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Energy security performance in Japan under different socioeconomic and energy conditions

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ABSTRACT

A secure energy supply is indispensable for Japan's economic activity, but it is becoming more difficult to attain, due to increasing energy demand in emerging countries. The pattern of socioeconomic development and the achievement of a low-carbon society are also strongly related to energy security. This study evaluated energy security performance in Japan under alternative scenarios of future socioeconomic and energy conditions by applying three energy security indicators derived from the Shannon-Wiener diversity index. The 2050 Japan Low Carbon Navigator was used to estimate energy structures under five socioeconomic scenarios and three selected combinations of effort levels toward producing a low-carbon society. It was found that the effort levels were the most influential factors in determining energy security performance, because they greatly affect energy supply and demand. The choice of socioeconomic scenario was also influential, although the impact of this choice was less significant than the choice of effort level. However, the impact of country-risk indicators is less substantial than the above two factors. The energy security performance of Japan will improve in the future, compared with the current level. However, if the country pursues further economic growth, its energy security performance will not greatly improve. Consequently, increasing efforts to achieve a low-carbon society will contribute to the realization of a highly energy-secure society with respect to Japan's current and future socioeconomic situation.

1. Introduction

In Japan in 2015, the self-sufficiency rate of energy (including nuclear energy as semi-domestic energy [1,2]) was 7.0%, the worst level in the history of the country. The country depends strongly on fossil fuels—these accounted for more than 80% of the energy supply before the Fukushima Daiichi nuclear disaster and currently account for more than 90% (Fig. 1)—and most are imported. Although Japan intended to diversify its energy sources after oil shocks in the 1970s, the share of oil in the primary energy supply is still the largest share (41.0% in 2015). More than 80% of Japan's oil supply is also derived from the Middle East, which entails high geopolitical risks, even though Japan has pursued diversification in its oil-supplying countries along with the diversification of its primary energy sources. The supply of oil for export is decreasing in Asian oil-producing countries, due to their own increase in energy demand. Because energy demands in emerging countries, such as China and India, are drastically increasing and therefore these countries will pursue measures to secure their own energy supplies, it will be more difficult for Japan to ensure cheap imported fuels in the near future. Thus, producing domestic energy sources and reducing dependence on imported energy are critical issues for the country.

Nuclear power has been one of the energy sources that could reduce dependence on fossil fuels; however, the Fukushima nuclear disaster completely changed the situation, highlighting safety issues with respect to nuclear power generation. At the time this paper was being written (March 2018), only three of 42 nuclear power plants in the country were in commercial operation. Thus, introducing renewable energy is an important alternative option in securing the national energy supply and in simultaneously solving other environmental issues, such as climate change and air pollution. Although multiple national policies were introduced to diffuse renewable energy after the oil shocks, renewable energy, except for large-scale hydropower generation, accounts for only a small percentage of the total primary energy supply (Fig. 1). After the introduction of the Feed-In Tariff (FIT) launched in July 2012, the share of renewable energy, particularly photovoltaics (PV), increased more than the historical trend. However, the share of renewable energy in primary energy is still very small (8.5% in

Abbreviations: IAM, Integrated Assessment Model; IGES, Institute for Global Environmental Strategies; FIT, Feed-In Tariff; NIES, National Institute for Environmental Studies; PV, Photovoltaics; LCN, Japan 2050 Low Carbon Navigator; LEAP, Long-range Energy Alternative Planning; ASEAN, Association of Southeast Asian Nations

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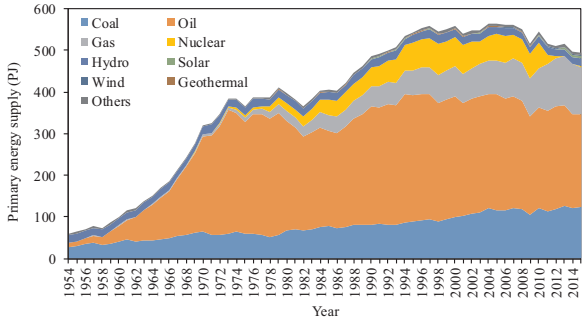

Fig. 1. Structure and transition of primary energy demand in Japan. "Others" refers to other types of renewable energy. 1 Mtoe is equivalent to 41.87 PJ. Source: Energy Data and Modeling Center [3].

2015).

In April 2014, the fourth version of the Strategic Energy Plan [4], developed after the Fukushima nuclear disaster, was endorsed by the government. The plan aims to reexamine and revise the energy strategy of Japan, particularly by reducing dependency on nuclear power, considering the Fukushima disaster. The plan prioritizes energy security, but it also considers economic efficiency and the conservation of the environment, all with a strong focus on safety (3E + S).

In July 2015, the government released the Long-term Energy Supply and Demand Outlook [5]. This outlook was developed based on the Strategic Energy Plan. According to the outlook, Japan will increase its share of renewable energy by 13–14% of primary energy (22–24% of power generation) by 2030. The share of nuclear power will also be increased to 10–11% of primary energy (20–22% of power generation). Drastic energy savings are also expected to reduce energy demand. However, considering the current situation in Japan, there are still difficulties inherent in resuming the use of nuclear power and increasing renewable energy to achieve the levels indicated in the outlook.

In transitioning toward a sustainable society, Japan faces many energy challenges, the main challenges in current energy policies being as follows. In the Strategic Energy Plan, coal-thermal power is still considered an "important baseload power," while the position of the government regarding nuclear power is not clear. The plan indicates that nuclear power is considered an important baseload power source, and the government has set the target for the share of nuclear power to be 10–11% of primary energy. However, at the same time, the plan indicates that dependence on nuclear power should be reduced. Because Japan depends on imports for most of its fossil fuel supply, energy costs and a stable energy supply may remain at risk as long as this continues to be the case.

Achieving a low-carbon society in the future is also closely related to improving energy security, particularly since 2011. In the wake of the Fukushima nuclear disaster, a stable energy supply was considered a key component in developing a low-carbon society [6]. The Ministry of the Environment [6] also indicated that the vulnerability of the domestic energy supply posed a significant challenge to the realization of such a society. To aim for a low-carbon society, it is essential to have a vision not only of the energy but also of the socioeconomic conditions of such a society.

The purpose of this study is to evaluate energy security performance in Japan up to 2050 under different future socioeconomic and energy conditions, using comprehensive energy security indicators. The socioeconomic conditions are represented by socioeconomic scenarios (i.e., different visions of the future society) and the country risks of energy exporters, while the energy conditions are expressed in terms of the level of effort dedicated to the achievement of a low-carbon society. This study focuses on energy security from the perspective of energy supply.

2. Literature review

Many types of research on energy security have been implemented in the literature, particularly those using some sort of indicator [7–20], studying different countries and regions and different periods with different methods. A significant number of studies have focused on Asian countries and a few on the case of Japan. Here, a literature review is conducted targeting Asian countries, including China, Hong Kong, Taiwan, Korea, Thailand, Indonesia, Malaysia, Singapore, India, Pakistan, Bangladesh, and Japan.

Many studies have analyzed China, for example, Ren and Sovacool [21,22], Wu [23], Yao and Chang [24,25], Su et al. [26] Zhang et al. [27], Zhao and Liu [28], Gao et al. [29], Matsumoto [30], and Cao and Bluth [31]. Ren and Sovacool [21] analyzed energy security from the perspective of availability, affordability, acceptability, and accessibility (often called the 4As) using the DEMATEL method. These authors [22] also evaluated energy security with respect to low-carbon energy, applying an analytic hierarchy process. Wu [23] examined the energy security strategies of China by focusing on overseas oil investment, strategic petroleum reserves, and unconventional gas development in the 11th and 12th Five-Year Programs. Yao and Chang [24] also used the 4As approach and evaluated the transition of energy security performance through the areas of a rhombus made by the 4As in the past (1980–2010). Yao and Chang [25], in another paper, also qualitatively analyzed the reasons why energy security has not improved in China during the period of economic reform. The authors particularly focused on the relationship between energy security and the country's energy policy. Su et al. [26] proposed ecological network analysis as a common tool to systematically evaluate energy supply security, analyzing the crude oil and natural gas supply system from 2000 to 2012. Zhang et al. [27] implemented a province-level analysis in 2013. The authors used a five-dimensional (20 components in total) energy security indicator and also applied multi-criteria decision-making methods to provide weights to the components and the dimensions. Zhao and Liu [28] focused on the relationship between the bioenergy industry and energy security and showed the contribution of the development of the bioenergy industry to China's energy security. Gao et al. [29], using their quantitative energy security model focusing on cost-benefit analysis and the benefits of ensuring energy security, evaluated the optimized scale of a strategic petroleum reserve and alternative fuels for energy security in China. Matsumoto [30] used a computable general equilibrium model and an energy security indicator to evaluate future energy security in China under climate mitigation scenarios. Cao and Bluth [31] qualitatively analyzed energy policy in China from the viewpoint of energy security. The authors investigated the energy mix of the country and the internal and external constraints that the country has faced with respect to its energy policy.

With respect to the other East Asian countries (except for Japan), Holley and Lecavalier [32] explored Hong Kong's challenges in dealing with energy security and environmental sustainability, based on interviews with public and private stakeholders, and made policy recommendations to solve the energy dilemma. Chuang and Ma [33] evaluated energy policy in Taiwan using six energy security indicators of four dimensions in the past (1990–2010) as well as for the future energy policy in terms of energy security, using both a modeling approach and the indicators. Chung and Ma [34] also evaluated the energy security of Taiwan in terms of energy supply diversity from 1996 to 2011. The authors used the Hirschman-Herfindahl index and the Shannon-Wiener index in their evaluation. Shin et al. [35] analyzed energy security in the Korean gas sector from the past to the future (1998–2015), using a model approach (quality function deployment and system dynamics). Chung et al. [36] also evaluated energy security in South Korea in the 2000s, using the indicators of supply reliability, the economy of power generation, environmental sustainability, and technology complementarity. Different from Shin et al. [35], Chung et al. [36] focused on energy security in the power generation sector.