CONSERVATION OF RESOURCES IN THE AUTOMOBILE INDUSTRY

1 Introduction

1. 1. Japanese Government Energy Policies

In April 2014, the Japanese government approved the new "Strategic Energy Plan (the fourth plan)", which forms the basis for Japan's energy policies for the immediate future[1]. In terms of primary energy, the plan discusses the use of nuclear power and ensuring safety, improving the efficiency of electric power generation, such as through the application of an integrated gasification combined cycle for coal, expanding the use of LNG and LPG, and also emphasizes reducing the cost of renewable energy. In terms of secondary energy, the plan cites the need to reform the structure of electric power 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 sets a target for the level of greenhouse gases in 2030 "to be reduced by 26% compared to the level in 2013".

In response to this, the Agency for Natural Resources and Energy within METI issued the FY 2015 Annual Report on Energy (Energy White Paper 2016)[2] in May of 2016. In this report the agency presented the following: (1) the current state of energy in Japan and the main measures being taken, (2) energy trends, and (3) the current status of the measures being taken regarding the supply and demand of energy in Japan in 2015.

1. 2. The Advent of Hydrogen as a Source of Energy

The use of hydrogen as a fuel source was also widely discussed in the Strategic Energy Plan, leading METI to draw up the Strategic Roadmap for Hydrogen and Fuel Cells in June of 2014. This roadmap stipulates the promotion of joint efforts among industry, academia, and government to realize a hydrogen-based society through the following three steps: (1) the dramatic expansion of hydrogen utilization, (2) the full-fledged introduction of hydrogen power generation and establishment of a large-scale hydrogen supply system and, (3) the establishment of a totally carbon dioxide-free hydrogen supply system.

In addition, the Revised Version of the Strategic Roadmap for Hydrogen and Fuel Cells, which included new goals and specific explanations of the new efforts to be undertaken, was released on March 22, 2016[3]. In concrete terms, the revised version of the roadmap stipulated the following. (1) Future price targets for household fuel cells were clarified. PEFC (polymer electrolyte fuel cells): 800,000 yen by 2019 and SOFC (solid oxide fuel cells): one million yen by 2021. (2) Targets for the dissemination of fuel cell vehicles were set: in total, about 40,000 vehicles by 2020, about 200,000 vehicles by 2025, and about 800,000 vehicles by 2030. (3) Targets for the construction of hydrogen stations were set: about 160 stations by 2020 and about 320 stations by 2025. (4) Descriptions concerning hydrogen power generation were fleshed out. (5) The technical and economic challenges concerning utilization of hydrogen generated using renewable energy will be discussed and examined.

2 International Energy Trends

2. 1. Energy Consumption Trends[2]

Final global energy consumption increased twofold over the 42 years from 1971 until 2013 (see Fig. 1). By sector, the amount of industrial energy consumption in the steel, machinery, chemical and other industries increased by 1.9 times. The amount of consumer energy consumption by households and businesses also increased by 1.9 times. By comparison, the amount of energy consumed by the transportation sector increased by 2.7 times. That strong increase in the amount of energy consumed by the transportation sector is due to the advance of motorization around the world during that time and a rapid rise in the demand for fuel for automobiles. As a result, the percentage of the total energy demand

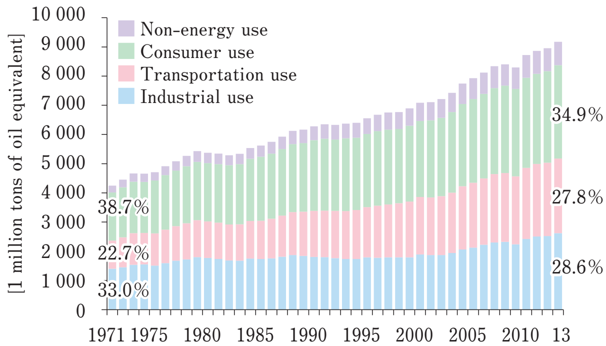


Fig. 1 Global Energy Consumption Trends

accounted for by the transportation sector increased by nearly 5% from 22.7% in 1971 to 27.8% in 2013.

The use of petroleum increased at an average annual rate of 1.3% from 1971 to 2013 due to robust fuel consumption by the transportation industry, and it still accounted for the largest share of total energy consumption at 31.4% in 2013. Over that same 42 year time period the consumption of natural gas and coal actually grew more than that of petroleum. The consumption of natural gas notably grew in terms of electricity generation and use in homes for heating and cooking due to increased demand in developed nations for a cleaner energy source to combat climate change.

In contrast, the strongest growth over that period was exhibited by nuclear power (average annual rate of 7.5%) and new energy sources (average annual rate of 8.8%), but in 2013 their share of the total energy consumption remained low, at 4.8% and 1.2% respectively. The cost of generating electricity has been decreasing recently, mostly thanks to solar power generation, and the portion of energy consumption drawn from new energy sources is likely to keep increasing.

The Paris Agreement was negotiated and adopted at the 2015 United Nations Climate Change Conference (COP 21) held in Paris, France in December of 2015. It is a fair and effective agreement for all participating nations that deals with greenhouse gas (GHG) emissions mitigation, adaptation, and finance starting in the year 2020. The agreement stipulates that all participating countries, including the major emitters, will submit and update GHG emissions reduction targets, have these submissions reviewed, and reduce the GHG emissions to keep the increase in the global average temperature well below 2° C above pre-industrial levels, as well as pursue efforts to limit that increase to 1.5° C above said levels. In the future, as the implementation of this agreement leads to progress in the efforts of individual countries to reduce GHG emissions, there is a strong possibility that the consumption of coal and other fossil fuels will change.

2. 2. Trends in Crude Oil[4]

According to a report by BP (British Petroleum) the total amount of petroleum produced around the world each day in 2014 was 88.67 million barrels. By country, Saudi Arabia is the leading producer and accounts for 12.9%, followed by Russia at 12.7%, the U.S. at 12.3%, Canada at 5.0%, China at 5.0%, the United Arab Emirates at 4.0%, Iran at 4.0%, Iraq at 3.8%, Kuwait at 3.6%, and Venezuela at 3.3%. The petroleum production of these ten top producers accounts for 66.6% or two-thirds of all production throughout the world.

In 2014, worldwide petroleum consumption was 92.08 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 12.4%, Japan 4.7%, India 4.3%, Russia 3.5%, Brazil 3.4%, Saudi Arabia 3.4%, South Korea 2.6%, Germany 2.6%, and Canada 2.4%. These top ten oil consuming nations account for 59.2% of all petroleum consumption in the world.

2. 3. Trends in Natural Gas[4]

The total amount of natural gas produced around the world each day in 2014 was 3 billion 461 million m^3. When this total amount is broken down according to the top ten producing nations, the U.S. is the leading producer and accounts for 21.4%, followed by Russia at 16.7%, Qatar at 5.1%, Iran at 5.0%, Canada at 4.7%, China at 3.9%, Norway at 3.1%, Saudi Arabia at 3.1%, Algeria at 2.4%, and Indonesia at 2.1%. The natural gas production of these ten top producers accounts for 67.5% (approximately two-thirds) of all production throughout the world.

In 2014, worldwide natural gas consumption was 3 billion 393 million m^3. Breaking this down by the top ten natural gas consuming nations reveals that natural gas consumption in the U.S. accounted for 22.7%, Russia 12.0%, China 5.4%, Iran 5.0%, Japan 3.3%, Saudi Arabia 3.2%, Canada 2.5%, Mexico 2.5%, the United Arab Emirates 3.2%, and the U.K. 2.0%. These top ten natural consuming nations account for 61.2% of all natural gas consumption in the world.

2. 4. Trends in GTL and DME[2]

The research and development of technologies that will expand the possibilities for new uses of natural gas, such as GTL (Gas to Liquids) and DME (Di-methyl Ether) that can be produced from natural gas, is making progress and some commercial production is already being carried out. Plans are also being drawn up in various countries around the world to develop non-conventional sources of natural gas, such as shale gas and CBM (Coal-bed Methane). The massive increase in shale gas production in the U.S. is particularly remarkable. According to the EIA (Energy Information Administration) in the U.S., the amount of natural gas produced in the U.S. from CBM increased by about 10 times from 5.3 billion m^3 in 2003 to 57.2 billion m^3 in 2008. After this however, production decreased down to 36.4 billion m^3 in 2014. In contrast, the amount of natural gas produced in the U.S. from shale gas deposits has increased rapidly since 2007 and had reached 389.2 billion m^3 by 2014.

The Panama Canal expansion project was completed and opened to ships on June 26, 2016. This expansion increased the width and depth of the lanes and locks allowing larger ships to pass through, creating expectations that Japan will be able to begin importing lower-priced shale gas from the U.S.

3 Energy Trends in Japan

3.1. Trends in Crude Oil in Japan[2]

In FY 2014 Japan's crude oil self-sufficiency rate was just 0.3%. The country's main oil fields are in Niigata Prefecture, Akita Prefecture, and Hokkaido (Fig. 2). This low self-sufficiency rate meant that Japan was dependent on imports of crude oil from overseas to meet 99.7% of its needs in 2014, with over 80% of that imported crude oil coming from the Middle East. In 2014 the U.S. depended on oil from the Middle East to meet 24.3% of its needs, while the European OECD countries were dependent on the Middle East for 15.8% of their crude oil needs. Compared to other countries, Japan is extremely dependent on Middle Eastern oil is extremely high. When the 2014 crude oil imports are ranked according to the supplying country, Saudi Arabia comes first at 32.5%, followed by the United Arab Emirates at 24.9%, Qatar at 9.6%, and then Russia at 8.4%.

Figure 3 shows the changes in the prices of crude oil, LNG, and methanol converted into yen at the applicable exchange rate[5]. For methanol and LNG, the prices shown are the calorific value equivalent price per 1 liter of diesel.

The prices of crude oil and LNG deviated from each other temporarily due to the large price fluctuations in crude oil, but the changes in the prices per caloric value remained largely the same. Of particular interest is the fact that the price of crude oil fell in the spring of 2016 down to about 20 yen per liter.

Methanol is mainly produced from natural gas, so its price closely follows that of LNG. Up until 2008 the annual production of methanol was fairly small at around 40 million tons, but after the global financial crisis production increased thanks to repairs and improvements at the production plants. Fluctuations in supply and demand caused large swings in the price of methanol, but these days it more closely follows the price of LNG. The 2015 annual production of methanol was predicted to reach 71 million tons due to stronger demand from China. Since 2014, sharp fluctuations in the price of crude oil have caused it to diverge from the price of LNG, but over the long-term, the price of crude oil is also expected to tend to follow that of LNG.

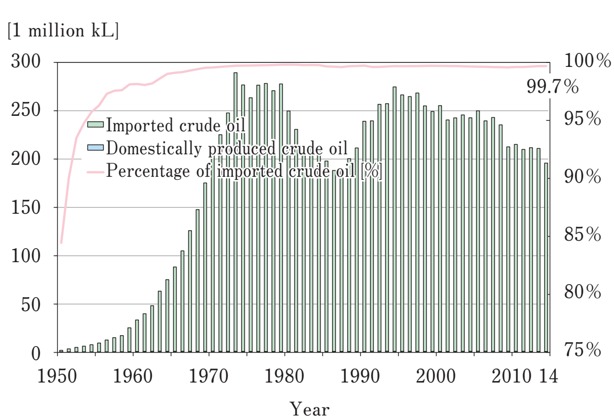


Fig. 2 Changes in the Amount of Crude Oil Supply in Japan

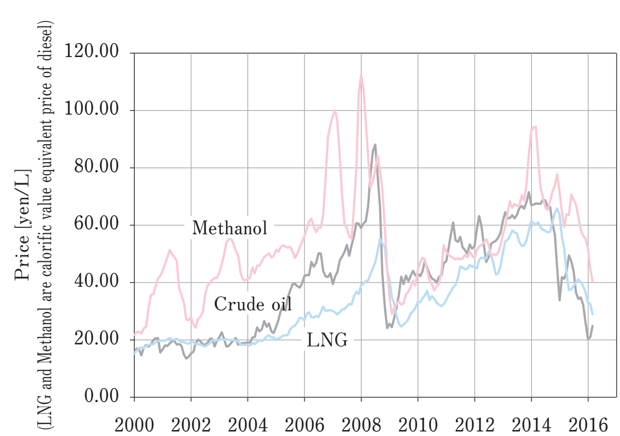


Fig. 3 Changes in the Prices of Crude Oil, LNG, and Methanol
(LNG and methanol are calorific value equivalent price of diesel)

3. 2. Trends in Natural Gas in Japan

The amount of natural gas imported into Japan was 89 million tons. According to the trade statistics from the Japanese Ministry of Internal Affairs and Communications (MIC)[7], the total value of all liquid natural gas imported by Japan in 2015 was 7.8 trillion yen. The main sources of Japan's imported natural gas and the proportion of their import value are as follows: Australia 21.4%, Malaysia 19.0%, Qatar 17.7%, Russia 8.6%, Indonesia 7.2%, United Arab Emirates 6.2%, Nigeria 5.6%, Brunei 5.0%, Papua New Guinea 4.8%, and Oman 2.1%.

In 2014 the average price of LNG imported into Japan (CIF) was $16.33 USD per 1 million BTU. Compared to the domestic price of natural gas of $4.35 USD per 1 million BTU in the U.S. and $8.22 USD per 1 million BTU in the U.K, the price in Japan was quite high. This is due to several factors, including the tight levels of supply and demand in the Asian market, the low levels of liquidity, and the fact that many of the factors that determine the price of the LNG imported into Japan are based on the level of crude oil prices. The LNG price for Japan is heavily influenced by the price of crude oil. However, the large price differences between Japan and Western nations have been shrinking since the beginning of 2015 due to the decline in crude oil prices and an easing in the supply and demand of LNG.

4 Biofuels

4. 1. Bioethanol

According to statistics compiled by F.O. Licht GmbH, global ethanol production continued to increase in 2015 by approximately 3% to a new record high of about 117.52 million kL[7]. Approximately 84% of this total was used for fuel, which is the same as it was in 2014. Fig. 4 shows the changes in the annual production of bioethanol in each country.

The two main bioethanol producing countries are the U.S. and Brazil. In Brazil, excessive rainfall reduced the amount of sugar that could be produced from sugarcane crop, while corporations raised the proportion of those crops used to produce ethanol since they can collect profit on it in a shorter period of time, leading Brazilian bioethanol production to increase by approximately 6% compared to 2014. The amount of bioethanol produced in the U.S. also increased by approximately 3% compared to 2014 thanks to high corn yields. On November 30, 2015 the U.S. Environmental Protection Agency (EPA) finalized the volume requirements and associated percentage standards under the delayed RFS (Renewable Fuel Standard) program for biofuels, and while the requirements were lower than the initial values, they were revised slightly upward from the initial proposal presented on June 10th[8]. In India, the production of bioethanol increased by approximately 10% compared to 2014 due to the resumption of the ethanol-blended gasoline program (E5) in 2013.

In Japan, the project to popularize the use of biofuels underway in Okinawa Prefecture to promote the use of biofuels supplied roughly 72,000 kL of E3 and E10 fuel in FY 2015 and had established 34 service stations supplying E3 fuel and 32 service stations supplying E10 fuel as of March 2016[9]. In Miyakojima City, the Japanese government is continuing to support a verification project for the high-efficiency production of bioethanol from molasses and the promotion and dissemination of E3 biofuel based on previous successes[10]. In contrast, the number of service stations in Japan selling bio-gasoline blended with ethyl tert-butyl ether (ETBE) decreased by approximately 2% from April 2015 to 3,230 stations (as of April 10, 2016)[11].

In terms of bioethanol production technology, researchers at Ryukoku University and Kyoto University in Japan announced the discovery of a new yeast strain that can produce bioethanol from starch via consolidated bioprocessing [12]. The DuPont company in the U.S. announced that it had opened the world's largest cellulosic ethanol plant in the state of Iowa, which will convert corn stover (corn cobs, leaves, and stalks) to 30 million gallons of fuel-grade ethanol annually[13].

4. 2. Biodiesel Fuel

The consumption of biodiesel fuel grew at a sluggish pace as the price of the fatty acid methyl ester (FAME) used to produce the fuel became relatively high in comparison to the falling price of crude oil. According to the REN21 *Renewables 2016 Global Status Report*, the total volume of biodiesel fuel produced worldwide was 30.4 billion liters in 2014. which essentially stayed at the same level in 2015 when 30.1 billion liters were produced. In contrast, spurred in part by the rising production of bioethanol, the number of countries mandating the blending of either biodiesel fuel or bioethanol, or both, into regular diesel and gasoline has increased from 64 countries in 2014 to 66 countries in 2015.

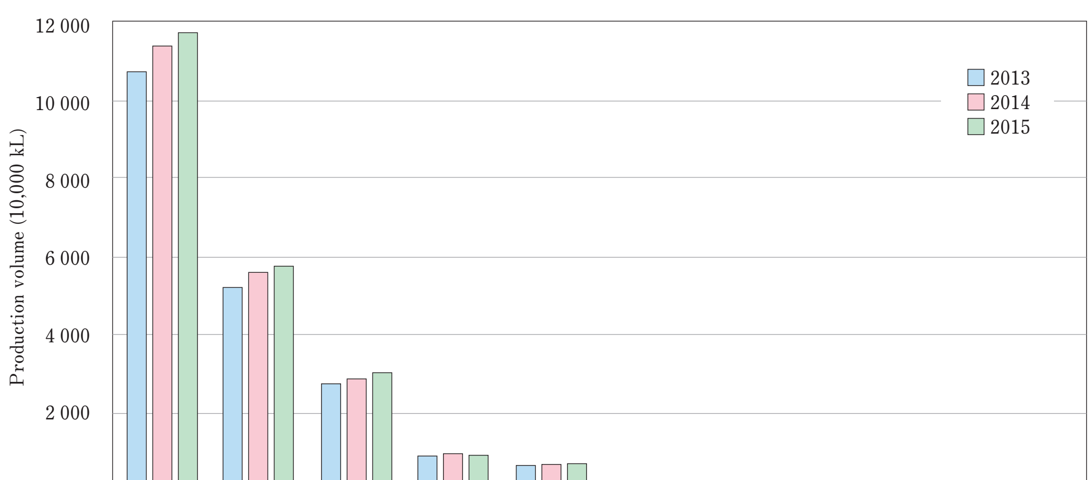
In Europe a new B20/B30 blended biodiesel fuel standard was drawn up and went into force in August of 2015. In response, Germany established the DIN EN16709 "Automotive fuels - High FAME diesel fuel (B20 and B30) - Requirements and test methods" standard as a framework enabling automobile manufacturers to use biodiesel fuels only on limited vehicle models. This standard stipulates that biodiesel fuels that satisfy the B100 fuel quality specified in the EN14214 standard can be blended, manufactured, sold, and used. This makes it very similar to the ASTM D 6467 standard in the U.S., which also stipulates the blending of B100 biodiesel fuel that complies with the ASTM D 6751 standard. The EN590 standard for diesel fuels stipulating that FAME can be blended into diesel fuel up to 7% by volume has already been recognized and accepted, and the EN16734 standard that allows for FAME to be blended into diesel fuel up to 10% by volume will be drawn up and is on schedule to go into force sometime in FY 2016.

One of the disadvantages of biodiesel fuel is its low volatility, and research into the use of a metathesis catalyst to lower the boiling point of FAME is drawing attention. Robert H. Grubbs was awarded the Nobel Prize in Chemistry in 2005 for the discovery of the family of ruthenium based metathesis catalysts, which were then used to perform a cross-metathesis reaction between FAME and 1-hexene under mild reaction conditions. This in turn caused the long-chain fatty acids to reform into medium-short-chain fatty acids, successfully obtaining distillation characteristics similar to those in regular diesel fuel(14). This reformed FAME can greatly reduce fuel dilution of the lubricating oil, and also has the potential to eliminate exhaust aftertreatment device malfunctions due to post injection. If this reformed FAME can be produced inexpensively, use of biodiesel fuel is likely to increase.

5 Methanol and DME (Di-methyl Ether)

Currently, methanol is produced from natural gas and coal. In 2015 the worldwide demand for methanol was assumed to be 71 million tons, of which the demand in China alone was 39 million tons, exceeding half of the world's total. When this demand for methanol is broken down according by usage, 23% of the methanol is used for energy (gasoline blends, DME, and biodiesel fuels, etc.)(15), and over 30% of the methanol is expected to be used as fuel in China, where 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(16).

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 it. Mitsubishi Gas Chemical Company Inc. and Mitsubishi Corporation, have similar plans in the works in Trinidad and Tobago, and Isuzu Motors, Ltd. is also producing low-pollution vehicles with DME engines(17).



	Total	U.S.	Brazil	China	EU	India	Canada	Thailand	Australia	Pakistan
2013	10 730	5 185	2 765	912	670	209	187	125	32	47
2014	11 367	5 576	2 860	980	723	215	187	141	27	49
2015	11 752	5 753	3 030	965	728	238	186	143	27	48

Fig. 4 Changes in Annual Ethanol Production Volume in Each Main Producing Country

6 Natural Sources of Energy

6. 1. Wind-based Electric Power Generation

According to the Global Wind Energy Council (GWEC), newly installed wind power in 2015 amounted to 63.0 GW[18]. By country, China led the way and accounted for 48.4% of the new installations, followed by the U.S. at 13.6%, Germany at 9.5%, Brazil at 4.4%, India at 4.2%, Canada at 2.4%, Poland at 2.0%, France at 1.7%, the U.K. at 1.5%, and Turkey at 1.5%. The total installed wind power capacity around the world as of 2015 amounted to 432 GW. Breaking this down by country in terms share of this global total, China again leads with 33.6%, followed by the U.S. with 17.2%, Germany with 10.4%, India with 5.8%, Spain with 5.3%, the U.K. with 3.1%, Canada with 2.6%, France with 2.4%, Italy with 2.1%, and Brazil with 2.0%.

6. 2. Solar-based Electric Power Generation[2]

The amount of new solar power generation introduced in the leading countries of the world since the second half of the 2000s has increased at an accelerating pace. During the 2000s many European nations introduced feed-in tariffs (FiT), a program designed to accelerate investment in renewable energy technologies. Its effect has been quite large, and energy producers have been offered a high price for the generation of solar power, triggering significant growth in solar power generation in Germany, Italy, and Spain. The FiT program was also introduced in Japan in July of 2012 and as a result the installation of solar power generating facilities expanded greatly. The cumulative amount of solar power generation installed by 2014 in Japan was 23.41 million kW, enough to rank third in the world behind only Germany at 38.25 million kW and China at 28.33 million kW. This means that Japan leapt past Italy, which had been third in the world in 2013 with 18.62 million kW of installed solar power generating capability.

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