Drawing an Energy & Environment Roadmap for the World: Japan's Challenge of Turning "Compactness" into "Competitiveness"

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It will take several more decades to completely stabilize the disaster-struck Fukushima-Daiichi nuclear power station, even though it was officially announced by the Japanese government on Dec. 16, 2011 that the station is now in cold shutdown. The government originally planned to establish an additional 14 nuclear power stations by 2030 and achieve a 90% capacity utilization rate for nuclear power stations and thus have them provide around 53% of the total electricity in Japan, according to the Basic Energy Policy Outlook published in June 2010, about a year before the disaster.

However, the nation's confidence in the safety of nuclear power declined drastically due to the Fukushima-Daiichi crisis. As a result, many of Japan's nuclear power stations will not be restarted after temporary shutdowns for regular safety testing due to the opposition of local residents.

A number of difficulties will emerge if Japan becomes unable to restart its nuclear power stations, namely an increase in power generating costs due to more expensive energy sources, greater political risks concerning energy security due to increased fossil fuel imports, and even more greenhouse gas emissions caused by greater dependency on higher CO_2-emitting energy sources such as fossil fuels.

The world is now watching Japan; no longer able to depend upon nuclear power, how can it raise its energy self-sufficiency ratio and reduce its GHG while maintaining the highest energy efficiency in the world? In the following analysis, I introduce my ideas on how to achieve this goal.

Brief Summary of Analysis Methodology

In this analysis, we use a technology model and an economy model as our tools. The former is a country model of the detailed electric power supply system in Japan with 10 transmission lines owned by 10 electric power companies and interconnected with each other by connection lines. The model considers the entire capacity of electricity flowing in these 10 transmission lines and their mutually connected networks. Thus, we assume that providing electricity among the networks without their being connected with each other is impossible and also that one network or line exceeding the total flow of electricity within all connected networks is impossible. This makes a more realistic assessment possible.

We also assume that there are two kinds of electricity in Japan, namely 50Hz in the east and 60Hz in the west, as indeed is the real case.

Electricity demand is divided into four seasons and three time zones (daytime, peak, and night). For renewable energy sources, we cover biomass, wind power (land and sea), solar power, and geothermal power. In addition, we consider CCS (Carbon Capture & Storage) technology for thermal power plants.

We adopted an econometric model on the basis of GTAP-E, a general equilibrium model which has been widely used for analyses on global warming such as our economy model. In this model, we introduced a new production function in the power generation sector with a technology unit.

Assessment of Impact of Shutdown of All Nuclear Power Stations in Japan

As mentioned above, many of the nuclear power stations in Japan which are to be subjected to regular testing will not be restarted in the future, and therefore in 2012 all nuclear power stations could be in a state of shutdown. The outcome of our economy model simulation shows the impact upon the price of electricity and the whole economy of Japan as follows.

The price of electricity will rise by 19.4% due to the additional costs of producing electricity at thermal power stations using fossil fuels such as LNG, which will replace the offline nuclear power stations.

Although a rise in the price of electricity will lower demand, replacing nuclear with thermal power will cause Japan's GHG to increase in 2012 by 14.3% compared with the case in which there had been no nuclear power incident. The increase in the price of electricity will also cause the GDP growth rate to decline by 0.9%. The largest portion of this decline is caused by a 1.1% drop in individual consumption growth, which occupies the greatest share of GDP. Stagnation of consumption growth would suppress business profits and hinder domestic investment (2.9% decline).

Meanwhile, exports will increase by 3.6% due to the increased pressure caused by a shrinking domestic market.

Roadmap Towards a Japanese Model

I believe that there are two objectives for any energy policy. The first one is energy security. The Japanese economy's consumption of fossil fuels is largely dependent upon overseas supplies and will be heavily affected by a change in energy price.

Considering the recent drastic fluctuations in energy prices, it is crucial for Japan to increase its national energy self-sufficiency ratio.

The second objective is a reduction of GHG. COP17 reached an agreement that an international framework for global reduction of GHG which all nations would join is to be determined by 2015.

Assuming these two energy policy objectives need to be fulfilled, what energy supply mix would be able to achieve them?

Policy targets are assumed to be a reduction in CO_2 emissions in the electric power generating sector of 80% in 2050 in comparison to 1990 and an energy self-sufficiency rate of 40% in 2050. Since at present there are no signs of nuclear power plants being restarted after being shut down for testing, we assume that all the nuclear power stations in Japan will remain shut down in 2012. It is also assumed that the electricity grid in Japan is divided into 10 and the amount of transmitted electricity among these 10 grids is to be equal to that in the existing connecting transmission lines.

The unstable nature of renewable energy sources such as wind power or solar energy is often brought up and it is said that its share of total power generation should be limited. In our analysis, we assume that the sum of the capacities of wind power and solar power will not exceed more than 50% of the total power capacity per grid and their generated power would not exceed 20% of the total generated power in 2012 and 40% in 2050.

Chart 1 shows the structure of the energy supply mix in our technology model necessary to achieve the above-mentioned targets by 2050. We see an increase in the share of wind power, namely 17.9% for wind power on land and 2.2% for wind power at sea in 2020, and 18.6% and 12.5% respectively in 2050. The share of LNG thermal power will be 45.1% in 2020 and 53.2% in 2050. We assume that most of these thermal stations are equipped with CCS and that CO_2 emissions from them are segregated within the earth.

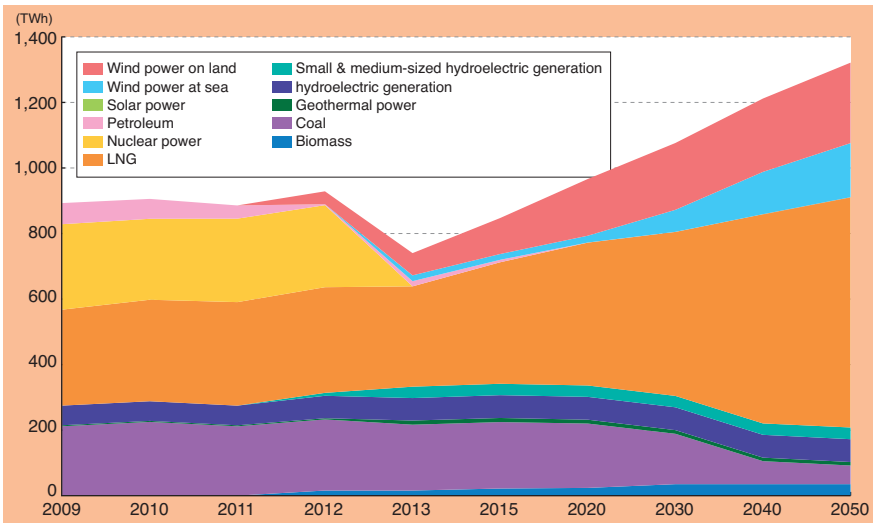
It is often pointed out that the division of the electricity grid in Japan into 10 separate grids makes it impossible to take full advantage of renewable energy sources, which are expected to be vital to raising Japan's electricity self-sufficiency ratio and reducing its GHG. For example, whereas the greatest potential for wind power generation exists in Hokkaido, the northern part of Japan, the largest demand for electricity exists in the Tokyo area, located in central Japan. With the separated electricity supply network as mentioned above, we cannot make use of the abundant and cheap wind power energy in Hokkaido.

In addition, a technical limit on the power generation capacity and the generated amount of wind power and solar power would prevent the use of renewable energy sources which exist only in specific areas.

Below, I assess the impact of an expansion of the interconnecting transmission lines among the separated electricity grids and an elimination of the technical limit on the capacity of renewable energy upon the utilization of renewable energy.

CHART 1

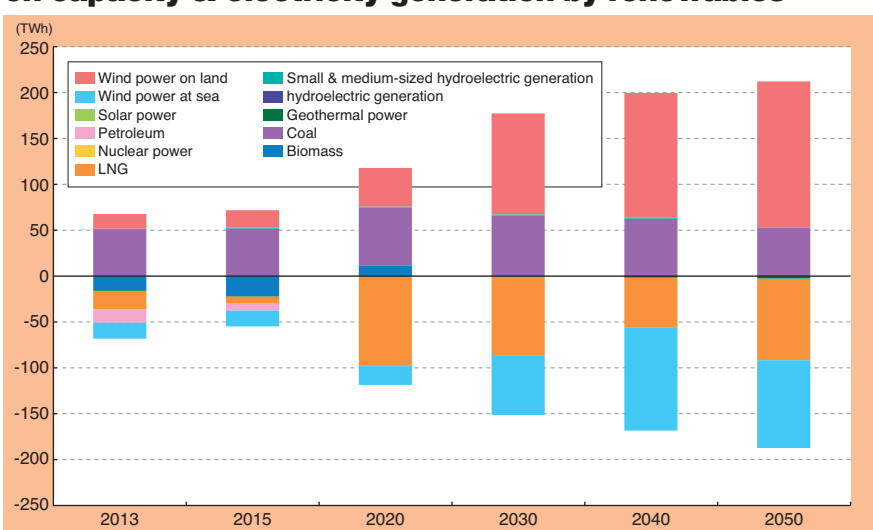
Supply structure of electricity sources in Japan



Source: Economic Research Center, Fujitsu Research Institute

CHART 2

Changed electricity generation amount of renewables by strengthened networks among the grids & lifting limits on capacity & electricity generation by renewables



Source: Economic Research Center, Fujitsu Research Institute

Chart 2 shows the amount of power generated by electricity sources with the above-mentioned two modified assumptions. We see from this Chart that land wind power and coal-based thermal power increase. This is due to increased utilization of a carbon storage area being created by separated electricity grids and also cheap wind power stations that had not been well used due to grid separation and a technical capacity limit on renewable energy.

Chart 3 shows generated electric power by renewable energy in Hokkaido, the most northern prefecture in Japan, with the two modified assumptions. In 2050, land and sea wind power generation will increase by 132 TWh and 47 TWh, respectively, compared to the case without modified assumptions.

The cheap wind power in Hokkaido is much better utilized in this case.

Our conclusion is that for greater utilization of renewable energy sources we would need to expand inter-network electricity transmission lines and thus better integrate renewable energy sources concentrated in specific areas into a general electricity supply network. Achieving full use of carbon storage spots is also important. All of this should be attainable without much difficulty, since Japan is a country no larger than California. In such a compact space, we have sufficient potential renewable energy and enough appropriate locations for CCS. In fact, Japan's compactness would be a source of competitiveness, since it would facilitate the integration of separated grids.

In order to get rid of the technical limit on renewable energy power generation capacity, we would need remarkable innovation to eliminate the existing technological constraints. We would have to pursue innovation which would make it possible to produce and consume electricity simultaneously just like oil and gas. For example, the question of whether electric car batteries can be used as cells is currently under investigation. Solar power makes it possible for a power station to have cells for homes. Thus it would be meaningless to make a distinction between electricity producers and consumers.

Short- & Long-term Strategies for Overcoming an Unprecedented Challenge in Human History

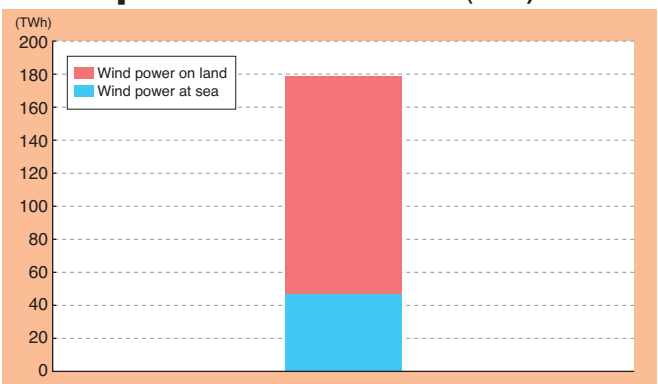
As has been explained above, Japan is now facing a challenge which no other country has ever faced: to raise its energy self-sufficiency ratio and reduce GHG simultaneously when most of its fossil fuel supply comes from overseas and it cannot depend upon nuclear power.

Though these issues cannot be solved by existing technology, our analysis shows what needs to be done in the short run using existing technology and what direction R&D for new technology should pursue in the long run.

In the short run, Japan should integrate all its electricity transmission lines and create a single grid; this would enable it to maximize the use of cheaper renewable energy sources and increase the overall efficiency of renewable energy source usage, and CCS at

CHART 3

Changed wind power generation in Hokkaido in Japan on the same assumptions as in Chart 2 (2050)



Source: Economic Research Center, Fujitsu Research Institute

coal-fired thermal power stations could be better utilized as well. A Feed-in Tariff system, which assures suppliers of renewable energy sources that the energy will be purchased at a fixed price, will be introduced in July of this year in Japan to encourage utilization of renewable energy sources. However, with separated transmission networks, such a system could in fact raise the price of renewables and thus even be an impediment to the spread of renewables.

In the long run, even with a single grid it would be impossible to achieve a stable supply of wind and solar power as provided by Mother Nature. There would be a variety of views upon the extent to which renewable energy sources can be introduced because of their technological constraints. Japan would need extra facilities to meet demand at peak times in order to achieve a sufficient supply of electricity generated from renewables. Looking to 2050, Japan should continue its efforts towards technological developments which would allow a breakthrough in such a high cost and unstable structure as electricity supply using renewables.

The Japanese business sector is said to be suffering from many disadvantages at present, such as a strong yen, high corporate tax, a shortage of electricity, and strict environmental regulations. However, throughout the history of mankind, many great innovations such as the invention of the steam engine or Information Technology have been achieved during transitory periods. In this light, I believe that the disadvantages that Japan faces could be sources for another great innovation.

It has been pointed out for a long time that the 21st century would be "the century of environment." The next decade, in which Japan will have to cope with an energy crisis, should be called the decade of "Green Growth" and the model Japan creates should become the model for the rest of the world.

I am sure that the high level of Japanese science and technology will achieve such an innovative model. JS

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