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Development of low-CO_2-emission vehicles and utilization of local renewable energy for the vitalization of rural areas in Japan

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ABSTRACT

Most of Japan's energy supply depends on imports from foreign countries, making the independence ratio of energy in Japan very low. The Fukushima nuclear power plant accident triggered by the Great East Japan Earthquake and Tsunami led to a mass shutdown of all the nuclear plants in Japan, a stoppage that is still in effect. In this paper, we review the energy supply situation and some social problems faced by rural areas in Japan. Given that lifestyles in rural Japan are reliant on automobiles, there is significant demand for the establishment of a sustainable mobility society. Furthermore, Japan is now entering an aging society ahead of other countries. In order to enhance the vitalization of rural areas and accelerate the establishment of sustainable society, our project developed low-CO_2-emission vehicles (i.e., a single-driver EV [micro-EV] and a low-speed E-bus) for elderly people and tourists through the cooperation of regional industries, a local university, and a city office. This paper also reports some trial test results on renewable energy utilization as the driving energy supply for these low-emission vehicles.

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1. Introduction

Energy is a fundamental element in sustaining society, the quality of people's lives, and economic development. A steady supply of energy is an important responsibility for national governments. Before 1800, the world's energy consisted largely of renewable energy, including biomass and a small amount of waterwheel, windmill, and animal energies, which were used for agricultural production and daily life. On the other hand, transportation was mainly dependent on animal energy. After around 1850, the main energy source changed to coal, which was used for industrial production. Later, the primary source of energy shifted from coal to liquid and gas fuels in the 1900s. In 2012, fossil fuels accounted for over 89% of the world's total energy [1]. P. Moriarty

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and D. Honnery [2] reported that the global energy consumption from 1950 to 2010 increased from 86 EJ (85×10^{18} J) to 503 EJ and that global energy usage in 2050 would reach roughly 1000 EJ if the global GDP continued to increase at the same rate. They also showed that the concentration level of atmospheric CO_2 has increased from 310 ppm (1950) to 390 ppm (2010). The crisis of climate change has become a serious problem, but the world is unfortunately still in need of more fossil energy.

Various types of new fossil energy have now been developed in many countries [3]. These new resources are called "unconventional resources" to contrast the "conventional resources" of coal, oil, and natural gas. Shale gas, developed in United States, has the potential to be one of these unconventional gas resources. Shale gas is natural gas found in the fine-grained sedimentary rock called shale [4]. As the gas is trapped in the rock, "hydraulic fracturing" technology is required to enhance gas production. The United States is set to become an exporter of shale gas in the near future.

Moreover, "tight gas" and "coal bet methane (CBM)" have been the subjects of aggressive development as unconventional gas resources. Tight gas is gas trapped in hard rock that has lower impermeability levels than the sedimentary rock of shale gas. On the other hand, CBM is gas stored in the coal seams, consisting mostly of methane and a small amount of heavier hydrocarbons, hydrogen, and so on. Some papers have suggested that there are abundant CBM reserves in China and that the resource will play an important role as the future energy of China [5,6].

Methane hydrate also has huge potential to become an alternative resource of conventional gas. An ice-like material that consists of water and methane or a mixture of light natural gas components, methane hydrate exists stably under the high-pressure and low-temperature conditions found in the world's deep seas [7,8]. Experts believe that the total volume of methane hydrate reservoirs is several times larger than the currently known reserves of conventional natural gas. Ensuring a stable supply of methane hydrate, however, requires economically practicable technology. Considering that methane is a greenhouse gas with a larger global warming potential (GWP) than CO_2, there is also a need for technology that helps prevent gas leakage into the atmosphere. As explained above, the world energy situation is in a state of major change.

As for Japan, most of the energy supply depends on foreign resources. The independence ratio of energy in Japan is very low [9]. Furthermore, the Fukushima nuclear power plant accident that occurred in the aftermath of the Great East Japan Earthquake and Tsunami on March 11, 2011, has exacerbated the energy shortage by prompting plant shutdowns that remain in effect [10]. After the Fukushima nuclear power plant accident, officials implemented a planned blackout—a rotational electric power shutdown in the area covered by the Tokyo Electric Power Company—that affected several railway operations. Simultaneously, the earthquake also triggered a gasoline shortage; long lines of cars waited, sometimes for days, at gas stations to fill up. Therefore, the problem of energy security is directly related to the transportation system. In rural Japan, people rely on their automobiles. Thus, the demand for the establishment of a sustainable mobility society is just as strong in rural areas as it is in urban areas [11–13]. However, marked depopulation and aging in rural areas have impeded efforts to construct a sustainable transportation system through public transportation.

In this paper, we review the energy supply situations and social problems of rural areas in Japan. We also discuss the development of renewable energy-based low-CO_2-emission vehicles for the vitalization of rural communities.

2. The energy and social situations of Japan

Most of Japan's energy supply depends on imports. Fig. 1 illustrates trends in the energy independence and oil dependence ratios of Japan. The independence ratio for energy from foreign countries decreased steadily and sank below 10% in 1980, eventually reaching a level of 4.8% in 2011 [9]. Furthermore, the proportion of oil dependence on the Middle East is higher than 80% today. Clearly, the energy supply of Japan is in a very vulnerable situation.

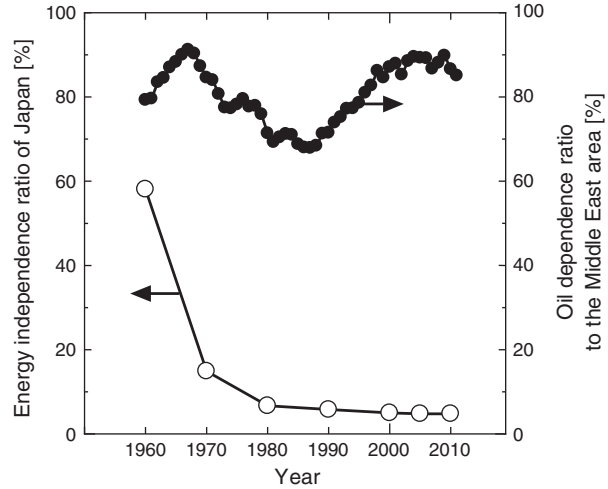

Fig. 1. Energy independence and oil dependence ratios of Japan.

The Fukushima nuclear power plant accident on March 11, 2011, altered Japan's energy supply situation significantly. Fig. 2 shows the primary energy distribution of Japan in 2010 and 2011. As a result of the Fukushima nuclear power plant accident, the proportion of energy created via nuclear power fell by 64.5%. In order to compensate for this power shortage, thermal power stations driven by natural gas have increased their energy production levels [14]. This heavier operational load on these power stations raised overall CO_2 emission levels by 4.1% from 2011 to 2012. In order to reduce CO_2 emissions and avoid accelerating climate change, we need to take a proactive approach to using more renewable energy.

Fig. 3 shows the sources of direct CO_2 emissions in Japan. Total CO_2 emissions in 2011 were 1241 Mt [15]. 37.1% of that total came from the energy power industry, while 27.3% came from the industrial fields. Transportation accounted for a share of 17.9%, equivalent to 222 Mt of CO_2. This represents a substantial quantity that cannot be ignored. The pie charts in Fig. 4 provide more detail on the CO_2 emissions from transportation, showing the indirect CO_2 emissions from various forms of transportation. In 2011, the total indirect CO_2 emissions from the transportation sector were 230 Mt. The ratios of freight and passenger transportation were 38% and 62%, respectively. Passenger transportation was thus responsible for 143 Mt of CO_2 emissions. The largest source of CO_2

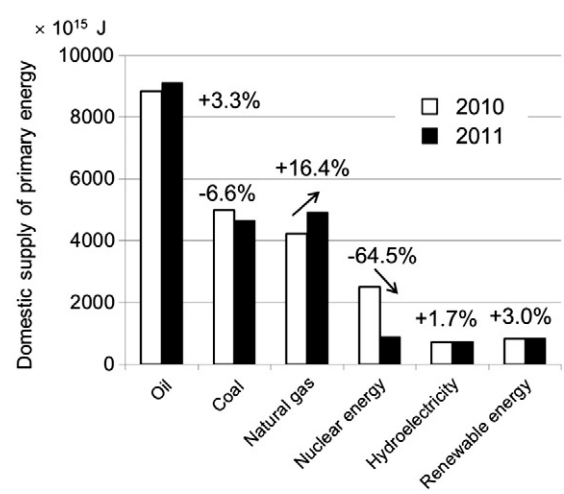

Fig. 2. Domestic supply of primary energy in Japan at 2010 and 2011.

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