# The Role of Nuclear Power Generation for a Low Carbon Society: Impact of the Fukushima Accidents on Japan

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**Status of Japan's $CO_2$ Emissions**

Japan is the fifth largest emitter of $CO_2$ in the world. She emitted a total of 1.145 billion tons of $CO_2$ emissions in 2009. In Japan, $CO_2$ accounts for about 95% of GHG. As Figure 1 shows, total $CO_2$ emissions has decreased significantly in 2008 and 2009 due to the economic recession resulting from the financial crisis.

Over the years 1990-2009, the industrial sector aggressively pursued improvement of energy efficiency in order to compete in international markets. As a result, the industry succeeded in reducing their $CO_2$ emissions by around one quarter. In the meantime, growth in $CO_2$ emissions has been notable in the household and commercial sectors. These two sectors accounted for 33% of total $CO_2$ emissions in 2009.

During 1990-2009, $CO_2$ emissions from the household sector rose by 27% while the commercial sector increased its $CO_2$ emissions by 31%. It is highly likely that these sectors will continue to record positive growth in $CO_2$ emissions. Therefore, these two sectors are now major target sectors to reduce $CO_2$ emissions in Japan.

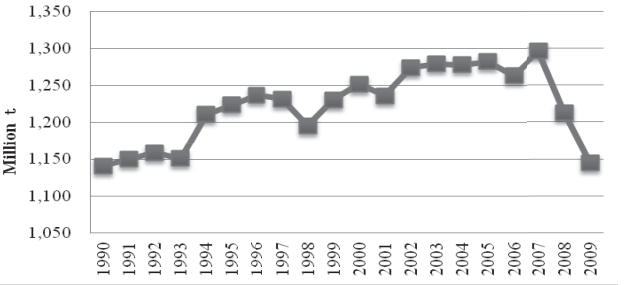


*Figure 1*
*$CO_2$ Emissions in Japan (1990-2009)*
*Source: Institute of Energy Economics (2011)*

**Analysis of $CO_2$ Emissions**

Applying the following Kaya Identity (Kaya, 1989), $CO_2$ emissions can be divided into three factors. Table 1 below shows the composition of changes in $CO_2$ emissions in the period of 1990-2009.

$$\Delta CO_2 = \Delta \frac{CO_2}{E} + \Delta \frac{E}{GDP} + \Delta GDP$$

Where $\Delta CO_2$ = annual rate of change in $CO_2$ emissions

$\Delta \frac{CO_2}{E}$ = annual rate of change in $CO_2$ intensity in energy

$\Delta \frac{E}{GDP}$ = annual rate of change in energy intensity in GDP

$\Delta GDP$ = annual rate of change in GDP

For the period of 2005-2009, all three factors comprising a change in $CO_2$ emissions recorded negative growth. Among contributing factors, the weak Japanese economy is conspicuous. It can be said that the sluggish economy has been a major factor bringing about the reduction in $CO_2$ emissions. The last column in Table 1 shows the ambitious target for 2005-2020 that former Prime Minister Hatoyama pledged. Given the 30% reduction target, Japan needs to reduce carbon intensity and energy intensity significantly assuming positive GDP growth.

**Energy Policy before Fukushima**

The Strategic Energy Plan is national energy policy. It was formulated first in 2003 and revised in 2007 and 2010. The Strategic Energy Plan of 2010 (the Plan) aims at achieving three *E*s that are *E*nergy Security, *E*nvironmental Protection and *E*fficient Supply. The Plan set various targets. Table 2 summarizes major goals involving nuclear power generation and renewable energies in the Plan.

Targets for nuclear power generation were thought to be quite ambitious in light of circumstances surrounding nuclear power such as a lack of public acceptance by local communities even when the Plan was crafted. The goal set for renewable energies is also very challenging due to the intermittent nature of renewable generation technology and the current cost level.

The government estimated the costs and amount of $CO_2$ reduction associated with diverse measures including nuclear and renewables. As Table 3 shows, it

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| | 1990-2000 | 2000-2005 | 2005-2009 | 30% Reduction Target (2005-2020) |
|---|---|---|---|---|
| Δ GDP | 1.1 | 1.3 | -0.6 | 1.1 |
| $\Delta \frac{CO_2}{E}$ | -0.5 | 0.3 | -0.6 | -3.5 |
| $\Delta \frac{E}{GDP}$ | 0.3 | -1.1 | -1.7 | |
| $\Delta CO_2$ | 0.9 | 0.5 | -2.9 | -2.4 |

*Table 1. Composition of $CO_2$ Emissions (1990~2009)*
Source: Data are from the Institute of Energy Economics (2011)

would cost 131 trillion yen to reduce about 500 million ton from $CO_2$ emissions in 2007.

Specifically, the amount of investment for new nuclear power plants is estimated to be 5.6 trillion yen which results in the reduction of $CO_2$ by 160 million tons while renewable energies cost 26.1 trillion yen to cut 60 million tons. The last column in the table 3 is cost of reducing one ton of $CO_2$. It clearly indicates that nuclear power generation is the most cost effective source of $CO_2$ reduction. The reduction cost by renewables is about 12 times higher than by nuclear power generation. Generally, generation costs by renewables are still higher than conventional power sources. To make use of a large bulk of on-grid renewable energies, power system operators need to also have extra measures to stabilize and balance the system. Installing batteries or re-dispatching thermal power plants are typical measures to make up for the intermittency of wind and PV. These measures are not inexpensive. Therefore, it is quite understandable that nuclear power generation is recommended as the most effective power source in order to achieve zero carbon generation. Either way, these estimates tell us that the marginal cost of achieving the $CO_2$ reduction target is quite high.

| | 2020 | 2030 |
|---|---|---|
| Nuclear Power Generation | •Build 9 new nuclear power plants<br>•Attain 85% capacity factor | •Build 14 new nuclear power plants<br>•Attain 90% capacity factor |
| Renewable Energies | - | •20% of total electric generation by expanded feed-in tariff and other measures to promote use of renewables |

*Table 2. Nuclear and Renewable Energies in the Strategic Energy Plan*

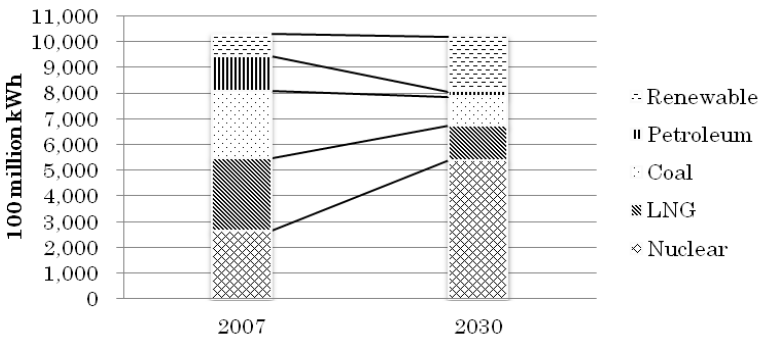


*Figure 2 Generation Mix in 2007 and 2030*
Source: Data are from Ministry of Economy, Trade and Industry (2010)

| Measures | $CO_2$ Reduction (million ton) | Investment (trillion yen) | yen/ton |
|---|---|---|---|
| Energy conservation of houses and buildings | 59 | 50.3 | 852,542 |
| High efficiency hot water supply devices for household | 19 | 4.6 | 242,105 |
| Highly efficient illumination | 28 | 4.2 | 150,000 |
| Energy conservation in IT equipment | 30 | 6.0 | 200,000 |
| Renewable energies | 60 | 26.1 | 435,000 |
| Nuclear power plants | 160 | 5.6 | 35,000 |
| Improvement in thermal efficiency | 25 | 2.5 | 100,000 |
| Others | 123 | 31.6 | 256,910 |
| Total | 504 | 130.9 | 259,722 |

*Table 3. $CO_2$ Reduction and the Amount of Investment by 2030*
Source: Ministry of Economy, Trade and Industry (2010)

**The Role of Nuclear Power after the Fukushima Accident**

The government has begun to review the Plan because of the accidents at the Fukushima Daiichi Nuclear Power Plant. The direction of revision is clear. As the Prime Minister stated at the Commemoration Ceremony of the 50th Anniversary of the OECD, renewable energies will be elevated to one of the core energy sources. His plan is that the share of renewable energy in total electric power generation is increased to at least 20% by the earliest possible in the 2020s. His plan appears to move up the Plan to earlier than 2030. To realize this target, the administration is expecting to lower the cost of PV as one of the key renewable energies to one third of the current level by 2020 and to one sixth by 2030. Yet the base of his plan has not been clarified. His ambitious plan is simply doubtful.

The biggest question is the role of nuclear power generation. It goes without saying that nuclear power is the most important power source to tackle climate change. For Japan, which lacks natural resources, nuclear power is also a quasi-indigenous energy source for energy security. According to the Plan formulated before Fukushima, 14 new nuclear power plants were supposed to be built by 2030 as Table 2 shows. In order to achieve the $CO_2$ target in 2020 and 2030, nuclear power was expected to play a central role.

However, it has become extremely difficult to attain public acceptance of nuclear power from local communities as a result of the accidents. Real-

izing the Plan is, therefore, highly improbable, particularly in light of public sentiment against nuclear power. There are also uncertainties for existing nuclear power plants in Japan.

As of May 15th, only 17 units are in operation. The remaining 37 units are not in operation. Fourteen units out of 37 units suspended operation due to the earthquake. Among these, four units of Fukushima Daiichi will be decommissioned. It is uncertain when ten units can resume operation. In addition, 21 units are under regular inspection and maintenance. For these units, utilities are facing opposition from local communities to resuming operation. In addition, two units at Hamaoka owned by Chubu Electric Power Company also halted operation in early May in response to the request by Prime Minister Kan. It will take several years to implement measures to withstand a tsunami as demanded by the administration. Consequently, about 70% of Japan's nuclear power generation has not been in operation since March 11.

To make up for the expected shortage of supply capability to meet peak demand in the short term, alternative sources will be thermal power generation using LNG and energy saving. Tokyo Electric Power Company is going to be installing gas turbines and opening mothballed thermal power plants. However, it is likely that not only Tokyo EPCO but other EPCOs will face a shortage of power depending on the availability of existing nuclear power plants. As for energy saving, the government imposed a 15% restriction on power uses of large customers in the summer, invoking Article 27 of the Electricity Business Act governing the electric power industry. Other users, including households, are asked to save as much electricity as possible as well.

The future of nuclear power generation in the mid-term and long-term is quite uncertain. One thing is clear, however. We will not be able to build new nuclear power plants as included in the Plan before the Fukushima accidents. Siting new nuclear power plants is now impossible at least until credibility of nuclear power is restored. In case of the U.S., it took almost thirty years to revive nuclear power after the Three Mile Island accident.

There are four options for the future of nuclear in Japan. The first option is expansion of the share in generation mix, which was the energy vision for the government and electric utilities before Fukushima. Nuclear power generation was supposed to account for about 50% of total electric power generation by 2030. This target was the base of reducing $CO_2$ by 30% in 2030 compared with 1990. The second option is maintaining the current share of nuclear power generation for the foreseeable future. Nuclear power generation accounted for about 30% of total electric power generation in 2009. To retain this share, all existing nuclear power plants will at least have to take additional costly measures to enhance safety. The third option is the phase-out of nuclear power plants. Several countries including Germany have decided to phase out nuclear power after the nuclear accidents at Fukushima. The fourth option is to abandon nuclear power immediately.

The first option is not available as we mentioned earlier. The fourth option is simply not realistic. Therefore, the remaining options are either the second or the third. That is, maintaining status quo of nuclear energy or eventual phase-out. In the case of the status quo, however, utilities are required to replace old units at some point of time after 40 years of commercial operation. As figure 3 and table 4 show, 70% of nuclear units were built in 1970's and 1980's. Even if we do not expand the role of nuclear power, we will need to replace aging units with new advanced units which will be safer and more costly. Needless to say, the consent of local communities is a necessary condition for replacement to maintain the status quo.

The critical question is whether we should or should not phase out nuclear power. This question is very contentious. We have learned from the Fukushima accidents that the ramifications of nuclear accidents are immense. An unexpected event such as a huge tsunami may happen again even if we can build much safer nuclear plants. The probability of a similar accident occurrence at the Fukushima Daiichi can never be zero. We must be humble before Mother Nature. From such a perspective, we would abandon nuclear power as soon as possible.

In the meantime, we need nuclear power from a different perspective. It appears that an energy mix without nuclear power is an implausible option for Japan from the standpoint of the international commitment to $CO_2$ reduction and in order to secure energy security. Renewable energy alone cannot replace conventional power sources including nuclear power in the foreseeable future. The intermittent nature of wind and PV requires thermal power plants to back them up. The batteries which are needed to maintain the reliability and stability of the power system are still very costly. Operating the power system with renewable energies also needs new technologies such as the Smart Grid. There are, therefore, a number of challenges ahead to harness renewable energies in the centralized power system.

In either the case of the status quo or phase-out of nuclear energy, we will not be able to achieve $CO_2$ reduction targets. Reportedly, the Ministry of Environment estimated that $CO_2$ emissions would increase by 26 million tons per year as a result of suspension of six units at the Fukushima Daiichi (Yomiuri Shin-

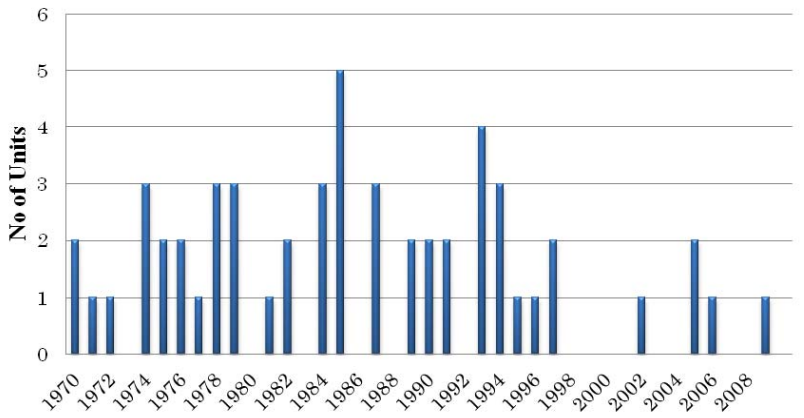


*Figure 3. Commissioning Year*
Source: Data are from Japan Atomic Industrial Forum (2011)

| Vintage | Units (%) |
|---|---|
| 30-40 | 19 (35%) |
| 20-29 | 19 (35%) |
| 10-19 | 11 (20%) |
| 1-9 | 5 (10%) |
| Total | 54 (100%) |

*Table 4. Distribution of Nuclear Units by Vintage*
Source: Data are from Japan Atomic Industrial Forum (2011)

bun, April 20, 2011). If nine new nuclear power plants as planned by the Plan are not built and fourteen existing nuclear power plants cannot resume operation, then emissions will increase by 120 million tons in 2020, which is a 10% increase in total $CO_2$ emissions compared with the 1990 level, according to another estimate conducted by the research institute (Tatsuo Kobayashi and Tetsuya Hattori, June 2011),

$CO_2$ will increase by 75 million tons next year which accounts for about 6% in total $CO_2$ emissions if all nuclear power plants were suspended and their capacity replaced by thermal power generation next year. In this case, Japan would face a serious shortage of power since the capability of thermal power is not sufficient to replace nuclear power.

**Concluding Remarks**

The ramifications of nuclear accidents are enormous. According to a study, the cost of the Fukushima accidents could be between 5.7 trillion and 20 trillion yen (Japan Center for Economic Research, April 2011). A major part of this cost is the cost of decommissioning. It would take at least ten years to decommission the damaged nuclear units, technically. However, since Tokyo EPCO has not succeeded in containing a meltdown yet, these estimates of decommissioning costs are indeterminate.

Nuclear power plants in Japan have been owned and operated by investor-owned electric utilities with the support of the national and local governments. The accident is forcing reconsideration of various issues involving the electric power industry. Whether we should nationalize nuclear power operation is one such issue. In light of nuclear power which contributes greatly to reducing $CO_2$ emissions and national security as public goods, there is an argument that the public sector rather than the private sector should be responsible for nuclear power operation. We have learned that the risks involving nuclear power operation transcend the capacity of a private company.

Discussion of such issues is beyond the scope of this paper. All that can be said is that it is time to review the electricity supply system fundamentally. The current electricity supply system was established 60 years ago immediately after the end of the World War II. Since then, the system has remained intact although there were some minor reforms in the Post-World War II era. The Fukushima disaster seems to be a wake-up call for us to create a better energy system for Japan.

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