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The Fukushima Nuclear Accident and a Long-Term Energy Vision for Japan

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About the institutes

(1) An objective evaluation of the accident and damage

On March 11, 2011 a number of massive tsunamis struck the Tohoku region on the east coast of Japan following a magnitude 9.0 earthquake. 14 nuclear power plants were stricken by the earthquake and tsunamis, 11 of which were in operation. While 8 plants withstood the earthquake and tsunamis well, remaining under control in stable, low-temperature standby, 3 units of the Tokyo Electric Power Company's Fukushima Daiichi Power Plant met with the severe disaster of a core meltdown. As a result, radiation from the nuclear plant dissipated into the environment. This disaster is still being dealt with and, as of now, core temperatures have stabilized below 100˚C.

Fukushima Daiichi is the oldest type of power plant. Designed in the 1960s and first put into operation in the 1970s, it is called an "early second-generation" nuclear reactor. This nuclear reactor was developed and designed by the American company GE and constructed as the Fukushima Daiichi Nuclear Power Plant.

Although the earthquake cut electricity to the plant, which was supplied externally, nuclear reactions stopped without incident, core reactors were cooled by an emergency power system and residual heat removed according to procedure. With the arrival of the tsunami, the turbine building adjacent to the nuclear reactor building flooded, then the emergency power system (a diesel generator) and the power panel were flooded with seawater and ceased functioning. Emergency core cooling was activated and continued by the emergency condenser maintained for such an occasion. Multiple power supply vehicles arrived in an attempt to restore power, but were unsuccessful due to flooding of the power panel, resulting in a total loss of power. Core cooling was also lost. As a result, core temperature rose and cooling water decomposed, forming hydrogen. This hydrogen leaked into the upper part of the building, causing explosions. It was this leaked hydrogen that exploded;

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not the core. However, this explosion caused radioactive material (iodine and cesium) -- which leaked along with the hydrogen -- to dissipate into the environment.

The hydrogen explosion occurred outside of the nuclear reactor and the containment vessel designed to protect it, leaving the reactor and containment vessel, housed within thick concrete walls, undamaged. However, the reactor gradually became subject to high pressure and high temperature conditions as it lost its cooling functions. This high pressure was relieved (through a valve) in order to protect the reactor – which was under high pressure – and the containment vessel surrounding it. Although radioactive material was released from the building while relieving this high pressure, cooling the nuclear fuel -- which had already begun to meltdown -- prevented an even bigger vapor explosion. The worst-case scenario was averted by adding seawater, limiting the amount of radioactive material released into the environment to one-tenth that of the Chernobyl nuclear accident (2012/3/13 Ministry of Education, Culture, Sports, Science and Technology press release). A complete return to normal will still take time, but for the time being the situation has been brought under relatively stable control.

The cause of the accident is clear. Of the 11 nuclear plants in operation, the difference between the stricken plants and the 8 plants that were shutdown and stabilized without issue was altitude above sea level (Fukushima Daiichi, at 10m, was the lowest, while the others were 14m or more above sea level), placement of the emergency power source and power panel, and the water-tightness of the building.

Consequently, it is less the problem particular to a nuclear power plant than the layout design and facility design of a power plant, including thermal electric power stations. A plant may flood, lose functionality, and result in a total power outage, but even so maintaining “cooling” and “lockdown” functions is fundamental to the safety designs of a nuclear power plant. Because safety designs lacked multiple cooling functions and assumed only short-term blackouts (cooling functions were, in fact, maintained for a short period), they could not hold up to a long-term power outage. Furthermore, while hydrogen formed as the core heated up, no design allowances whatsoever were made to deal with this hydrogen, nor were there any regulations for such. Design guidelines for such severe disasters will surely be subject to further scrutiny in the future.

Designs for severe disasters being what they are calls into question accountability for the designs that resulted in a total power outage. The designer cannot avoid responsibility for the permeability and layout of the power room. As I will discuss below, reports by experts from both the IAEA (International Atomic Energy Agency) and the American NRC (U.S. Nuclear Regulatory Commission) point to designs for an emergency power source without either multiplicity or diversity.

As discussed above, the primary cause of this accident was the inadequacy of the simple layout design and facility design. The secondary cause was the lack of endurance of the cooling system when the plant lost power, which is a conceivable event. Furthermore, that protection systems were not thought out for when a severe disaster occurred exacerbated the accident and complicated recovery efforts.

(2) Biased media reports vs. levelheaded IAEA and NRC reports

The media uproar following the accident and the deluge of coverage and irresponsible information piqued the apprehensions of the Japanese people more than necessary, further complicated a serious situation and conjured up the image of an impossible extent of damage. All sorts of unbelievable questions were posed from outside of Japan as many foreigners evacuated Tokyo at the urging of government directives based on coverage of the accident broadcasted in their own country. During my business trip overseas in May I, myself, was also repeatedly asked questions by engineers that could only have been excessively fueled by the coverage -- questions I was at a loss as to how to answer.

Twenty experts from the IAEA visited Japan in May to conduct a thorough study of the people and sites involved in the accident, and released an emergency investigative report on June 1. Most experts around the world read the report, changing their perception of the accident. In short, scientists and engineers whose judgment had been confused by media reports became familiar with accurate information and facts surrounding the incident. Subsequently, even when I visited the American Society of Mechanical Engineers on a business trip in mid-June and when I attended a symposium in Italy with European physicists in August, I found that experts were sharing accurate, levelheaded information. What resonated most with them was that there was not a single fatality from the nuclear power plant accident nor were there any hospitalizations due to public exposure, despite the fact that the earthquake and tsunami produced nearly 20,000 fatalities and missing persons. They no longer lumped together the destruction of the town, reduced to a pile of rubble by the tsunami, and the destruction atop the Fukushima Daiichi building.

So, what did the IAEA say in their interim report?

The IAEA openly and directly evaluate the data of the government and those involved in electrical power. They came to the following conclusions through their professional meticulousness, on-site observations, and interviews with on-site supervisors and plant operators.

First, they assessed the plant operators in the midst of such dire circumstances and without light and information, as having done their best to take the best possible measures. The agency appraises their dedication and high level of technical expertise.

Next, they appraise the government as having taken precise and prompt action to issue a mandatory evacuation order to residents. The truth is that, as a result, not a single person fell ill from damage caused by radiation. Not a single on-site staff member lost his or her life or suffered injury from the reactor accident.

However, the report points out that there was considerable room for improvement in terms of the complexity and effectiveness of the chain of command of Japan's regulatory and emergency systems, and also to pursue the question of liability of the manufacturer's plant design. The report takes issue with the naivety towards the tsunami and lack of foresight towards such an extraordinary and excessive natural phenomenon on the part of electric power providers (plant operators) and regulatory authorities. It also highlights the inadequate design of the plant for its lack of multiplicity, diversity and independence of safety systems.

In addition, it discusses the need in the future to maintain and ensure the integrity of facilities and critical functions for responding to severe disasters, including hydrogen explosions.

This interim report, a mere three A4 pages in length, had a major impact when it was released around the world. This is because the world had gotten an impression of events differing from that of previous media reports. Even so, it is unlikely that the Japanese media accurately covered this report. They had the tendency to repeat only the emotional critique of the naivety and the need for organizational improvement of electric power providers and regulations.

On July 12, the U.S. Nuclear Regulatory Commission (NRC) released the Japan Task Force report on "Recommendations for Enhancing Reactor Safety in the 21st Century". In the report on observations about the Fukushima Daiichi Nuclear Plant accident, the commission conducts a detailed investigation of the series of accidents that occurred at Fukushima Daiichi, determines that such an accident could not occur in the U.S., and recommends bolstering safety capacity in anticipation of power outage accidents to minimize damage. Above all, the report recommends further increasing the reliability of the vent design of containment vessels in boiling water nuclear reactors of the same type as Fukushima Daiichi, emphasizing securing multiple safety systems (that is to say, the residual heat removal system).

Including "in the 21st Century" in the title of the report is an overview of the Fukushima Daiichi accident considered from a long-term perspective and suggests a concealed determination not to give up on nuclear energy. Stating that the same accident will not occur can be understood based on the fact that everything came out alright with 2 nuclear power plants along the Missouri River when the river flooded in June, submerging both plants. This owes to the fact that designs have ensured the impermeability and water-tightness of the plants. Incidentally, in May the NRC announced protection standards and emergency accident management guidelines (so-called *B.5.b strategies*) to protect nuclear power plants from terrorism. Reading these, one can see how the U.S. has made thorough efforts since 9/11 to ensure multiple defenses of nuclear power plants. One gathers from this report the NRC's resolve to build on the Fukushima Daiichi disaster to continue improving safety. There is a clear confidence behind their determination to continue maintaining and promoting nuclear plants in the U.S. into the future that is based on a culture of safety.

In the wake of the recent accident, Western intellectuals have apparently gotten the strong impression from media reports coming out of Japan that Japanese politicians and the Japanese people have made irrational decisions and responded emotionally to the situation. Many people have actually said as much and I have gathered from conversations with friends in the U.S. that there are more than a few Japanophiles concerned with the poor average of scientific knowledge among the Japanese people.

I feel that the Japanese media's emotional coverage and Japanese people's tendency to be easily-influenced by this coverage have greatly damaged national interest and I am deeply concerned that to those overseas the government and policy must have appeared not supported by intellectual groups.

Meanwhile, with an emotional review of medium-term energy policy and the formation of unbalanced long-term planning, we are in danger of losing considerable nuclear expertise accumulated over the last 50 years.

The technology of the Fukushima Daiichi Nuclear Plant was 100% introduced by the U.S. company GE. The accountability of the company in designing of the plant will likely be called into question eventually. Meanwhile, Japan has introduced commercial reactor technology and cumulatively invested trillions of yen since the 1960s to develop its own nuclear plants.

The first and only Japanese nuclear powered ship Mutsu, an Advanced Thermal Reactor Fugen, a prototype fast-breeder reactor Joyo-Monju, and the high-temperature gas reactor are all self-developed technologies built from scratch, technologically successful, and are of a practical technical caliber. Mutsu and Monju, however, did experience some rudimentary trouble, a type of trouble common to plant development that fell short of being called an accident but fell prey to the media. The hype fuelled the concerns of local residents and invoked a crisis to discontinue development of these technologies upon reopening as it was offered up in trade-offs such as compensation of the fishing industry and attracting a bullet train line.

The fast breeder reactor in particular, whose fuel cycle technology is coupled with a light water reactor, was promoted as a long-range plan for the nation. Currently, Russia, China, and India have undertaken its development to meet mid- to long-term ambitions. Technological development is the driver of progress and the creator of technology-intensive nations and new industries. Reviewing energy policy without a mid- to long-term perspective surely works against national interest, further stagnates the industrial economy, and weakens Japan's national vigor. To avoid this, I would like to suggest the following mid- to long-term energy vision.

(3) Medium- and long-term energy vision

The financial crisis, energy and resource crisis, food and water crisis, global warming crisis, and security crisis (coastal resources and interests) are slowly coming to a head, progressing all at once.

We must realize that we are in what I call "savage struggle for survival" Overcoming these interwoven crises will be extremely difficult, an epochal challenge not only for Japan but for the entire world. International cooperation will be essential – and Japan's role significant – in meeting this challenge.

The global energy situation has been changing dramatically in the last few years. There are 3 main trends. The first is the transition among fossil fuels from oil to natural gas. As we approach peak output of crude oil, the shale gas revolution (currently centered in the U.S.) will see the abundant commercialization of natural gas extracted from shale strata deep underground that could not be extracted previously. The price of natural gas is expected to remain low in the mid- to long-term. Abundant shale gas deposits have also been discovered in China. There is a wide price differential between natural gas and liquefied natural gas, as the price of liquefied natural gas in Japan is nearly 3 times higher than the price of natural gas in the U.S. The future trend of maritime transport, which is subject to strict fuel regulations, favors a switch to natural gas.

The second is the battery revolution. We are entering an age in which electricity is stored. This means that something akin to an industrial revolution is taking place. Sunlight and wind power, irregular forms of energy, will become available as stable sources of power, while the proliferation of technology such as smart grids will see expanded utilization of these forms of power. The competition in research and development is increasing not only for lithium-ion batteries but for next-generation batteries as well, which is becoming an opportunity for those who control batteries to control the world. Although Japan currently has the advantage, the competition with the U.S., China, and Korea will almost certainly intensify.

Third is progress in nuclear technology. While the Fukushima Daiichi Nuclear Power Plant belongs to an early class of the oldest second-generation plants (reactors developed in the late 1960s), safer late third-generation nuclear reactors (called third-generation plus) are under construction in the U.S. and China. On February 8th, NRC issued the Combined Construction and Operating License (COL) for the Vogtle nuclear plant in eastern Georgia. This was the first license for new plant construction issued in 32 years after TMI.

The operation of passive safety reactors, typified by the "AP1000," does not depend on operating personnel in the event of a power outage. Gravity provides the core with cooling water and the natural environment cools the core over a long period of time. China is already constructing over 40 plants with this type of nuclear reactor. Furthermore, development of fourth-generation reactors (to be put into use around 2030) is moving forward in the U.S., China, India, and Russia, propelling advances towards the use of sustainable nuclear energy exemplified by the fast breeding reactor.

Bill Gates and the founder of Google are using private funding to launch the development of next-generation small- and medium-type reactors is still fresh in mind.

On March 23, 2010,the news that Toshiba' cooperation with a company TerraPower LLC backed by Microsoft chairman Bill Gates about joint development of a nuclear reactor with the potential to run for100 years without refueling filled the front page of the NIKKEI newspaper. Nuclear News magazine reported in 2009 that Google might be interested in supporting thorium molten reactor (p 30, Volume 52, Number 10 September 2009).

Japan's mid- to long-term energy vision will require an architecture consistent with the above 3 trends. It will be fundamental to spur the all-out mobilization of energy sources to secure a good balance of abundant and economical coal and natural gas, nuclear energy essential for combating global warming and reinforcing energy security, and renewable energy under development that is currently costly, inefficient and unstable. Japan's energy technology is in a position to lead the world. It is moving towards reducing its dependence on fossil fuels from 85% to 50%. The remaining 50% should then be split between highly-efficient and clean technologies for utilizing fossil fuel (combined cycle power generation technology through natural gas and gasified coal), continually evolving and ever-safer nuclear power technology, and stabilized renewable energy technology (utilizing solar and wind power, along with ocean energy, geothermal energy, and biomass energy). There is no alternative but to work towards achieving this kind of energy structure. As a technology powerhouse, Japan's task moving forward will be to demonstrate to developing countries that a highly-developed industrial nation with manufacturing at its industrial core pursues such an energy vision.

The field of energy is most rife with opportunities for innovation. At the same time, it can serve to help Japan contribute to the world and carry the Japanese economy as a key national industry. In light of the 3 major trends discussed above, Japan needs to overcome the current energy policy crisis while remaining conscious of its leadership and national interest.

※Minor revisions have been made to this essay, which originally appeared in Seirindo's *Japanism 04*.