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Japan's energy supply: Mid-to-long-term scenario – A proposal for a new energy supply system in the aftermath of the March 11 earthquake

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ABSTRACT

After the Fukushima nuclear plant accident, Japan is facing an unprecedented situation with its energy supply. This paper provides an overview of Japan's current energy landscape with descriptions of the kinds and production of energy. Since it is inevitable that the use of nuclear energy will decrease, we shall propose a best mix of electric sources of the large-scale and centralized network as well as the decentralized network as an alternative. The hub for this proposal is regional power centers (RPC) to control the electric supply as well as fuel transportation and storage on an area-by-area basis. As technologies that will realize this power center, we will discuss fuel cells, hydrogen production and storage and furthermore, the potential of CCS, which is requisite technology for carbon dioxide emissions reduction.
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1. Introduction

The Fukushima nuclear power plant accident caused by the eastern Japan earthquake has forced Japan to review her electric power supply system. This work presents a vision of Japan's mid-to-long-term supply of energy beyond electrification, i.e. for a heating supply system as well.

It is well known that Japan's domestic energy resources can cover only 4% (self-sufficiency ratio) [1] of the required national energy demand (see Fig. 1). This is a staggering low percentage in comparison to the corresponding percentages in other developed countries. For example the U.S. can cover 61% of her energy demand by domestic energy sources and the corresponding numbers for England, Germany, and Russia are 87%, 27%, and 175%, respectively. The self-sufficiency ratio for Japan could be as high as 18% if nuclear power were included. Given that the nuclear option is under question, the 4% self-sufficiency ratio indicates that Japan needs to become resourceful regarding energy supply and independence. The Third-Stage Science and Technology Basic Plan for Science

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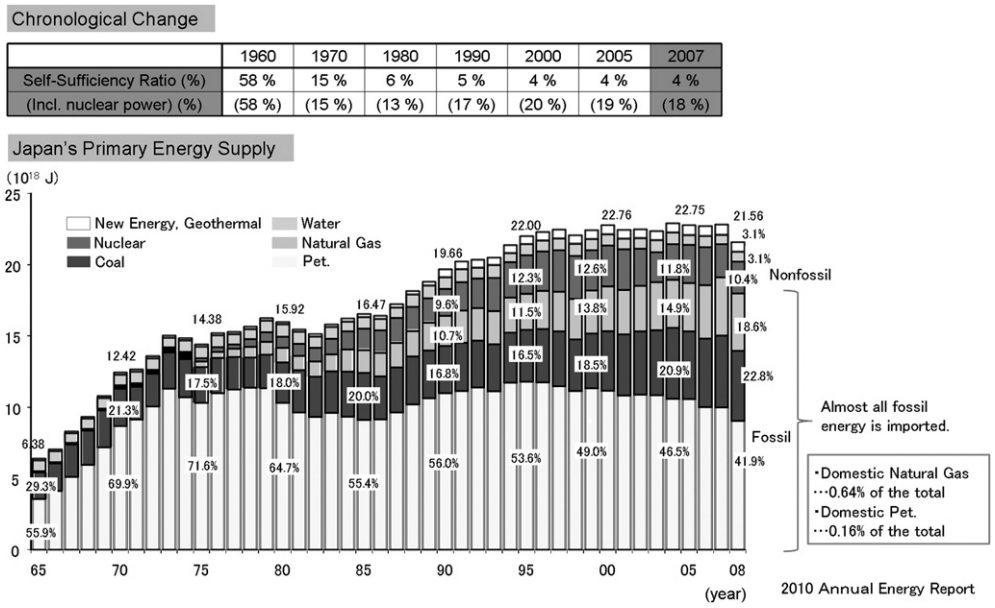

Fig. 1 – Japan's energy self-sufficiency ratio.

and Technology (2006–2010) [2], issued by the Government of Japan on December 1, 2010 identifies and groups the high priority national objectives as follows:

- Four priority fields: *Life Sciences, Information and Communication, Environment, Nanotechnology and Nanomaterials*.
- Four fields to be promoted: *Energy, Manufacturing (traditional shop-floor production) Technologies, Infrastructure*.

As can be seen, energy was not categorized as a single top-priority objective but was lumped in the same category with other three objectives to promote. In the post-Fukushima disaster era, however, energy topped the national priorities.

In the 4th Science and Technology Basic Plan [3] issued on the Great East Japan Earthquake, 11 March 2011, the following "Key challenges" were identified:

(1) Realization of a safe, affluent and high-quality life.
(2) Enhancement of industrial competitiveness of Japan.
(3) Contribution to the resolution of global problems.
(4) Promoting fundamental R&D of the nation's existence.
(5) Enrichment and enhancement of common bases for S&T.

Examples of "Key Challenges to the Priority Issue" addressed by items (1) and (3) above are: large-scale climate change, new resources/energies and cyclic use, and alternative resources in order to ensure a stable supply of resources and energy. Certainly neither this list of policy challenges covered energy as the key challenge including (2), (4) and (5). Again, in light of the nuclear accident however, it is obvious that energy has become the utmost and most urgent policy challenge; without solving the energy problem other objective, e.g. (1) cannot be realized.

In addition, there is a marked difference between the Third and Fourth Science and Technology Basic Plans with regard to the use of the " Key Challenges to the Priority Issue" term: the expression of "Science and Technology driven policy" in the Third has been changed to "Issue driven policy" in the Fourth.

After the 3.11 earthquake, the Japanese society overwhelmingly requested that nuclear energy be replaced by renewable energy sources such as sunlight, wind, and geothermal heat. Although these energy sources are safe and renewable and should certainly be part of the national portfolio, they are insufficient to solve the energy supply problem. In particular, they are insufficient to solve the electrification problem.

The challenges that photovoltaics (PV) face include cost, efficiency, fluctuation, installation site availability, power generating time window, etc. Fig. 2 which is an example of PV data over 11 months (with generator installed on a house roof) [4] clearly shows that the issues of fluctuation and power production time are handled by steady supply from the power grid. It must be noted that even though the total amount of power generation per month appears approximately equal to the consumption per month for some periods, these are the integrated amount per month. Because PV energy production fluctuates greatly on a daily basis, it is only 40% (130 days out of 334 days) of the time during which production exceeds demand. Even in the months of May, June and August when PV generation meets monthly demand, daily demand is satisfied only for 2/3 ~ half of a month.

The first wind power generation unit (300 kW) was placed in operation in Okinoerabu island, Okinawa in 1982 and since 1996 similar units were installed all over Japan. These units generated 2442 MWh in 2010 [5]. Although development of renewable energy should be enhanced, there are a number of potential restrictions on wind power generation as they apply specifically to Japan. For example,

(1) Areas with good wind conditions are often found in precipitous terrain such as mountains, isolated islands,

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