Japan's Nuclear Energy and Hydrogen Alternatives

ノリコ, ベーリング

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氏　　名　：Noriko Behling（ノリコ　ベーリング）

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論　文　内　容　の　要　旨

It has been seven years since the Great Tohoku Earthquake and Tsunami. The Fukushima accident costs as estimated by several independent sources are expected to top $500 billion, while disruptions to the lives of tens of thousands who evacuated contaminated areas can never be truly measured. Fukushima is not the only nuclear accident that has happened in Japan. There have been several, some of them leading to loss of life, putting Japan in the category of having one of the more accident-prone nuclear programs. This thesis conducts a thorough review of the Japanese nuclear history, nuclear programs, successes, failures, and concludes with suggestions as to how safety could be improved and the prospects for supplementing or replacing nuclear energy with a hydrogen alternative.

Japan is now at a crossroads with respect to alternative power sources. The government has yet to address the fundamental question of how Japan can maintain a safe and economically viable nuclear power industry over the long term. Current policy, which is to pursue a step-by-step approach to restart reactors, does not appear to be economically or politically viable. All 54 power reactors were shut down following Fukushima and now must meet new safety criteria before they can restart. So far only nine have met the criteria.

History shows how the interaction of technology, institutions, and human behavior have led to nuclear events and accidents in unexpected ways. Chapter 1 examines Japan’s motivation after World War II to increase electricity capacity. It describes how Japan enacted legislation and established regulatory structures to rapidly build nuclear R&D institutions as well as lay the foundation for the commercial nuclear industry. This period was notable for irregularities and lack of transparency with respect to nuclear safety. The chapter examines how bureaucratic entities reacted to nuclear events and accidents and describes how this affected government oversight of the nuclear industry.

The establishment of R&D institutions led to the development of Japan’s Four Big National Projects, including uranium enrichment, advanced thermal reactors (ATRs), fast breeder reactors (FBRs), and reprocessing capabilities. These projects evolved over time as Japan’s priorities changed and the global nuclear industry matured. Government ministries made efforts to promote these projects and the resulting technology was transferred to the private sector for commercialization. In the end, none of the Big National Projects successfully transitioned to the commercial sector or became commercially successful. Chapter 2 discusses two of the Big National Projects, the ATR and FBR. FBR Monju was the most highly regarded project among the four. Japan saw it as key to the country’s energy independence because it would create more fuel than it consumed. If the project was successful, Japan would no longer need to depend on foreign imports of uranium. FBR Monju was not successful. It had two major accidents, operated only for several

months, and cost Japan over $10 billion. The commercial sector did not see the project as commercially viable. In Chapter 3, we examine Japan's effort to commercialize the other two Big National Projects, enrichment and reprocessing. Japan's R&D institutions, pressured to use indigenous technology for the Rokkasho Reprocessing Plant, ran into technical difficulties by adopting technology that was not yet mature.

Chapter 4 described the rapid growth in worldwide reactors as well as Japan's plans to rapidly expand its nuclear power reactor fleet. In the early 1960s, Japan had a good start in commercializing the US-designed light water reactors. Following the 1973 oil shock, the government accelerated reactor construction by means of the Dengen Sampo (Three Power Laws) to facilitate the acceptance of nuclear reactors in various regions. The law was successful in encouraging reactor construction, but it also had some side effects: It facilitated the building of multiple nuclear reactors at one plant location, which increased the risk that an event such as a major earthquake and tsunami might affect reactors that were clustered at the same location. Chapter 5 discusses how the Fukushima Daiichi nuclear disaster happened and how Japan is coping with the costs of damage compensation, decontamination of land and water, locating melted fuel, and decommissioning of the reactors. Japan's need for a permanent nuclear waste storage site and the challenge of finding an acceptable location for the facility are described in Chapter 6. The scope of the reactor decommissioning program is explained in Chapter 7. Japan currently has 21 reactors slated for decommissioning, which is a three-fold increase compared with the pre-2011 period. These tasks will require skilled talent at the very time that Japan's nuclear industry is having difficulty in attracting new talent. The declining interest of Japan's young engineers and scientists is highlighted in Chapter 8.

How Japan might manage its nuclear reactor fleet in the future is the topic of Chapter 9. Alternative scenarios, including upgrading and hardening existing reactors or constructing a fleet of advanced reactors are assessed in terms of costs and safety implications. The human dimension of safety is also discussed in terms of the need for experienced program managers, the application of lessons learned, and the adaptation of management principles of Admiral Rickover and the findings of the Kemeny Commission's assessment of the accident at Three Mile Island.

As an alternative to the nuclear power scenarios, Chapter 10 considers how Japan could broaden its energy resources by implementing a Basic Hydrogen Strategy. Such a strategy would ensure that all power sources, including nuclear power, renewable energy, and hydrogen-based power are fully integrated in terms of construction, interconnection, and concepts of operation.

Considering the challenges facing Japan's nuclear industry and the limited progress that has been made over the last decades on hydrogen-based technologies, Chapter 11 concludes why progress has been slow and recommends steps that government, industry, and academia could take to accelerate progress in both fields. These steps are similar to those enacted in 2002 by US President Bush to support fuel cell and hydrogen development. A potential goal for Japan's nuclear and hydrogen energy alternatives would be to create and manage a nuclear power infrastructure that is as safe as humanly possible and which is integrated with a hydrogen infrastructure. If the technologies were integrated, for example, nuclear reactors could be used to create hydrogen during periods when electric power was in surplus, such as when renewable energy sources were at peak output. Hydrogen could be converted into forms that are amenable to long-term storage and which minimize carbon release. Hydrogen could be converted back and used to generate power when demand was high. The development of a hydrogen infrastructure would also hold the potential for hydrogen to supplement, or possibly replace nuclear energy. Investments in hydrogen and fuel cell technology could provide "off-ramps" from nuclear if the situation warrants.

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