled by F.O. Licht GmbH, global ethanol production increased by approximately 3% in 2022 from 2021 to about 126.11 million kL, which is still below the level prior to the COVID-19 pandemic. The proportion of this production for fuel remained at 84%, an increase of approximately 3%. Figure 1 shows the an-

Table 1 Comparison of National Biodiesel Fuel Utilization Promotion Council Standards and JIS K 2390

Item	Unit	Council standards		JIS K 2390	
		New	Old	2016	2008
Fatty acid methyl ester content	Wt%	96.5 min.	96.5 min.	96.5 min.	←
Density (15℃)	g/cm^3	0.86 to 0.90	0.86 to 0.90	0.86 to 0.90	←
Kinematic viscosity (40℃)	mm^2/s	2.0 to 5.0	3.5 to 5.0	2.0 to 5.0	3.5 to 5.0
Pour point	℃	-30 to +5 (depending on climate)	-30 to +5 (depending on climate)	Agreed between the relevant parties	←
Cold filter plugging point (CFPP)	℃	-19 to -1 (depending on climate)	-19 to -1 (depending on climate)	Agreed between the relevant parties	←
Flash point (PMCC)	℃	100 min.	120 min.	100 min.	120 min.
Sulfur content	ppm	10 max.	10 max.	10 max.	←
Carbon residue (100% residual oil)	Wt%	0.05 max.	—	—	
Carbon residue (10% residual oil)	Wt%	0.30 max.	0.30 max.	0.30 max.	←
Cetane number		51 min.	51 min.	51 min.	←
Sulfuric ash content	Wt%	0.02 max.	0.02 max.	0.02 max.	←
Water content	mg/kg	500 max.	500 max.	500 max.	←
Solid impurities	mg/kg	24 max.	24 max.	24 max.	←
Copper plate corrosion (3 h @ 50℃)		1 max.	1 max.	1 max.	←
Acid number	mgKOH/g	0.5 max.	0.5 max.	0.5 max.	←
Oxidation stability (110℃)	h	10 min.	(6 min.)	10 min. or agreed between the relevant parties	Agreed between the relevant parties
Iodine number	gI_2/100g	120 max.	120 max.	Report	120 max.
Linolenic acid ME	Wt%	12.0 max.	12.0 max.	12.0 max.	←
Methanol	Wt%	0.20 max.	0.20 max.	0.20 max.	←
Monoglycerides	Wt%	0.7 max. or 0.6 max.	0.60 max.	0.7 max. or 0.6 max.	0.60 max.
Diglycerides	Wt%	0.20 max.	0.20 max.	0.20 max.	←
Triglycerides	Wt%	0.20 max.	0.20 max.	0.20 max.	←
Free glycerin	Wt%	0.02 max.	0.02 max.	0.02 max.	←
Total glycerin	Wt%	0.25 max.	0.25 max.	0.25 max.	←
Metals (Na + K)	mg/kg	5 max.	5 max.	5 max.	←
Metals (Ca + Mg)	mg/kg	5 max.	5 max.	5 max.	←
Phosphorus	mg/kg	4 max.	10 max.	4 max.	10 max.

nual production trends for bioethanol in each country. Of the two major producing countries, production in the U.S. increased by approximately 2% to 60.01 million kL and production in Brazil also increased by approximately 2% to 30.54 million kL. It should be noted that the production of ethanol from corn is forecast to increase by approximately 37% in Brazil to 4.50 million kL, which is equivalent to 15% of total ethanol production. However, this production is geographically limited to areas at a distance from export centers, which means that this ethanol continues to be mainly consumed domestically.

With respect to initiatives aiming to encourage the use of biofuels in Japan, in 2022, 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.) In addition, according to Announcement No. 32 by the Japanese Ministry of Economy, Trade and Industry on March 31, 2023, the annual target defined in the Act on Sophisticated Methods of Energy Supply Structures will be maintained at 500,000 kL (crude oil equivalent) for the period 2023 to 2027.

With respect to ethanol production technologies and the like, six companies (ENEOS Corporation, Suzuki Motor Corporation, Subaru Corporation, Daihatsu Motor Co. Ltd., Toyota Motor Corporation, and Toyota Tsusho Corporation) established the Research Association of Biomass Innovation for Next Generation Automobile Fuels (raBit) to study ways of optimizing the process of producing fuels such as bioethanol. Similarly, the Public-Private Council to Promote the Introduction of Sustainable Aviation Fuel (SAF) was established on April 22, 2022. This council is also studying technologies for refining bioethanol into jet fuel (alcohol-to-jet, ATJ) and released interim proposals for policy directions to promote these technologies.

5 Biodiesel Fuel

The Guidelines for Biodiesel Usage in the Construction Industry were revised in March 2023. These guidelines were formulated and issued by the National Biodiesel Fuel Utilization Promotion Council (under the auspices of the Japan Organics Recycling Association) with participation from academic experts, producers, and users in 2008, as well as observers from the relevant ministries and other parties. The guidelines assume the domestic production and use of biodiesel fuel as B100 (BDF).

The main revisions covered (1) the criteria of the BDF Utilization Promotion Council standards, which consist of 26 items and (2) notes related to the production and usage of BDF.

First, with respect to (1), the criteria were revised based on JIS K 2390 (Automotive fuels-Fatty acid methyl ester (FAME) as blend stock), which was updated in 2016, the EAS-ERIA Biodiesel Fuel Benchmark Standard (2008), and the Biodiesel Guidelines from the Worldwide Fuel Charter (2009). Table 1 compares the old and new standards of the BDF Utilization Promotion Council with the 2008 and 2016 editions of JIS K 2390. Of the 26 items in the BDF Utilization Promotion Council standard, seven (kinematic viscosity, water content, methanol, triglycerides, diglycerides, monoglycerides, and free glycerin) are regarded by the Council as monitoring standards. Producers are expected to periodically measure (monitor) these seven items to help prevent issues reaching users. These items have been part of the standard since the guidelines were established.

With respect to revision (2), notes were inserted related to the reduced pressure heating distillation process, which has been added recently to many BDF refinement processes. These notes described the necessity of introducing a reduced pressure distillation process that factors in the reduction in oxidation stability and low-temperature fluidity caused by heating and the energy profit ratio (EPR). In addition, although the fuel regulations of Tokyo, Saitama Prefecture, Chiba Prefecture, and Kanagawa Prefecture allow the application of these criteria to B5, a note was added explaining that the carbon residue and cetane index for 10% residual oil cannot be applied to BDF (B100).

Furthermore, notes for BDF usage clarified that engine lubricating oil fuel dilution is more likely to occur than with diesel due to post fuel injection into the cylinder for automatic or forced regeneration of the diesel particulate filters (DPFs) adopted on clean diesel vehicles, and that fuel injection upstream in the exhaust system (i.e., the rich spike process) may be a cause of poor NOx conversion in vehicles with a NOx storage-reduction catalyst.

6 Methanol and Di-methyl Ether (DME)

Methanol is mainly produced from natural gas and coal. In 2022 the worldwide demand for methanol was estimated to be 91.7 million tons, with China forecast to account for about 60% of that total. Methanol is mainly used as a precursor for formalin or olefins. Fuel applications account for approximately one-quarter of total methanol demand. 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. There is robust global demand for methanol as a raw material, and methanol is being used as an environmentally friendly source of energy.

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 working to produce renewable dimethyl ether (rDME) and blend it into LPG. In the UK, Dimeta announced plans to synthesize rDME.

In Japan, NEDO announced plans to develop technology for reusing carbon dioxide. Plans have been formulated to accelerate production technology for diesel, SAF, methane and other liquid fuels, as well as green LPG. This NEDO project has selected a concept of synthesizing methanol from carbon dioxide primarily using chemical products such as plastics as feedstock.

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