Decommissioning: The new goal of the Fukushima Daiichi road map

BY DICK KOVAN

The first anniversary of the March 11, 2011, Fukushima Daiichi accident sees a new and hopeful road map in place.

ON APRIL 17, 2011, just over a month after the massive earthquake and tsunami hit the Fukushima Daiichi nuclear power station, Tokyo Electric Power Company (Tepco) issued a "road map" to recovery, setting out a pathway to bring the plant's damaged reactors back under control within nine months and to make the plant and site safe again. Tepco then developed and pursued a plan of action based on the road map, formally called the *Roadmap towards Restoration from the Accident at Fukushima Daiichi Nuclear Power Station,* aimed at stabilizing the reactors and significantly reducing emissions from the site.

Despite numerous setbacks, the efforts of Tepco—and of many others working to resolve the accident—achieved the two critical steps set out in the road map by December 2011, nine months after the disaster struck. Step 1, described as a "steady downward trend in radiation levels," was achieved in July 2011, and Step 2, which was described as bringing the reactors to a "stable cooling condition," equivalent to "cold shutdown," was completed five months later. These achievements were officially recognized by Prime Minister Yoshihiko Noda, who announced on December 16 that the reactors had reached a state of cold shutdown and that an adequately low level of exposure at the site boundaries could now be maintained under any circumstances. This has also been referred to as the end of the "accident phase" of the ongoing event, which began on March 11, 2011.

In the meantime, Yukio Edano, head of the Ministry of Economy, Trade and Industry (METI), and Goshi Hosono, the minister charged with overseeing the resonse to the accident, had ordered Tepco, along with the Agency for Natural Resources and Energy and the Nuclear and Industrial Safety Agency (NISA), to prepare the new *Mid-and Long-term Roadmap towards the Decommissioning of Fukushima Daiichi Nuclear Power Units 1–4,* with the ultimate goal of decommissioning the plant.

By the time Step 2 of the original road map was reached, Tepco was ready to expand the basic strategy to include preparations for the decommissioning of the plant, along with the other main concerns. In particular, according to a document that Tepco issued on the new road map, the first priority on the path to decommissioning is to remove all fuel material from the plant "so that evacuated residents will be able to return to their homes as soon as possible, and the people of the region, and of the country as a whole, will be able to live without fear."

With this shift in focus, the Government-Tepco Integrated Response Office, which was largely responsible for implementing the original road map, was abolished, and a new government-Tepco committee was established to manage the preparation and progress of the new road map. As decommissioning is expected to take decades, the implementation of this road map must be considered a long-term task with many technical challenges that have never been confronted before, and it will be important to bring together experts in Japan and in other countries to work in close partnership.

The three phases

While the adoption of the new decommissioning road map marks a shift in strategy, Tepco's priority remains to maintain and improve the stability of the reactors and to further reduce emissions. At the same time, the new road map outlines a plan for preparing the site for fuel removal, plant dismantlement, and final decommissioning.

The decommissioning road map divides the journey into three phases:

■ Removal of fuel from the spent fuel pools of Units 1–4.

■ Removal of the fuel debris (fuel, cladding, and other materials that have melted and resolidified) from the reactors, including the material that fell through the reactor pressure vessels (RPV) into the primary containment vessels (PCV).

■ Dismantling and decommissioning of all units, which should take a total of 30–40 years.

Phase 1, which covers the first two years of the new road map, ends with the start of the removal of fuel from Unit 4's spent fuel pool. Also during this phase, planning will begin on a number of activities that are designed to prepare the plant for decommissioning, along with the continuation of others. These activities include the following:

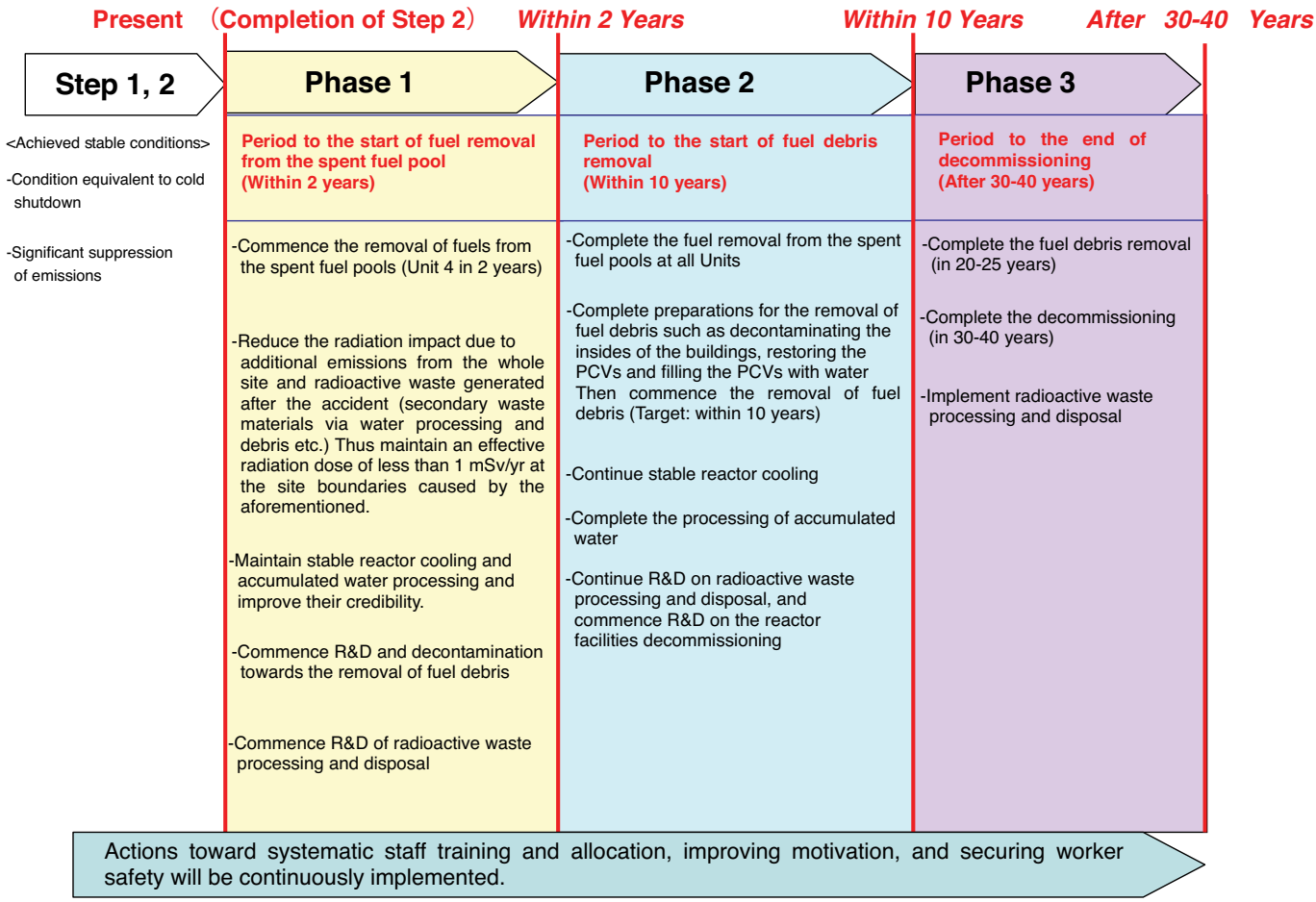
■ Reducing the radiation impact of continuing emissions, including emissions from the radioactive waste generated after the accident—for example, secondary waste material created by processing radioactive water to remove contaminants—with the goal of keeping the effective radiation dose below 1 mSv/year at the site boundaries.

■ Maintaining and improving reactor cooling and the processing of contaminated water.

■ Commencing a research and development program to meet the expected technical challenges for the removal of fuel debris.

■ Initiating R&D activities focused on problems with treating, storing, and disposing of the radioactive waste generated by the accident and during the decommissioning program.

Phase 2, which covers 10 years from the road map's starting point, sees the completion of the removal of the fuel from the spent fuel pools of all four units and the start of preparations for the removal of fuel debris from Units 1–3, which will begin during this phase. Work will include decontaminating the inside of the reactor buildings and repairing the PCVs and filling them with water so that the RPV heads can be opened. R&D on reactor decommissioning will be initiated during this phase, while research on radioactive waste pro-



Summary of the mid- and long-term road map for the decommissioning of Fukushima Daiichi Units 1–4

cessing and disposal issues continues. Another goal is to complete the processing of the contaminated water that had accumulated before the recycling of coolant through the reactors was established.

Phase 3 sees the completion of decommissioning. The removal of fuel debris should be completed about 20–25 years from the starting point of the road map, with the remaining work of plant dismantling and radioactive waste processing and disposal expected to be completed within the following 5–10 years.

Road map goals

The new road map sets out a pathway to continue to improve the safety of the site, with decommissioning as the final goal. Besides outlining the major milestones according to the three phases described above, the plans behind the road map also identify a set of goals to be achieved along the way. These include the initial aims of the work that was undertaken last year to achieve Steps 1 and 2, with new goals being set. For example, containing and halting the release of activity generated at the plant continues, with a focus now on processing, storing, and disposing of contaminated material. This is expected to create many unprecedented challenges that will require a substantial amount of R&D to ensure steady progress along the path. Considering the extent of this work, research laboratories around the world will be asked to participate.

Tepco has also said that it will maintain the current site organization, which includes approximately 400 partner companies. It will set up specialized offices at its headquarters to deal with every element of the road map. A good working environment and staff training will be maintained on site, as this is considered important to secure the performance required for this difficult project.

According to the road map, the many goals that will have to be achieved along the way are divided into the following eight areas:

1. *Reactor cooling/processing accumulated water*—In order to maintain the reactors in a stable cold shutdown condition, water injection will be continued until all the fuel and fuel debris are removed. One of the main achievements during the first year was to create closed water-recirculation loops with decontamination systems to maintain reactor cooling. Work will now be focused on improving these systems, including simplifying and scaling down the recirculation loops in a step-by-step process. New decontaminated water processing facilities will be installed to remove radionuclides that the existing cesium treatment facilities cannot handle.

During Phase 2, the processing of the accumulated water in buildings at the plant will be completed after measures are taken to stop water leakage, primarily between the reactor and turbine buildings, while repairs of the lower part of the PCVs will be done to prevent further leakages from these.

2. *Mitigating seawater contamination*—A number of measures are to be implemented to prevent contaminated underground water from flowing into the ocean. Besides installing shielding walls, contaminated seabed soil in front of the intake canal is to be covered and solidified to prevent the diffusion of radioactive materials into the sea. By early 2013, the continuous operation of the circulating seawater purification facilities should reduce radioactive materials in the seawater inside the plant site's port to the allowable levels outside the port. Sediments that were dredged in order to secure an adequate depth for large ships to enter the port will be covered.

3. *Radioactive waste management and dose reduction at site boundaries*—Plans to reduce the effective radiation dose at the site boundaries to below 1 mSv/yr should be carried out this year. This will require controlling emissions from radioactive waste stored on the site since the accident, including secondary waste materials generated by water processing and other on-site operations and by contaminated rubble.

Continued

4. *On-site decontamination*—In order to reduce exposure to the public and workers while improving the working environment at the plant, decontamination measures will be implemented in a step-by-step procedure, starting with the offices and working areas, in conjunction with efforts to reduce radiation dosage outside the site.

5. *Fuel removal from the spent fuel pools*—Unit 4's spent fuel pool will be the first to have its fuel removed, with the Unit 3 pool next in line, as these two should be the easiest to unload. Considerably more work will be needed to prepare Units 1 and 2 for fuel removal, including an investigation of the remaining reactor building structures, the removal of rubble, the decontamination of surfaces, and the installation of equipment such as covers and cranes. Methods for treating and storing the removed fuel are to be determined during Phase 2.

6. *Fuel debris removal*—Before fuel debris can be removed from the reactors, a substantial amount of preparation work must be done. In particular, because the PCVs must be flooded before the RPV is opened, they must be extensively inspected for leaks and any required repairs undertaken. After a structure is installed to cover the reactor, the vessel head will be opened, followed by a full investigation of the inside of the vessel, which will allow for the development of an appropriate methodology for debris removal before the removal procedure begins. Special debris containers will be built. Debris removal is expected to begin about 10 years after the completion of Step 2.

A significant amount of technology development will be needed to carry out fuel debris removal, which will include difficult remote operations. R&D efforts will be needed to develop technologies for the decontamination of the reactor building interiors, the investigation of the PCV interiors, the identification of areas of leakage in the PCVs, and repair technologies for the PCVs.

7. *Dismantling reactor facilities*—The dismantling of Units 1 to 4 should take place within 30 to 40 years. A basic radioactivity database of the facilities must be established to allow for efficient planning of activities such as demolition and decontamination, and for the development of a waste disposal plan.

8. *Radioactive waste processing and disposal*—During Phase 1, R&D was started on developing techniques for specifying, storing, processing, and disposing of the radioactive waste generated during and since the start of the accident because its contents, such as nuclide composition and amount of salts, will differ from normal plant radioactive waste. Methods for determining waste specifications will be needed, and the applicability of existing disposal concepts, as well as safety regulations and technical standards to govern disposal efforts, will have to be developed. The processing and disposal of waste should begin during Phase 3 after the development of the disposal facility and the creation of a disposal plan.

A road map for the industry

The Japanese government has already begun a process to revise its energy policy with the aim of reducing the country's reliance on nuclear power. This process will have to consider the public's opposition to nuclear power, which is and likely will re-

In the United States, near-term changes and a wait for more data

The response in the United States to the Fukushima Daiichi accident has been led by the Nuclear Regulatory Commission, with the general concurrence of the nuclear industry (as represented by the Nuclear Energy Institute) on the topics being addressed. There is, however, some disagreement on the details and scheduling of actions. The NRC has asserted from the beginning of the accident in Japan that power reactors in the United States are safe as they are, and that any changes in plant equipment and procedures would be to address potentialities that were made more apparent at Fukushima Daiichi but are still very remote and not likely to lead to the same degree of catastrophic failure.

The basis for all current NRC and industry initiatives is a document issued last July by six senior members of the agency's staff, *Recommendations for Enhancing Reactor Safety in the 21st Century: The Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident* (*NN,* Sept. 2011, p. 27). The importance and frequent citation of this document, and its cumbersome title, have driven virtually everyone to refer to it by some other name; in *Nuclear News,* we call it the Near-Term Task Force (NTTF) report. Its 12 recommendations and 35 specific actions have since been assigned different priorities (in three tiers) and varied interpretations. They also are receiving different kinds of treatment in the ways that the agency is setting tasks for licensees. Rulemaking, to alter the regulations themselves, can take about five years from project start to full compliance by licensees, and some of the Tier 1 (immediate action) tasks include this process, which, obviously, does not have the effect of being immediate. The NRC can also issue orders (generally when it has already been decided what must be done) and information-request letters (to gather data to lead to decisions).

A longer-term NRC review is also planned, but it depends to a great degree on the receipt of more information from Fukushima Daiichi. Because such data can be gathered no more quickly than the recovery and cleanup work at the site—which is expected to take many years—there is no timetable at the NRC for the development of longer-term actions.

NEI representatives and other industry figures have frequently stated that there should be as few orders as possible, and that licensees should be given the opportunity to work out their own ways to address the NTTF report's recommendations. NEI has lately referred to this approach as FLEX, presenting it as a diverse and flexible means of achieving the goals set out in the NTTF report.

While the industry would prefer not to do what the NRC wants exactly the way the NRC wants it done, there are other stakeholders (mainly citizen organizations that are frequently critical of nuclear power) that assert that the NTTF recommendations are not being extended far enough, or are themselves insufficient. In several proceedings for license renewal or new reactors, petitioners have tried to use the NTTF report to block further action on the grounds that the report is a major federal action that requires all reviews conducted under the National Environmental Policy Act (such as environmental impact statements) to be restarted from scratch. Thus far, all such arguments have been rejected by the NRC and its licensing boards, and no support for this position has been provided by the federal courts.

At this writing, some deadlines were yet to be met, but the NRC has been aiming to issue its first orders and information-request letters on or before March 9, the last business day before the first anniversary of the accident. The orders are to address the protection from external events of equipment that is on site to cope with the loss of large areas of a plant to fire or explosions; hardened vents for boiling water reactors with Mark I and Mark II containments; and spent fuel pool instrumentation. The NRC will request information on seismic and flooding reevaluations and walkdowns, the adequacy of licensee staffing to respond to multiunit events, and the powering of communications equipment during a prolonged station blackout. Actions to fulfill more NTTF recommendations, generally in Tiers 2 and 3, will follow in the coming months and (in the case of rulemaking) years.—*E. Michael Blake*

Unit 1 at the Fukushima Daiichi nuclear power station on March 12, 2011, following the earthquake and tsunami and after an explosion that opened up the top of the outer reactor building's shell . . .

main quite strong. The governor of Fukushima Prefecture, for one, has already said that he wants nuclear power to be abandoned there. To what extent the advantages of nuclear energy can counter this mind-set is difficult to say.

While public support for nuclear power in Japan may recover, as it has in some countries, the current level of opposition is particularly troublesome for the industry because of the veto powers that local authorities have over plant operation. This has meant that by mid-February, no plant had restarted operation after it was shut down for its periodic inspection, which is normally done annually. As of January 27, only three nuclear plants were in operation, and according to Takashi Imai, chairman of the Japan Atomic Industrial Forum, "If nothing is done, every reactor in Japan will be out of service within this fiscal year (by March)—meaning power shortages and rate hikes. As a result, Japanese industry's competitiveness will be weakened, accelerating the hollowing out of industry as production shifts to other countries."

The large loss of nuclear generation has played a big part in the economic consequences of the earthquake and the subsequent tsunami due to constraints on electricity use and the need to import expensive fossil fuel. Domestically, there have been job losses and large trade deficits, something very unusual for Japan.

At least there is a way forward for gaining national government approval for restarting plants, as this will be based on the results of national nuclear stress tests. Imai warned, however, that "justifying restarts based only on the stress tests . . . will be difficult." More measures will certainly be needed, he said, such as ensuring that a plant that is in a cold shutdown state will remain so "under any circumstances." Imai also wants the government "to act promptly and persuade local municipalities" to allow the continued use of nuclear power. But industry, he said, will also have to be proactive to win support, coming up with relevant measures on its own.

Another issue the industry faces is what approach to take regarding plants still under construction or planned. Utilities will have to make some modifications to plants under construction to take into account the lessons learned from the accident, as well as to convince the local population and authorities that the plants are safe. Nevertheless, Imai said, in light of the government's decision to continue a policy in favor of exporting nuclear plants, as well as for environmental and energy supply reasons, all parties should do all they can to ensure that nuclear technology can achieve the high levels of safety that are now required. He also made the point that the replacement of older reactors with new designs might be required as well.

Regarding the understandable public resistance to nuclear power, Imai noted how difficult it will be to recover the public's trust, now that its belief in what he called the "nuclear safety legend" has collapsed. Already, however, useful measures have been taken by the government, such as launching a new nuclear regulatory organization that will be totally independent and will have the necessary authority to regulate safety. "The nuclear industry must also reform itself," Imai said. "Electric utility companies must be open and transparent about their plants, releasing all data and information on problems and technical issues and announcing plans and actions." NN

. . . and on October 14, 2011, nearing the completion of the unit's new outer structure, which is designed to contain airborne contamination (Photos: Tepco)