

SHORENSTEIN APARC WORKING PAPERS

# Japan's Fukushima

# Nuclear Disaster

Narrative, Analysis, and  
Recommendations

Kenji E. Kushida





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Recommendations

*Shorenstein APARC Working Paper*

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Shorenstein APARC Working Papers  
June 2012

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# INTRODUCTION: JAPAN'S FUKUSHIMA NUCLEAR DISASTER

The Tohoku earthquake that struck off the northeastern coast of Japan on March 11, 2011 had a magnitude of 9.0. It was the fourth largest in modern recorded history, shifting the island of Honshu 2.4 meters to the east. The earthquake was followed shortly by a massive tsunami, as high as thirty meters in some places, devastating 500 kilometers of Japan's northeastern coast. Damage from the earthquake and tsunami led to a nuclear disaster in one of the several nuclear power plants along the eastern coast—Fukushima Dai-Ichi (number one), owned and operated by the Tokyo Electric Power Company (TEPCO).

The Fukushima Dai-Ichi plant included six nuclear reactors, three of which were in operation, with the rest undergoing routine maintenance. All reactors shut down successfully immediately following the earthquake. However, all external power lines were severed. The pumps to cool the reactors, necessary even after shutting down, therefore required on-site emergency backup power to function. When the tsunami hit within an hour, it reached a height of over twelve meters at the plant—well exceeding the maximum safety design of 5.7 meters, and obliterating the ten-meter-high seawall. Virtually all emergency backup power sources were irreparably damaged, and the reactors could not be cooled. Over the next three days, the three reactors experienced fuel core meltdowns and hydrogen explosions blew off three of the reactor buildings' roofs and walls.

Estimates vary, but the accident emitted at least 168 times the amount of radioactive cesium 137 as did the Hiroshima atomic bomb, although nobody died of immediate radiation exposure. Mandatory evacuation zones of a radius of 10 kilometers were imposed on March 11, and expanded to 20 km the following day, affecting over 80,000 residents. The disaster was eventually declared level 7 on the International Nuclear Event Score (INES)—the maximum. Chernobyl was the only other level 7 nuclear accident, although it released approximately six times the amount of radioactive material vis-

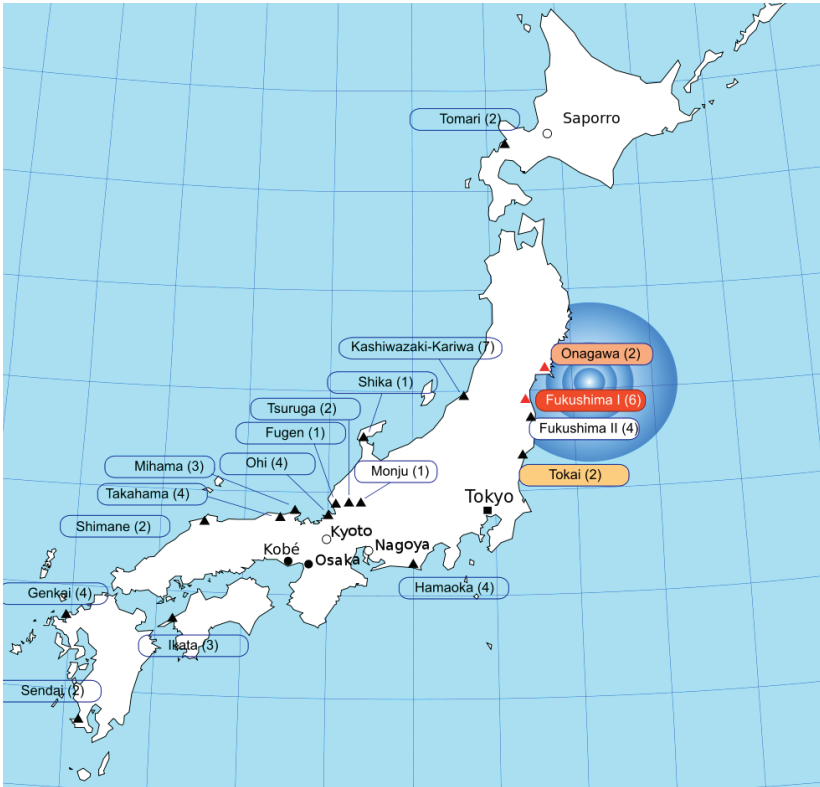


FIGURE 1 Nuclear plants in Japan, showing earthquake epicenter.  
 Source: Wikimedia Commons [http://commons.wikimedia.org/wiki/File:Nuclear\\_plants\\_Japan\\_in\\_2011.svg](http://commons.wikimedia.org/wiki/File:Nuclear_plants_Japan_in_2011.svg).

à-vis Fukushima, since it was an explosion of the core reactor during active operation. In Fukushima, sea water pumped into the reactors and used fuel storage pools created more than 100,000 tons of contaminated water, about a tenth of which was released into the ocean.

### The Disaster as a Critical Juncture

The Fukushima nuclear disaster has unleashed a major wave of industrial, institutional, political, and social challenges. The issues are complex and intertwined, with acute short-term crises and highly transformative medium-long term implications for change. Political processes will invariably shape the nature of change, as one of Japan's largest companies is restructured, the crucial energy industry is restructured, and government organizations





FIGURE 2 Explosion at Fukushima Dai-Ichi plant Reactor 3  
*Source:* Screen capture from Fukushima Chuo Television.



FIGURE 3 Aftermath at Fukushima Dai-Ichi plant Reactor 3  
*Source:* TEPCO.

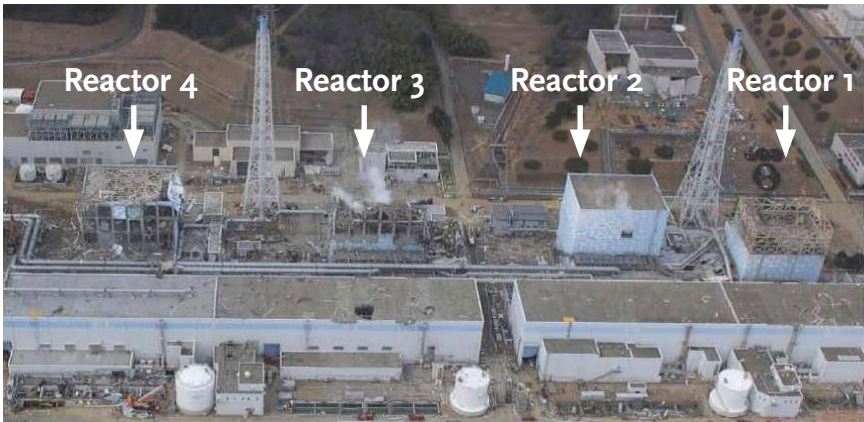


FIGURE 4 Aerial View of Fukushima Dai-Ichi Plant  
*Source:* Miller et al., 14.

that manage energy are reorganized. Social forces, with media attention on nuclear “refugees” who cannot or choose not to return to Fukushima, and voter support for localities that stand up to the national government and refuse to restart local nuclear plants, will also shape outcomes.

Unfortunately, the potential for bold and decisive political leadership in the face of the crisis was squandered, with political discourse turning into squabbles within and among political parties—highly disappointing to most voters and observers. Yet, there is potential for Japan to emerge from this experience with new strengths and international relations.

This paper sorts through the myriad of complex issues surrounding the restructuring of the energy industry. These range from the technical as-

pects of how to implement a market system for managing Japan’s electricity shortage and the specific political challenges of liberalizing the industry, to the broader structural challenges to reform and the potential pitfalls of adopting new technological solutions for power transmission. Many of the insights were derived from a conference held at Stanford University, hosted by the Walter H. Shorenstein Asia-Pacific Research Center on February 27, 2012.<sup>1</sup>

At the broadest level, the questions we must ask include: What happened? What are the challenges – particularly institutional, technical, and political? What are some potential solutions?

In the *short term*, Japan faces an acute crisis in electricity capacity to cope with demand during peak summer months. Stable supplies at reasonable prices are critical not only for societal wellbeing, but also for Japan’s industrial competitiveness—which feeds back into societal wellbeing. In the *short-medium term*, emergency procedures should be put into place, and technological choices for “smart” electricity grids must be made in a way that can advantage Japan in global competition. In the *medium-long term*, the energy industry, i.e., governance structures for the industry, and procedures during times of emergency need to be significantly restructured and reconfigured.

This paper unfolds in four parts. Part I is a narrative of the disaster itself as it developed. Such a narrative, based on emerging Japanese sources, must precede useful analysis, and is intended to be readable in stand-alone form. Part II analyzes the disaster by focusing on the locus of decision making, the locus of expertise, and information and communications linking the two. Part III addresses the challenges facing Japan’s restructuring of its energy industry from a market and industry standpoint. Part IV provides a brief analysis of the political dynamics shaping the politics following the disaster with implications for future reform.<sup>2</sup>

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1 [http://jsp.stanford.edu/events/one\\_year\\_after\\_japan\\_311\\_disaster/](http://jsp.stanford.edu/events/one_year_after_japan_311_disaster/)

2 The author wishes to extend his sincerest thanks to the Walter H. Shorenstein Asia-Pacific Center, participants in the “Looking Back, Looking Forward: One Year After the March 11, 2011 Disasters” conference at Stanford University on February 27, 2012, and in particular Masahiko Aoki for guidance and Trevor Incerti for research assistant work with the revised edition.

# THE DISASTER AS IT UNFOLDED

In order to identify the challenges and potential solutions, we must first unpack the critical juncture that is the disaster itself. A number of recent reports and publications in Japanese are emerging,<sup>3</sup> two government committees to investigate the accident were conducted, with public hearings held along the way.<sup>4</sup> The U.S. Nuclear Regulatory Commission has also published a report.<sup>5</sup> (See Appendix A: A Note on Sources). When synthesized, these provide a detailed view of events as they unfolded. However, a full and readable narrative with the relevant facts has yet to be published in English. Therefore, to facilitate further research and analysis beyond this report, let us begin with a narrative of the disaster, interlaced with relevant facts, before moving to a systematic analysis.<sup>6</sup>

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3 Hideaki Kimura, “Kanei no itsuka kan [5 Days in the Prime Minister’s Residence],” in *Purometeusu no wana: akasarenakatta fukushima genpatsu jiko no shinjitsu* [The Trap of Prometheus: The Truth about the Fukushima Disaster], ed. Asahi Shimbun Special Reporting Group (Tokyo, Japan: Gakken, 2012); Yasuaki Oshika, *Merutodaun: Dokyumento Fukuok daiichi genpatsu jiko* [Meltdown: Documenting the Fukushima Dai-Ichi Nuclear Accident] (Tokyo, Japan: Kodansha, 2012); *Purometeusu no wana: akasarenakatta fukushima genpatsu jiko no shinjitsu* [The Trap of Prometheus: The Truth about the Fukushima Disaster]. (Tokyo, Japan: Gakken, 2012); “Fukushima Genpatsu jiko dokuritsu kenshou iinkai chosa/kenshou houkokusho [Fukushima Nuclear Accident Independent Investigation Commission Research and Evaluation Report],” (Tokyo, Japan: Rebuild Japan Initiative, 2012).

4 “The Investigation Committee on the Accident at Fukushima Nuclear Power Stations of Tokyo Electric Power Company” was appointed by the Cabinet Office under Prime Minister Kan. The interim report of the former includes a wealth of details, though not in easily readable form. <http://icanps.go.jp/eng/interim-report.html> “The National Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission (NAIIC)” was formed by a statutory law by the National Diet in October 2011, with a final report published in July 2012. More details on sources in Appendix.

5 Charles Miller et al., “Recommendations for Enhancing Reactor Safety in the 21st Century: The Near-Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident,” (United States Nuclear Regulatory Commission).

6 This narrative follows the structure of Oshika and Kimura most closely, and is cited as such, but the facts were cross-checked with the other sources where possible.

## The Earthquake

The magnitude 9.0 earthquake occurred at 2:46 p.m. on March 11, 2011. The three operating reactors at the Fukushima Dai-Ichi nuclear plant immediately shut down. However, the earthquake severed all external power lines connecting the plant to the external power grid, and the on-site emergency backup power generators kicked in.

The quake itself caused major damage at the plant. Much of the plant was over forty years old, and, in particular, the operations buildings with the control rooms, monitoring devices, information, and equipment, were catastrophically damaged to the point of becoming unusable. The extent of earthquake damage to the reactor buildings themselves is still unclear. However, while the reactor buildings themselves had been strengthened to some degree over the years, the operations centers were essentially forty-year-old buildings whose walls, ceilings, and other structural elements were vulnerable.

The vibration frequency of the earthquake was particularly damaging to the Fukushima plant. Despite the truly massive amount of force from the 9.0 earthquake, it is notable that most buildings in much of the Tohoku region remained relatively undamaged. For wooden buildings, frequencies of around 1 second are known as the “killer pulse,” since the buildings resonate at that wavelength, magnifying the sway to create catastrophic damage. The Tohoku earthquake had a far shorter wavelength of approximately 0.1 to 0.3 seconds. Unfortunately, the nuclear facilities, which consist primarily of massive concrete structures, thick steel reaction chambers, and a myriad of pipes, have short resonance frequencies of approximately 0.02 to 0.4 seconds. The Tohoku earthquake therefore fell exactly within the range of resonance frequencies for much of the nuclear facilities, creating massive damage even before the tsunami hit.<sup>7</sup>

After the earthquake, the Fukushima Dai-Ichi operations headquarters staff quickly evacuated to a new operations center on slightly higher ground, designed to withstand strong earthquakes. *This seismically-reinforced operations center had been completed just eight months before the earthquake*—without which there would have been no local operational staging ground for efforts to contain the catastrophe. Of the 6,350 workers at the Dai-Ichi plant, 5,000 or so of whom were contract workers, about 400 remained after the tsunami, with the rest leaving to check on their families and houses.

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7 Makoto Saito, *Genpatsu Kiki no Keizaigaku* [The Economics of the Nuclear Crisis] (Tokyo, Japan: Nihon Hyoron Sha, 2011), 97–98.

## The Tsunami: Devastating Excess and Critical Deficiency of Water

The tsunami hit in multiple “waves” (though less a wave than a wall of water) starting at 3:27 p.m., forty minutes after the earthquake. The second wave, which hit at 3:35 p.m., exceeded 12 meters, easily obliterating the 10 meter high concrete seawall designed to withstand a tsunami of only up to 5.7 meters. The tsunami took out much of the primary cooling system, largely consisting of pumps responsible for pumping seawater into the reactor building to cool the fuel rods. Devastatingly, it also irreparably damaged virtually all emergency backup power sources, including diesel generators, batteries, and circuit boards. The generators and batteries were located in the basement of the turbine buildings, in between the seawall and the reactor buildings. Without these power sources, there was no way to run the emergency backup cooling pumps.

The need for truly massive quantities of water for nuclear reactors cannot be exaggerated. The Fukushima Dai-Ichi Reactors 1, 2, and 3 that were operating at the time of the disaster were Boiling Water Reactors (BWR). In essence, heat from the nuclear reactions of the fuel rods within a sealed chamber boiled water under high pressure, creating steam that rotated turbines to generate electricity. The primary, or first stage cooling system for the three reactors required *5600 tons, 7570 tons, and 7760 tons of seawater, respectively, per hour* during normal operations. Then, in addition, to cool the steam and convert it back to water, approximately 20 tons per second, 70,000 tons per hour, or *1.7 million tons per day* of seawater is required.<sup>8</sup> This massive amount of water required is why nuclear power plants are built next to large bodies of water.

Even after successful emergency shutdowns of the fuel core reactions,<sup>9</sup> the fuel rods retain considerable heat, requiring non-negligible amounts of water for cooling. For Reactor 1, this was approximately 20 tons per hour immediately after halting the reaction, 5 tons per hour after ten days, 3 tons per hour for a month, and then 2 tons an hour for a prolonged period. For Reactors 2 and 3, these numbers are 30, 10, and 7 tons, respectively. Put simply, *the three reactors combined required approximately 70 tons of water per hour for 10 days, even after shutting down, to avoid a catastrophe.*<sup>10</sup> Restarting the pumps, or at minimum, the emergency cooling system as a short term solution,<sup>11</sup> was critical. To do this, electricity was needed.

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8 Ibid., 22.

9 This is a process known as scram.

10 Saito, *Genpatsu Kiki no Keizaigaku* [The Economics of the Nuclear Crisis]. 22.

11 The emergency cooling system was actually not a viable long-term solution, capable of only temporarily cooling the reactor for short periods of time. Ibid.

Yet, the plant had lost all external power in the earthquake, and the tsunami destroyed almost all emergency backup diesel generators and batteries. There was no way to pump the large amounts of water absolutely necessary to cool the reactors.

### TEPCO's Top Leadership Vacuum

The situation was dire, and events unfolded rapidly. During this initial time of crisis, however, neither TEPCO's chairman, widely considered the center of power, nor the president, were at TEPCO headquarters. Worse yet, since telephone networks were down following the earthquake, neither could communicate effectively with TEPCO headquarters, let alone the Fukushima plant operations center. The president's whereabouts were uncertain. (He was on vacation with his wife in Nara.) *Neither could return to TEPCO headquarters for more than twenty hours after the earthquake and tsunami.* Moreover, the political leadership, led by Prime Minister Kan Naoto, who became intimately involved with the Fukushima disaster mitigation efforts, was unaware that TEPCO's chairman and president were absent from TEPCO until much later.

Chairman Katsumata Tsunehisa was in China at the time of the disaster on a tour with Japanese press and labor leaders, and had no way to return to TEPCO headquarters.<sup>12</sup> The Chinese government offered free use of an airplane, but the Tokyo airports of Narita and Haneda were closed. Kansai airport, near Osaka, was not an option either, since domestic rail travel and freeways were all shut down due to the earthquake. Katsumata returned to Japan the following morning. In the meantime, most communications lines were down within Japan, and it is not clear that he was able to communicate effectively with headquarters.<sup>13</sup>

President Shimizu Masataka was in Nara on a short vacation following meetings in Shikoku. His whereabouts were seemingly unknown to many of his staff. His attempts to return to headquarters border on the comical, if not for the fast-developing nuclear crisis. With rail and road transportation to Tokyo closed, Shimizu traveled to Nagoya, attempting to use a TEPCO-affiliated company's helicopter to fly to Tokyo. However, by the time he reached the heliport, it was discovered that the company had neither the equipment nor permits to fly at night. Shimizu and his staff were then able to contact the government for use of a Self-Defense Forces (SDF) aircraft to fly

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<sup>12</sup> For a list of primary actors involved in the disaster, see Table 2 at the end of Section I.

<sup>13</sup> Oshika, *Meltdown*, 12–16.

Shimizu to Tokyo. The large C-130 transport aircraft, with Shimizu as the sole passenger, took off towards Tokyo at 11:30 p.m., eight hours after the disaster. Yet, due to a combination of terrible judgment by the Minister of Defense and information failures within the SDF, the plane made a U-turn at 11:45 p.m. and returned to its base in Aichi Prefecture.

What had transpired was the following. Upon hearing that Shimizu would be transported via C-130, the Defense Minister had ordered that all SDF resources should focus on rescue and recovery from the earthquake/tsunami disaster. The SDF at the time was fully consumed with the disaster, which far exceeded anything it had ever dealt with. Somewhere in the chain of command, the information that the aircraft was already on its way had been lost, and the Minister's order was interpreted as a command for the plane to turn back.

Shimizu had to wait until the next morning to take the helicopter, which landed him at the Tokyo heliport. From there he was stuck in the post-disaster traffic jam that gridlocked Tokyo on March 12. It took him two hours to reach TEPCO headquarters, finally arriving around 10:00 a.m.—almost twenty hours after the disaster. By then, the Fukushima reactors were deep into the crisis—likely already melted down—and about to experience the first hydrogen explosion. The prime minister's office and TEPCO had been working through the night in an attempt to contain the crisis, making a series of critical decisions, and more seriously, not making particular decisions that might have helped the situation.

### **Early Information and Communications Difficulties**

Rewinding to the afternoon of the disaster on March 11 and to the Fukushima plant, the severity of information and communications problems was immediately apparent. The plant was not designed to operate under conditions entailing complete loss of external and on-site backup power, and it lacked measures to cope with a breakdown in communications. The nearby cellular communications tower was damaged in the earthquake, rendering cellphones useless. Handheld transceivers also incurred massive static. From the operations headquarters, the plant manager in charge, Yoshida Masao, was working with very little information. Control panel indicators and sensors were mostly unusable or unreliable due to earthquake and tsunami damage, and a lack of electric power. To grasp the situation on the ground, Yoshida had to repeatedly send staff into the plant, near the reactors, to assess the situation.

Some information and communications failures were worse than others. It turned out that the emergency cooling system in Reactor 1, which converts steam into water, had started automatically. However, eleven minutes later, an operator had manually stopped it because *it was cooling the reactor faster than the guidelines* set by the Nuclear and Industrial Safety Agency (NISA). Yoshida, unaware that the system had been stopped, was given unreliable instrument readings, and assumed that it was operating. He therefore prioritized cooling Reactor 2 rather than Reactor 1, though in reality Reactor 1 was in far worse condition.<sup>14</sup>

At 3:00 p.m. on March 11, Yoshida sent faxes to TEPCO headquarters and NISA (located within METI), officially declaring that a nuclear emergency was likely to occur. This was the first time ever that such a notice was sent.<sup>15</sup> At 4:30 p.m., he sent another message upgrading it to “emergency in progress,” a status that automatically triggers an evacuation order.<sup>16</sup> This was also unprecedented. Yoshida noted that they were unable to cool the reactors and could not monitor the water levels of Reactors 1 and 2. The implications were serious, since the reactor fuel cores needed to be immersed in water; if the hot core evaporated all the water, the core would be exposed, and fuel core rods would overheat and become damaged—the phenomenon commonly known as a “meltdown.” At 4:54 p.m., Prime Minister Kan Naoto issued a two minute statement at the press room saying that the nuclear reactors had stopped and no radiation leakage had been observed. He took no questions. While Kan’s statement was true, it did not acknowledge that a report of “nuclear emergency in progress” had been issued by the Fukushima Dai-Ichi plant.

Kan’s two close aides, Terada Manabu, age 34, and Hosono Goshi, age 39, both DPJ members, were at the prime minister’s residence when Kaieda Banri, Minister of METI, rushed to join them at about 5:45 p.m.

Kaieda wanted Kan to immediately declare an emergency. However, although Kan listened to Kaieda’s report and urgings, he left in less than thirty minutes (around 6:15 p.m.) to attend a meeting between his party and opposition parties to seek cooperation in the disaster recovery. Only

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<sup>14</sup> Oshika, *Meltdown*, 570; “Interim Report,” ed. Yotaro Hatamura (The Investigation Committee on the Accident at Fukushima Nuclear Power Stations of Tokyo Electric Power Company, 2011), <http://icanps.go.jp/eng/interim-report.html>.

<sup>15</sup> This was in accordance with Article 10 of the Nuclear Emergency Preparedness Act (Act on Special Measures Concerned Nuclear Emergency Preparedness) passed in 1999 following a nuclear criticality accident at a nuclear fabrication plant in Tokaimura, operated by JCO. “Interim Report.”

<sup>16</sup> This is known as an “Article 15” event, as stipulated in the Nuclear Emergency Preparedness Act.



after he returned from this meeting did he proceed to finalize the emergency declaration.<sup>17</sup> Kaieda later testified to a Diet investigation commission later that it took time to get Kan's understanding and agreement to declare the emergency.<sup>18</sup>

One problem was that the prime minister's office lacked the know-how of exactly how to do so, with secretaries and aides busy reading the relevant laws. NISA staff, who were METI bureaucrats rotating through the agency every few years, also lacked such operational knowledge. The relevant law was the Special Law for Emergency Preparedness for Nuclear Disasters, which had been formulated after a 1999 nuclear accident at the Tokaimura uranium reprocessing plant in Ibaraki prefecture. The problem with this law, however, was that it did not provide for a nuclear disaster occurring simultaneously with an earthquake/tsunami disaster. It called for a gathering of the Nuclear Safety Commission (NSC), which was to establish an emergency technical advisory group to advise the prime minister. The problem was that the NSC was comprised of about forty members, and with communication networks offline, all public transportation in the Tokyo Metropolitan area frozen, and roads in gridlock, there was no way to gather the members.<sup>19</sup>

At 7:00 p.m., Kan declared a nuclear emergency to the nation—the first time such a declaration had been made. This should have triggered an evacuation order, but Kan's staff were unable to effectively orchestrate evacuation procedures. He and his staff could not gain information about conditions on the ground, and although according to law, several off site emergency operations centers were to be established, the transportation and communications paralysis made it impossible to set up the designated twenty-two locations, including Fukushima. At 7:45 p.m., Chief Cabinet Secretary Edano Yukio advised the public not to panic and flee, but to stay indoors and wait.<sup>20</sup>

At 8:50 p.m., around four and a half hours after the “nuclear emergency in progress” was declared, the Fukushima prefectural government took matters into its own hands. It announced that residents within a 2 km radius of the Fukushima Daiichi plant should evacuate. Half an hour later, at 9:23 p.m., the Kan government announced a 3 km radius for evacuation, ordering people to stay indoors in the radius between 3–10 km; this was three

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17 “Interim Report.”

18 “Kinkyuu sengen no okure “Kanshi no Rikai ni Jikan” Kaiedashi shougen Kokkai genpatsu jikocho [The delay in declaring emergency due to “Time needed for Kan's understanding/approval” Kaieda's testimony at the Diet Nuclear accident investigation commission],” *Asahi Shimbun*, March 18 2012.

19 Oshika, *Meltdown*, 43–44.

20 *Ibid.*, 48–49; “Interim Report.”

hours after Kan had declared an emergency.<sup>21</sup> It was later determined that by around 5:00 p.m., four hours earlier, Reactor 1's core was already exposed, and by 5:50 p.m., the radiation monitor began showing increased radiation levels.

### The Race to Provide Electricity

Hours before issuing the evacuation order, Prime Minister Kan had actually begun to involve himself personally in the Fukushima Dai-Ichi plant crisis. Starting in the late afternoon of March 11, Kan directly dispatched power trucks, carrying large batteries, to the Fukushima Dai-Ichi plant to provide electricity for the cooling systems. Kan had an engineering background with a degree from the Tokyo Institute of Technology, which had given him a basic grasp of nuclear plant design and operations. He understood the critical need to supply water to the reactors, and procure electricity to operate the pumps.

Around 6:00 p.m., the Fukushima Prefecture Emergency Headquarters announced that TEPCO had sent eight of its power trucks, the SDF Fukushima base had sent one, and TEPCO had asked the Tohoku Electric Power Company to send any available power trucks. However, since all highways and roads surrounding the Tokyo Metropolitan area were gridlocked, with many roads in the Fukushima area impassable due to earthquake damage, their progress was slow. Kan ended up spending much time making phone calls to dispatch SDF power trucks, involving himself in minute details of the operations. A whiteboard was carried into his office, with constantly updated information about which trucks were headed from where, and through what route.<sup>22</sup>

With land routes uncertain and slow, Kan explored other options. Attempting to arrange an airlift of the power trucks, at one point Kan phoned the SDF, investigating the power trucks' weights and measurements. Finding the weight prohibitive for SDF helicopters, Kan also inquired of the U.S. military—but the trucks were simply too heavy.<sup>23</sup> All told, 40–69 power trucks were dispatched by Kan's political leadership.<sup>24</sup>

After 9:00 p.m., one of the power trucks finally reached the Fukushima Offsite Center, 5 km from the reactor. More arrived over the next few hours. However, to everyone's dismay, they were unusable—the voltage was incorrect, and the plug sockets were incompatible. Kan was furious at TEPCO,

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21 *Meltdown*, 48–49.

22 *Ibid.* “Fukushima Report.”

23 *Meltdown*, 48–49.

24 *Ibid.*, 49; “Fukushima Report,” 77.

and Yoshida's attempts on the ground to use converters within the Reactor 2 building were unsuccessful, since extensive debris and damage within the plant made it impossible for the truck to get close. A 200-meter-long cable was needed, far longer than the cable equipped by the truck. It took some time to locate a cable within the plant, since much of the knowledge of such details was held by contract workers rather than TEPCO staff. Then, even when someone remembered seeing a cable in a storage facility, the door lock did not easily open. As these reports flowed into the prime minister's office ("Truck arrived." "Doesn't fit!" "Needs longer cable." "Don't have cable." "Identified cable location." "Can't open door."), Kan's mistrust of TEPCO's competence and sense of responsibility increased.<sup>25</sup>

Once the cable was located, transporting and connecting it was a challenge, since it weighed more than one ton and most equipment was unusable. A four-ton truck with a crane was mobilized to haul the cable out of storage, and about forty men began pulling it to where it was needed. Phones did not work, the area was pitch dark, debris was scattered, strong aftershocks kept occurring, and with manhole lids often missing, this was highly treacherous—and, critically, time-consuming—work.

At 11:50 p.m., with the power truck yet to be connected, plant manager Yoshida faxed another report to NISA: radiation levels within the reactor building were rising. Radiation was leaking.

This is when it became apparent that Yoshida's assumption that the emergency cooling system for Reactor 1 was working was clearly wrong. It also became clear that the instrument panel he relied upon was unreliable, since it read that water levels were sufficient.<sup>26</sup> Water levels were clearly insufficient, and the exposed fuel core had damaged the containment vessel, leading to radiation leakage.

All the while, the political leadership was unaware that TEPCO executives were not in command at headquarters, with Katsumata stuck in China and Shimizu's SDF transport plane just having turned back to Aichi Prefecture. Although there are no reports of Kan directly demanding that TEPCO leadership contact him, he and his aides were clearly frustrated at the lack of information from TEPCO. Kaieda later testified that they knew that the "messaging game" of indirect communications was ineffective.

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<sup>25</sup> *Meltdown*, 49; "Fukushima Report," 77.

<sup>26</sup> *Meltdown*, 53–54.

Deeply mistrustful of not only TEPCO, but also of government bureaucrats and nuclear researchers possibly tainted by TEPCO,<sup>27</sup> Kan had already begun assembling a private group of friends for advice about the nuclear plant.

Back on the ground at Fukushima, operational and informational difficulties frustrated crisis management efforts on the ground. Earlier that night, Yoshida had wanted to use fire trucks to inject cooling water into parts of the plant. However, since nobody had foreseen such an action, the lines of command were unclear, and the plan was not actually operationalized. There were no useful operations manuals to fall back upon either. Although there were fifty pages in the operations manual for nuclear critical events, in its sixteenth revision at the time and released just two months earlier, it was almost completely useless; it did not assume the loss of electricity to the nuclear plant.<sup>28</sup>

### Venting the Reactor Buildings

Around 11:50 p.m., Yoshida discovered that the pressure containment vessel in Reactor 1 had reached an internal pressure of 600 kilopascals (kPa), well exceeding its maximum design of 427 kPa. Unless pressure was reduced, the containment vessel for the fuel rods could break. Yoshida decided to “vent” the reactor—the process of releasing hot air from the vessel itself into the atmosphere in order to lower the reactor pressure and temperature. The design of the Fukushima Dai-Ichi reactors was such that this would release substantial radioactive material into the atmosphere.<sup>29</sup> There were two types of vents in these reactors, motor operated valves and compressed air operated valves. Without electricity, neither worked. Therefore, they would have to be opened manually. Yet, nobody in the operations headquarters knew the exact design or location of the manual open hatches. This was knowledge held by contractors rather than TEPCO staff, who rarely went into the reactor buildings, and most contractors had left. Yoshida had to send staff with

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27 His mistrust was not irrational, having gained fame while Minister of Health and Welfare in the mid-1990s for exposing a major scandal in which collusion between ministry officials and a private company that hired retired bureaucrats had covered up a major scandal involving giving untreated, HIV-tainted blood to hemophiliacs and pregnant women.

28 Oshika, *Meltdown*, 60–61.

29 As we note later, the air vents in the reactors did not have air filters to reduce the amount of radioactive material released. These filters were installed in U.S. and European nuclear plants after the 1979 partial nuclear meltdown accident at Three Mile Island in the US.

flashlights into the destroyed operations rooms in search of design schematics showing whether the vents could even be opened manually.<sup>30</sup>

At the prime minister's residence, in the underground emergency operations center, Kan, Kaieda, Edano, Fukuyama, Hosono, the head of NISA, and a senior official of TEPCO debated the venting procedure. The politicians other than Kan lacked knowledge about venting, so questions such as the potential amount of radiation released and the degree of evacuation needed, were discussed. By 1:00 a.m., they decided that venting was necessary. They asked Yoshida to commence with venting procedure after the government would announce its action at 3:00 a.m. After Edano announced to the press at 3:12 a.m. that venting would occur shortly, the political leadership expected imminent news of venting—but it never came.

As Kan waited, his mistrust and suspicion of TEPCO no doubt growing by the minute, he began saying that he would visit the Fukushima Dai-Ichi plant himself that morning.<sup>31</sup>

During the night, as they worked straight through until morning, the prime minister's staff learned to their surprise that the TEPCO executive in the emergency headquarters in the prime minister's residence, former TEPCO Vice President Takekuro Ichiro (at the time with the title "fellow"), was not directly in touch with the Fukushima Dai-Ichi plant. He was instead relaying messages via TEPCO headquarters. As the political leadership's frustration mounted, Takekuro could not provide clear answers to their inquiry as to why the venting had not occurred by 5:00 a.m.

At 5:44 a.m., the prime minister decided to widen the evacuation area from 3 km to a 10 km radius. Around this time, reports came from the Fukushima Dai-Ni plant, 8 km south of the Dai-Ichi plant. Another crisis was looming. The report from Fukushima Dai-Ni was that temperatures in three of its four reactors were rising. The primary water pumps facing the ocean had been damaged by the tsunami, and the reactors could not be cooled. Therefore, it looked as though both Fukushima plants were headed for catastrophe. Receiving this news, Kan issued a second nuclear emergency decree, ordering that everyone within a 3 km radius of both plants evacuate, and that people stay indoors in the radius between 3 km to 10 km.

### **Kan's Visit to the Fukushima Dai-Ichi Plant**

At 6:00 a.m. on March 12, only fifteen hours after the earthquake hit, Kan officially decided to visit the Fukushima Dai-Ichi plant. His aides

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<sup>30</sup> Oshika, *Meltdown*, 62–63.

<sup>31</sup> *Ibid.*, 64–66.

warned him about the potential political repercussions, but he was determined. Kan left the prime minister's residence by helicopter at 6:30 a.m. In the meantime, he had instructed Kaieda to issue a legally mandated order to TEPCO to commence venting. Kaieda did so at 6:55 a.m. Kan clearly no longer trusted TEPCO to act voluntarily, assuming that its delay to vent the reactors was deliberate.<sup>32</sup>

Kan visited the emergency operations building at the Fukushima Dai-ichi plant for just under an hour, meeting Yoshida and seeing the exhausted ground-level workers throughout the building.<sup>33</sup> He was reportedly reassured by Yoshida's competence and strong leadership. The latter promised that he would gain control of the situation even if it meant assembling squadrons of workers prepared to die in the attempt. During the helicopter ride, Kan was accompanied by Madarame Haruki, the chairman of Japan's Nuclear Safety Commission (NSC). Kan directly inquired whether a hydrogen explosion might occur from the reactor's zirconium case<sup>34</sup> melting and reacting with water. Madarame's answer was no—there was no oxygen so there would be no explosion.<sup>35</sup>

Kan left the Fukushima plant just after 8:00 a.m. At the plant at 9:04 a.m., two-man teams began heading to the reactor building to manually open the vent. In the absence of mobile communications, the second group had to wait for the first group to return in order to get information. The first group opened one of the vents about a quarter of the way before their radiation levels reached the maximum levels deemed reasonably safe. The second team, however, had to turn back before reaching the vent due to high levels of radiation that triggered their alarms. One of them received a dose of approximately 106 millisieverts (mSv), far exceeding the yearly limit of 1 mSv deemed safe (the others received 89 and 95 mSv). The most exposed worker reported a headache and high body heat, suggesting that he had been irradiated, or *hibaku*—a Japanese term loaded with connotations of the Hiroshima and Nagasaki atomic bomb victims. There was no doctor within the operations center, so he was rushed to the local hospital. However, it had already been evacuated, so no doctors were available there either. Yoshida deemed it too unsafe to send the third group into the reactor building.<sup>36</sup>

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32 Ibid., 81.

33 Ibid., 83–84.

34 To be precise, in its use as fuel rod casing, the zirconium in part of a compound is called zircaloy.

35 Oshika, *Meltdown*, 81.

36 Ibid., 86–88.

Yoshida then attempted to connect a compressor to one of the vents that could be opened with compressed air. He sent staff to procure such a device from one of the contractors' offices. They succeeded in finding one, but discovered that they could not find an adapter to connect the compressor. At 12:30 p.m., they used a truck with a crane to carry out the compressor and found something that could function as a converter.



FIGURE 5 Explosion at Reactor 1  
*Source:* Screen capture from Fukushima Chuo Television.

At 2:00 p.m. they were finally able to vent Reactor 1—almost fourteen hours after Yoshida's decision, and eight hours after Kan's legal order. The reactor pressure, designed for a maximum of 427 kPa, had risen over 840 kPa at one point.<sup>37</sup>

By then, the fuel core of Reactor 1 had already melted through. An hour and a half later, at 3:36 p.m. on March 12, a hydrogen explosion blew off its roof and upper walls. The explosion is shown in Figure 5, and its aftermath in Figures 6 and 7.

### The Reactor Building Explosions

The explosion at Reactor 1 blew debris all over the plant, injuring two workers. It severely disrupted operations on the adjacent Reactor 2. Falling debris damaged the 200-meter cable that connected the power truck to Reactor 2. A fire truck that had been preparing to inject sea water was also

<sup>37</sup> *Ibid.*, 88–89.



FIGURE 6 Central Control Room after  
Reactor 1 Explosion  
*Source:* TEPCO.



FIGURE 7 Aftermath of Reactor 1  
Explosion  
*Source:* TEPCO.

damaged, as was its hose. Workers had been close to powering up a system that would insert a boric acid solution at high pressure to cool the reactor, but fear of high radiation kept workers away. By this time, the core fuel had melted considerably. Five months later, TEPCO revealed that radiation levels near an exhaust duct between Reactors 1 and 2 at this time read 10 sieverts (Sv), or 10,000 mSv, an hour, with 5 Sv an hour inside Reactor 1's building pipes (enough to kill a person in forty minutes.)<sup>38</sup>

At 6:00 p.m., March 12, Kan expanded the 10 km evacuation radius to 20 km.

### **Injecting Sea Water**

By 5:00 p.m. on March 12, the prime minister's command center had been moved from the underground emergency headquarters to his fifth floor office. The problem was that the underground emergency headquarters could not receive cellular phone signals—a serious hindrance for operations. As it later became clear, however, the move to the fifth floor entailed its own set of problems. Many of the dedicated emergency land line phones and faxes from various agencies to the prime minister's office were connected

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<sup>38</sup> Ibid., 93.



directly to the underground headquarters. Staff had to manually relay messages up to the fifth floor—sometimes losing information along the way. This certainly increased the prime minister's sense of frustration in receiving timely information from TEPCO.<sup>39</sup>

By 6:00 p.m., Kan strongly advocated injecting seawater into the reactors. This would produce radiation contaminated seawater, and almost certainly ruin the reactors. Confusion during this period created a situation that later became infamous. It turned out that plant manager Yoshida had already begun injecting seawater at around 7:00 p.m., before the political leadership had given the order. However, the TEPCO executive in the prime minister's office, Takekuro Ichiro, thought that it would look bad if TEPCO was found injecting seawater before the prime minister's office issued the order. He therefore advised TEPCO to command Yoshida to halt injection of seawater until further notice. Yoshida acknowledged but disobeyed the order, continuing to pump sea water. When Kaieda ordered TEPCO to pump sea water at 8:05 p.m., as relayed by Takekuro to TEPCO headquarters immediately thereafter, the political leadership did not know that seawater injection had already begun, and TEPCO leadership was unaware that it had not stopped.<sup>40</sup>

Fukushima Dai-Ichi's Reactor 3 was deep into crisis as well. Some combination of miscommunication and bad judgment from the prime minister's office led to an attempt to shift the cooling method of Reactor 3 from sea water to foam water from fire engines. Fire trucks were sent by the NISA, but the Fire and Disaster Management Agency (FDMA) was unwilling to send them to the Fukushima Offsite center 5 km from the Dai-Ichi plant, since the evacuation zone was 20 km. Fire engines on the ground had to find and uncover connectors to the storage tanks of anti-fire foam. To inject water from fire trucks, pressure within the reactor had to be released through a safety release valve, but there was insufficient battery power to open the valve. Yoshida collected his employees' commuter car batteries to get enough power for the operations center, opening the valve just past 9:00 a.m. on March 14. Six hours and forty-three minutes had elapsed since

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39 Others, such as METI Minister Kaieda, also testified to the Diet that communications with TEPCO was like playing a game of oral note passing.

40 In a blame game that occurred later, in May, some of the popular press was misled to believe that Kan had ordered a halt of seawater injections, which were carried through and contributed substantially to the disaster. *Yomiuri Shimbun*, the daily newspaper with the largest circulation in Japan, even ran the story as a headline. Only two months later, when plant manager Yoshida spoke up and revealed that he had disobeyed TEPCO orders to stop seawater injections did it become clear that it was TEPCO's Takekuro rather than Kan that ordered the halt.

the high pressure coolant injection system had stopped, and heat had risen to 2000 degrees Celsius. At about 10:30 a.m., just as Yoshida attempted to switch back to sea water since water tanks were becoming depleted, a strong aftershock hit, delaying the switch-over. As a result, there was a gap of over an hour between the end of sending foam, and the recommencing of seawater injections at 1:12 p.m.<sup>41</sup>

Reactor 3, which was later thought to have reached temperatures exceeding 2000 degrees Celsius, had already begun to melt down around 8:00 a.m. Earlier in the morning at 6:50 a.m., as pressure within the reactor chamber had begun to rise, all outdoor workers were given evacuation orders. At 11:01 a.m., the Reactor 3 building exploded—a much stronger explosion than that of Reactor 1. A black plume like a mushroom cloud rose high into the sky. (See Figure 2) Approximately eleven people were injured, and the operations center was thrown into panic.

Efforts to sustain temperatures in Reactor 2 were halted as fire trucks and hoses were destroyed. Vents had been opened approximately twenty-five percent, but they slammed shut again with the explosion, and all workers evacuated to the operations center for some time. At this point, the battery for Reactor 2's cooling system ran out, just after 1:00 p.m.. Another process of gathering car batteries to open the safety valve to lower the pressure and connect fire engines was completed by around 7:20 p.m. It was then discovered that the fire trucks had run out of fuel, with no supplies on hand. Kan, who had received this latest update, was furious, ordering helicopters to send in fuel.<sup>42</sup>

It was later estimated that Reactor 2 experienced a meltdown about 6 and a half hours after the cooling system stopped. Large quantities of hydrogen were produced as a result of the zirconium shell of the fuel rods drawing oxygen from the surrounding water – which can occur at high temperatures. By 10:50 p.m., Yoshida determined that the internal pressure had risen to 540 kilopascals (kPa), exceeding the 427 kPa maximum.

## TEPCO's Abandonment Request Controversy, Establishment of Joint Headquarters

After the hydrogen explosion in Reactor 3, TEPCO executives began asking the political leadership whether they could abandon the Dai-Ichi plant and regroup at the Dai-Ni plant, 8 km to the south. TEPCO President Shimizu telephoned Kaieda, then Edano. In events that became the focal

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<sup>41</sup> Ibid., 108–10.

<sup>42</sup> Ibid., 120–21; *Prometheus*. 262–63.



FIGURE 8 Car Batteries Powering Control Panel  
*Source:* TEPCO.

point of intense scrutiny in subsequent investigations, TEPCO executives and Shimizu later insisted that they were not seeking permission to fully abandon the Dai-Ichi plant. They contended that they had said “retreat,” implying that key personnel would stay behind to continue seawater injection operations. Kaieda and Edano dispute this view, contending that nothing was ever said about core personnel remaining. They argued that if it was simply a strategic “retreat” leaving necessary personnel, Shimizu would have had no need to call each of them, and after making no headway, then attempt to reach the prime minister.<sup>43</sup>

Kan was awakened around 3:00 a.m. on the fifteenth, with Kaieda, Edano, Fukuyama, Hosono, and Terada in the prime minister’s office on the fifth floor. He was informed that TEPCO was considering abandonment of the Dai-Ichi plant. Kan forcefully asserted that this could not happen. He summoned TEPCO president Shimizu at around 4:00 a.m., and Shimizu arrived around 4:20 a.m.<sup>44</sup>

Kan was concerned not only with Reactor 2, which was close to exploding, but also with the pools of used fuel stored in the reactor buildings of Reactors 4, 5, and 6, shut down for maintenance at the time of the disaster.<sup>45</sup> We will revisit this issue later.

The prime minister took the unprecedented step of ordering a joint government-TEPCO headquarters within TEPCO. He told Shimizu to get

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43 *Meltdown*, 123–29; “Kaieda’s Testimony.”

44 “Fukushima Report,” 85; *Prometheus*. 263.

45 *Meltdown*, 126.

a desk ready for Hosono within half an hour, and that he, Kan, would visit TEPCO headquarters within the hour.

Kan rode into TEPCO headquarters at 5:35 a.m., announcing to the 300 or so employees working around the clock that TEPCO would not be allowed to abandon the Dai-Ichi plant. He told them that they, TEPCO, were responsible, and if they fled, there was no way the company would survive. This visit increased antagonism between TEPCO and the political leader-

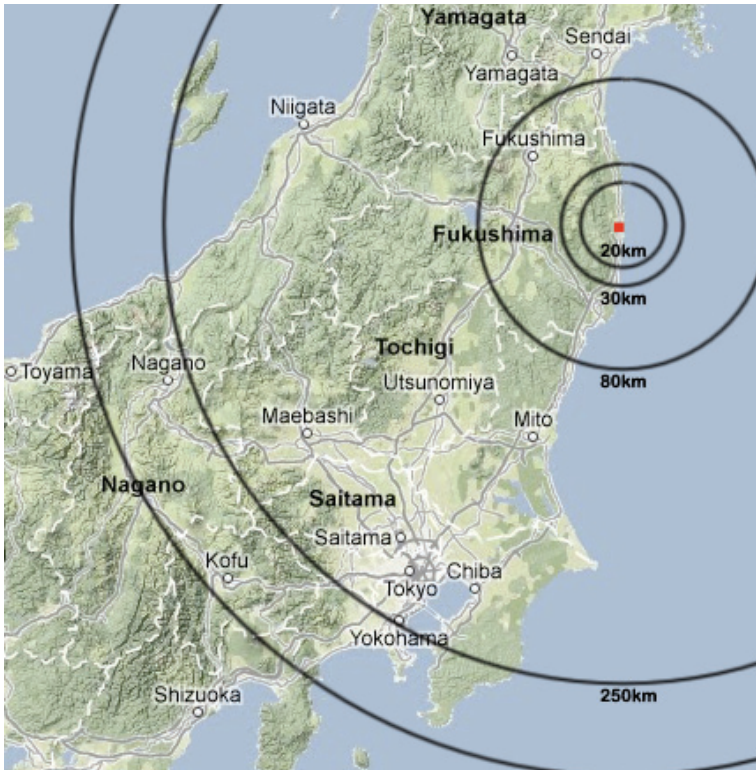


FIGURE 9 Map of Radiation Spread Showing 250 km Radius Covering Tokyo  
*Source:* Adapted from Google Maps.

ship. However, the establishment of joint headquarters was later considered a critical turning point in management of the disaster.<sup>46</sup>

At the TEPCO headquarters, Kan saw for the first time that there were video feeds from the Dai-Ichi plant emergency headquarters. Once Hosono and some of his staff were established in TEPCO's headquarters, they were

46 Ibid., 129–30; “Fukushima Report.”

able to communicate far more effectively with the prime minister's office, rather than waiting for TEPCO to relay information from the ground operations.

During Kan's visit, just after 6:30 a.m., a large explosion sound emanated from Reactor 2. It later became apparent that hydrogen gas from Reactor 2 had leaked into Reactor 4 through a shared (and likely damaged) venting pipe. There it accumulated in the Reactor 4 building, and when it ignited, the explosion blew off the roof and much of the walls. The sound of the explosion traveled back through the pipes and reverberated through the Reactor 2 building. Yoshida sought permission to leave 70 critical operations staff for water injections and take the rest of the approximately 650 staff to Fukushima Dai-Ichi plant to stage operations from there. Kan observed and interacted with the TEPCO chairman and president during the exchange, as much of plant manager Yoshida's staff were evacuated to the Dai-Ni plant. All the while Kan continued to forcefully demand that some TEPCO staff remain at the Dai-Ichi plant to continue water injections. He was at TEPCO headquarters for approximately three hours, until 8:45 a.m.<sup>47</sup>

At 11:00 a.m., Kan expanded the evacuation radius to 30 km.

### Reactor Pools: The Other Serious Danger

Kan's forceful rejection of TEPCO's apparent request to abandon the Dai-Ichi plant was a response to potentially critical problems with the reactors undergoing routine maintenance at the time of the disaster—in particular Reactor 4, located right next to Reactors 1–3. (See Figure 4)

The fuel rods of Reactor 4 had been taken out of the reactor and placed in storage pools. The fuel rods still required cooling – at least several tons of water per hour to avoid additional nuclear catastrophe. The storage pools of these fuel rods, numbering in the thousands, were at the top of the reactor buildings.

Although the explosion that rocked the Dai-Ichi plant at 6:00 a.m. on March 15 was not from the “live” Reactor 2, but actually the building of the stopped Reactor 4, in some ways, this was worse. The used fuel pool had 1535 fuel assemblies (of which 204 were actually unused), each with a dozen fuel rods. Since the pumps had stopped, the temperature of the pool had risen from 40 degrees Celsius to 84 degrees. *Unlike the nuclear reactor cores, which were inside multiple layers of containment vessels, the storage pools were unprotected.* Once the hydrogen explosion blew off the roof and much of the walls, the pool itself was exposed directly to the outside. This

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<sup>47</sup> *Meltdown, 131–33; Prometheus.*



FIGURE 10 Reactor 4 Explosion Aftermath (Reactor 4 in Center, Reactor 3 on Left)

*Source:* TEPCO (picture taken some days after explosion).

could speed up the evaporation of water in the pools, which could then lead to various terrifying scenarios; if a meltdown began, the fuel rods could burn through the bottom of the containment pools, falling all over inside the reactor building. Radiation would be so strong that cleanup and cooling activities would be highly problematic, and a vast area would need to be evacuated, jeopardizing operations at the Fukushima Dai-Ni plant as well. Without sufficient protection from radiation in the operations centers, let alone near the reactor buildings, on-the-ground efforts to pump water into the reactors in both Fukushima plants would have been critically hindered; therefore, the possibility of uncontrolled reactions was a real possibility.

With the roof and walls severely damaged from the hydrogen explosion, a strong aftershock could potentially bring the entire water pool, with its fuel rods, tumbling down into the reactor building. This was not a far-fetched scenario by any means. On March 12, a day after the 9.0 earthquake and three days before Reactor 4's roof and walls blew off, a magnitude 6.6 after-

shock, centered in northern Niigata, occurred—a major earthquake when compared to almost any quake other than the March 11 quake. Moreover, the heavy lids of the containment vessel and the equipment used to move it were all stored in the upper parts of the reactor building 4, making it further vulnerable to structural collapse. (See Figure 10)

The U.S. government was highly concerned about the vulnerability of these used fuel pools. It feared that the bottom of the pool in Reactor 4 had already given out, with exposed nuclear rods falling around the building. The U.S. embassy recommended evacuation of U.S. citizens living within a 50 mile (80.5 km) range, and Japan's stock market plunged as soon as news of the explosion at Reactor 4 was announced.

Indeed, internal worst case scenarios within the prime minister's office suggested the possibility of an evacuation radius of 250 to 300 km. This included the entire Tokyo Metropolitan area.<sup>48</sup> In interviews and Diet testimonies months later, Kan stated that his concern was that Japan as a country might not survive the accident if Tokyo had to be evacuated.

### Emergency Mobilization to Cool Used Fuel Pools

A positive turning point in the disaster came on March 17, almost 6 days after the earthquake and tsunami hit. The previous day, a SDF helicopter with TEPCO employees on board confirmed visually and through photographs that Reactor 4's used fuel pool contained water, and that the fuel rods were not exposed. On the morning of the seventeenth, another SDF helicopter, reinforced with tungsten on its lower side to mitigate radiation, flew over the reactor and dumped a large bucket of water onto Reactor 3, which was issuing white steam. Although the amount of water was miniscule in comparison to what was needed even in the short-medium term—and disheartening television broadcasts seemed to show that some of the first buckets missed almost entirely—it was the first indication that the government was finally able to take some tangible measures to manage the disaster.

More importantly, on the evening of the seventeenth, a number of SDF fire trucks equipped for aircraft catastrophe grade fire extinguishers were collected from SDF land and air forces. At 7:35 p.m., they began dousing Reactor 3 with water, taking turns for five dousings. The following day, they moved in even closer, hitting Reactor 3, and expanding to cover Reactor 4 from the twentieth.<sup>49</sup> Coordination between SDF, the Fire and Disaster Management Agency, and National Policy Agency was necessary for these

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48 "Fukushima Report."

49 Oshika, *Meltdown*, 145.

actions, and the government succeeded in bringing them together.<sup>50</sup>

On March 20, power from the electricity grid to the Fukushima Dai-Ichi plant was finally restored. However, to the shock and dismay of all involved, the cooling systems did not restart. Monitoring instruments were unstable, and the motor to pump water to the used fuel pools did not work.<sup>51</sup>



FIGURE 11 “Kirin” Injecting Water into Reactor 4, March 22, 2011  
*Source:* TEPCO ([http://www.tepco.co.jp/en/nu/fukushima-np/review/review1\\_2-e.html](http://www.tepco.co.jp/en/nu/fukushima-np/review/review1_2-e.html)).

Luckily, further reinforcements for the manual hosing of the reactors and storage pools were on the way. A large concrete pump truck called “Kirin” (giraffe) was deployed on March 22. In an incredible (but in this case, positive) coincidence, it was passing through Yokohama port on route to Vietnam, from Germany; all parties agreed to divert it to Fukushima (See Figure 11). Two other large concrete pumps, with cameras on top, also arrived from other parts of Japan, pumping water into the 30-meter-high fuel pools. On March 23, a pump truck with an arm reaching 63 meters high arrived from China, as a gift to TEPCO. Just after that, the world’s tallest pump truck with arm reaching 70 meters arrived from the United States.

<sup>50</sup> “Fukushima Report.”

<sup>51</sup> *Meltdown*, 152.



These measures were used until March 24, when the cooling pumps became operational.<sup>52</sup> On April 11, the government announced a 20 km radius for emergency and planned evacuation areas.

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TABLE I

Simplified Timeline of Events in the Fukushima Dai-Ichi Disaster

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|                |  |
|----------------|--|
| March 11, 2011 |  |
| 2:46 p.m.      | 9.0 earthquake occurs  |
| 2:47           | All reactors lose external power   |
| 3:27           | Tsunami first wave hits  |
| 3:35           | Tsunami second wave hits   |
| 3:37           | Reactors 1, 2, 3 all lose power completely   |
| 3:42           | Nuclear emergency report (Article 10—complete loss of power)   |
| 4:36           | Nuclear emergency report (Article 15—emergency cooling inoperative)<br>Prime minister’s office establishes nuclear plant disaster headquarters |
| 4:40           | Reactor 1 core meltdown begins (estimated)   |
| 6:00           | Reactor 1 core damaged (estimated)   |
| 7:03           | Nuclear emergency declared   |
| 8:00           | Reactor 1 pressure containment vessel damaged (estimated)  |
| 8:49           | Backup lights restored to operations centers of Reactors 1 and 2   |
| 8:50           | Evacuation order for 2 km radius around Fukushima Dai-Ichi   |
| 9:23           | Evacuation area expanded to 3 km radius, 3–10 km ordered to remain indoors   |
| 9:51           | Radiation levels of Reactor 1 building rising  |
| March 12       |  |
| 12:06 a.m.     | Pressure levels of Reactor 1 containment vessel rising. Plant manager Yoshida orders venting   |
| 1:30           | Prime Minister Kan agrees to vent Reactors 1 and 2   |
| 3:12           | Chief Cabinet Secretary Edano announces venting to press   |
| 3:59           | Major aftershock of 6.6 centered in northern Nagano Prefecture   |
| 5:44           | Prime Minister Kan issues 10 km radius evacuation order  |
| 5:46           | Fire truck begins injection of foam water  |

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52 “Fukushima Report,” 88.

|            |  |
|------------|--|
| 6:60       | METI Minister Kaieda orders TEPCO to vent  |
| 7:12       | Prime Minister Kan arrives in Fukushima Dai-Ichi   |
| 8:03       | Yoshida orders vent procedure to aim for 9:00 a.m.   |
| 8:05       | Prime Minister Kan departs Fukushima Dai-Ichi  |
| 9:15       | First group opens vent of Reactor 1 25 percent   |
| 9:30       | Second group turns back due to high radiation  |
| 10:00      | TEPCO President arrives at headquarters  |
| 11:36      | Reactor 3 Cooling system stops   |
| 2:30 p.m.  | Reactor 1 vessel pressure decreases, judged to be successful venting. Radiation leaked.        |
| 3:30       | Power truck successfully connected to benzene pump   |
| 3:35       | Hydrogen explosion in Reactor 1 building   |
| 4:27       | Emergency alarm from radiation rise, 1015 msv per hour recorded                                |
| 6:25       | Prime Minister Kan orders 20 km radius evacuation  |
| 7:04       | Fire truck injects sea water into Reactor 1  |
| 7:55       | Prime Minister Kan orders sea water injection  |
| March 13   |  |
| 2:42 a.m.  | Reactor 3 high pressure coolant injector stops   |
| 5:10       | Reactor 3 Nuclear emergency report (Article 15—emergency cooling inoperative)                  |
| 7:40       | Reactor 3 core exposed (estimated)   |
| 8:35       | Reactor 3 manually vented  |
| 9:24       | TEPCO determined Reactor 3 vented  |
| 10:20      | Reactor 3 core damaged (estimated)   |
| 1:12 p.m.  | Fire truck begins injecting sea water into Reactor 3   |
| 10:10      | Reactor 3 pressure containment vessel damaged (estimated)                                      |
| March 14   |  |
| 11:01 a.m. | Reactor 3 experiences hydrogen explosion<br>Damages Reactor 2 venting circuitry, closes valves |
| 12:30      | Reactor 2 pressure and temperature rises recorded  |
| 1:25 p.m.  | Reactor 2 Nuclear emergency report (Article 15—emergency cooling inoperative)                  |
| 6:00       | Reactor 2 core exposed (estimated)   |
| 8:50       | Reactor 2 internal pressure exceeds maximum specs  |

March 15

- 3:00 a.m. METI Minister Kaieda reports to Prime Minister Kan that TEPCO wants to evacuate
- 4:17 TEPCO President Shimizu visits prime minister's office
- 5:26 Government-TEPCO accident response joint headquarters announced
- 5:35 Kan arrives at TEPCO headquarters
- 7:00 Reactor 4 building explodes  
TEPCO employees other than direct operations crew evacuate to Dai-Ni
- 8:46 Kan returns to prime minister's residence
- 11:00 Kan issues evacuation order for 20–30 km radius
- 4:45 p.m. U.S. Secretary of State Hillary Clinton states that if accident had occurred in the United States, evacuation zone radius would be 50 miles (80.5 km)

March 16

Fire in building 4. Reactor 3 emits white steam/smoke

March 17

SDF helicopters and fire trucks begin dousing Reactor 3 with water

TABLE 2  
Selected Primary Actors in the Fukushima Disaster Narrative

| Name (surname first) | Position (at the time)   |
|----------------------|--|
| Kan Naoto            | Prime Minister (June 2010 – Sept. 2011)                          |
| Kaieda Banri         | METI Minister  |
| Edano Yukio          | Chief Cabinet Secretary  |
| Hosono Goshi         | DPJ Member, Prime Minister’s Aide                                |
| Terada Manabu        | DPJ Member, Prime Minister’s Aide                                |
| Katsumata Tsunehisa  | TEPCO Chairman   |
| Shimizu Masataka     | TEPCO President  |
| Yoshida Masao        | TEPCO Fukushima Nuclear plant manager                            |
| Takekuro Ichiro      | TEPCO “Fellow” (former VP of nuclear division)                   |
| Madarame Haruki      | Nuclear Safety Commission (NSC), Chairman                        |
| Terasaka Nobuaki     | Nuclear and Industrial Safety Agency (NISA),<br>Director-General |

# UNPACKING THE DISASTER

Having reviewed the unfolding disaster as narrative, let us now take a step back and analyze two sets of issues in the critical juncture: *immediate disaster response (Crisis) issues* and *longer-term factors contributing to the disaster (Non-Crisis)*. The two are, of course, inter-related.

The main **Crisis** issues can be separated into:

- *Uncertainty about the Locus of Decision Making*: who was responsible for which decisions at what juncture.
- *Failure of Information Flows* linking the disaster site to headquarters, and to the centers of expertise.

Major **Non-Crisis** issues include:

- *Regulatory Capture* by power companies, the so-called nuclear “village” problem.
- *Design Problems and Policy* regarding nuclear reactors that led to aged facilities.
- *The “Mythology of Safety”* that nuclear operators, in conjunction with the government, advocated and embraced, constraining their actions.

Concepts such as the governance structure—how the regulatory organizations should be configured, the relationships between them, and the relationships between government and industry—all fit within the conceptualization above. The fast-moving crisis revealed multiple problems not apparent during normal times, and the crisis itself brought dormant and deep seated structural issues into sharp relief.

## The Crisis: Uncertainty over the Locus of Decision Making

The immediate problem facing Japan as the nuclear crisis began was uncertainty over the locus of decision making.<sup>53</sup>

The *legal framework* stipulates that during an emergency, the nuclear operator will take primary responsibility for actions, with oversight by the

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53 Masahiko Aoki and Geoffrey Rothwell, “A Comparative Industrial Organization Analysis of the Fukushima Nuclear Disaster: Lessons and Policy Implications,” (Stanford University, 2012).

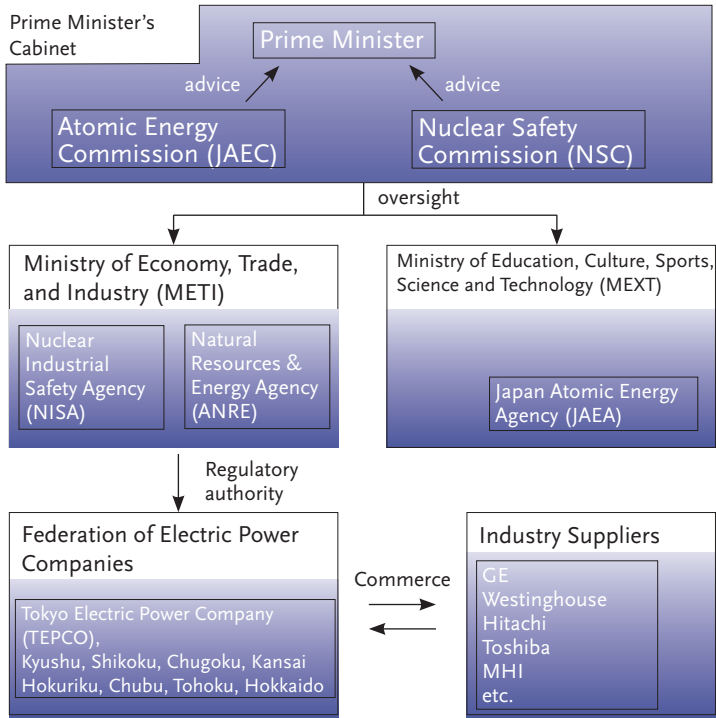


FIGURE 12 Organizational Chart of Japan's Nuclear Governance, March 2011  
 Source: Author.

prime minister's office.<sup>54</sup> However, Prime Minister Kan took an unusually active role, well beyond oversight. Contributing factors to his active role included Kan's personal management style, his lack of trust in TEPCO, the lack of reliable (in his perception, at least) official advisors, and the lack of reassurance from TEPCO's top management (who were absent).

Not all of Kan's involvement was necessarily productive. Later evaluations note that despite his dispatch of forty SDF power trucks, the power truck that eventually worked was one of TEPCO's. Despite his order and repeated pressuring of TEPCO to proceed with venting, TEPCO proceeded at its own pace, beginning the procedure eight hours after Kan's order. Kan's visit to the Fukushima Dai-Ichi plant on the morning of March 12 was criticized as distracting the ground crew, and in particular, plant manager Yoshida, from critical tasks on the ground.

That being said, Kan was reacting to the decided lack of perceived leadership by TEPCO's top management—whom he did not know were not pres-

54 For technical legal details, see "Interim Report."

ent during the first day. The prime minister was also frustrated by recurring evidence that advisors legally stipulated to aid him during a nuclear emergency were handicapped by severe problems in communication and information, rendering them much less helpful than he might have hoped. Yet Kan did play a critical role in overcoming information and coordination problems that had plagued the government's efforts early on in the disaster. His establishment of a joint headquarters within TEPCO, though lacking a concrete legal basis (until later justified), created flows of live information—and was later highly commended as effective. Moreover, the coordination provided by the prime minister's office was critical in enabling the SDF, Police agency, and Fire and Disaster Management Agency to effectively coordinate in cooling the reactors until power was restored.<sup>55</sup> Given how events unfolded, with great confusion of information—it seems irrational to blame Kan excessively for his active crisis management efforts, stemming from his deep mistrust of TEPCO. More fundamentally, the various ad hoc measures were clearly a response to the severe governance and oversight problems during the crisis itself.

*The governance structure within TEPCO* itself has been identified as a problem. Within the company, the nuclear power division was relatively autonomous, with a center of expertise concentrated within that division.<sup>56</sup> It is unclear the degree to which TEPCO's fourteen hour delay in venting the plant after Yoshida's decision was due to the absence of top leadership, since devastation on the ground certainly created operational challenges. However, it seems unlikely that the procedure should have taken fourteen hours. Yoshida's decision was made around midnight of March 11, and TEPCO's chairman and president did not arrive at TEPCO headquarters until mid-morning the following day, about ten hours later. The venting occurred in early afternoon. Venting had serious ramifications for the company; releasing radioactive material directly into the atmosphere would not only ruin its reputation, but incur uncertain although major costs. It derailed TEPCO's core nuclear energy business and threatened to undermine Japan's entire Long Term energy plan, calling for expansion of nuclear power from thirty percent to fifty-five percent. It is not clear that Yoshida on his own had the authority to execute the venting procedure before getting approval from headquarters.

Arguably a more serious issue was whether TEPCO's immediate response should have been to inject seawater into the reactors at the first op-

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55 "Fukushima Report"; Oshika, *Meltdown*.

56 Aoki and Rothwell, "A Comparative Industrial Organization Analysis of the Fukushima Nuclear Disaster: Lessons and Policy Implications."; Oshika, *Meltdown*.

portunity, rather than focusing on restoration of the emergency cooling systems, which could only provide temporary relief. An injection of seawater catastrophically damages the reactors, which were highly valuable assets. Such actions would decisively undermine the myth of nuclear safety upon which Japan's nuclear energy rested. We will return to this topic in the next section, but whether Yoshida acting independently should have had not only the autonomy, but the procedural authority to immediately attempt to inject seawater is a major issue.

Japan's governance structure of nuclear power, and channels of information and coordination between various advisory organizations, became dysfunctional during the crisis. Japan's formal governance structure over nuclear energy is shown in Figure 3.

The Nuclear Safety Commission (NSC) and Atomic Energy Commission (JAEC) are located within the Cabinet, advising the prime minister. Of these two, the NSC is responsible during nuclear disasters. (JEAC advises on broader policy issues and strategies.) NISA was located within METI, with direct oversight of the electric power companies. The Japan Atomic Energy Agency (JAEA) focuses on technical research, and is under the jurisdiction of the Ministry of Education, Tourism, Sports, Science and Technology (MEXT). Industry suppliers construct the actual nuclear facilities, as contracted by the electric power companies.

During the emergency, Kan quickly found that the NSC and NISA, who were supposed to advise him from the Nuclear Emergency Headquarters (NEA), the establishment of which was triggered by declaration of a nuclear incident as faxed by Yoshida in the immediate aftermath of the tsunami, were not useful in providing live information or expertise. The joint headquarters that Kan later established within TEPCO essentially bypassed the NSC and METI/NISA, connecting the prime minister's emergency headquarters directly with TEPCO headquarters. In Figure 2, this would be represented by an arrow linking the prime minister's office directly with TEPCO. Next we turn to why NSC and NISA were unable to provide useful guidance and information.

### **The Crisis: Information, Communications, and Expertise**

Information, communications, and expertise problems led to NISA and NSC not functioning as the valuable advising organizations during the time of crisis.

One of NISA's weaknesses was that officials were not nuclear specialists, but rather METI bureaucrats who rotated through the agency every



few years. They tended to be University of Tokyo economics or law majors. In the opening hours of the crisis, NISA's top executive, director-general Terasaka Nobuaki was at Kan's side, informing him that the electricity had failed, and cooling was impossible at the Fukushima Dai-Ichi plant. Kan reportedly asked Terasaka if he was a nuclear specialist, to which Terasaka replied that he was an economics major at the University of Tokyo. In fact, before becoming NISA's director-general in 2009, he had been director-general for METI's commerce and distribution policy. Kan repeatedly dismissed the NISA advisors dispatched to him, questioning their background and forcefully pointing out that they had little operational knowledge of the nuclear power plants, let alone live information from the site of the disaster, and that they relied on secondhand reports from TEPCO.

The NISA spokesmen that appeared in public press conferences on live television during the first few days of the crisis did little to allay the fear felt by the public upon hearing that a nuclear emergency was underway. Most were clearly not specialists, and the public was given the strong impression that the government was literally in over their heads, with no one aware of exactly what was happening. And worse yet, analysts quickly pointed out that NISA officials were clearly not specialists.

To advise the prime minister, Terasaka ended up making an emergency joint appointment for an official with a nuclear engineering background who had been assigned to The Natural Resources & Energy Agency (ANRE), also within METI. In short, NISA had to procure somebody from outside its organization to find an official with a suitable technical background to satisfy the prime minister.<sup>57</sup>

Physical communication problems played some role in hindering the NSC from giving adequate or accurate advice, contributing to Prime Minister Kan's decision to bypass the organization. The basement emergency headquarters in the prime minister's residence had no cellular reception, so Madarame, though a nuclear expert, could only guess at what was happening based on the information available to him—largely through the media—concerning the hydrogen explosions. Madarame had advised Kan during the helicopter ride to the Dai-Ichi plant on the morning of the fourteenth that a hydrogen explosion was not possible. They were in the emergency headquarters together when an aide rushed in to inform them to change the channel of the television in the room, which had just begun showing a long-range shot of a reactor building in the Fukushima Dai-Ichi plant blowing up. Madarame reportedly held his head in his hands, while Kan shouted

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<sup>57</sup> Kimura, "Kanei no itsuka kan [5 Days in the Prime Minister's Residence]," 217–21.

something along the lines of “You told me there would be no explosion!”<sup>58</sup> Put simply, NSC (and NISA) first learned about the explosion on television, and were unsure until later that it was a hydrogen explosion.

The lack of information available to NSC was partly due to inadequate emergency plans within the government. The plans did not anticipate the importance of cellular communications and the physical need for space equipped with sufficient information technology and telecommunications access for advisory organizations. Within the prime minister’s residence, the underground emergency headquarters’ lack of cellular reception hindered operations and coordination. While operating from the basement, NISA and TEPCO representatives, for example, could not get updates directly from their own organizations in advising Kan. The Nuclear Emergency Headquarters, set up in accordance with the Nuclear Emergency Preparation Law, was established in a small room in the mezzanine above the prime minister’s basement emergency headquarters. The location was chosen for easy access to the emergency headquarters, but the space turned out to have only two phone lines, no fax (until one was installed two days later), and no cellular reception.<sup>59</sup>

This nuclear emergency headquarters was also used by NSC. However, in the late afternoon and evening, NSC chairman Madarame found to his amazement that there were no diagrams of the Fukushima Dai-Ichi plant available. NISA, rather than NSC, possessed the diagrams, and for whatever reason, the diagrams were not as yet in the emergency headquarters. Given the various types of reactors and configurations, Madarame, in advising the prime minister, only had his memory of the Fukushima Dai-Ichi plant and the television to go by.<sup>60</sup>

By the next day Kan had moved his emergency headquarters to his office on the fifth floor, as did the nuclear emergency team. Here there was adequate cellular phone reception. However, the communication problem then became the necessity for aides to transfer to the fifth floor any land line calls arriving to the emergency headquarters. Faxes needed to be hand-delivered. Information from computer simulations of radiation spread, which showed a radiation contamination area quite different from the concentric circles that the government declared for evacuation, seem to have been lost in this transfer process.

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58 Ibid.; *Prometheus*.

59 “Kanei no itsuka kan [5 Days in the Prime Minister’s Residence],” 223–25; “Interim Report.”

60 “Kanei no itsuka kan [5 Days in the Prime Minister’s Residence],” 223–25.

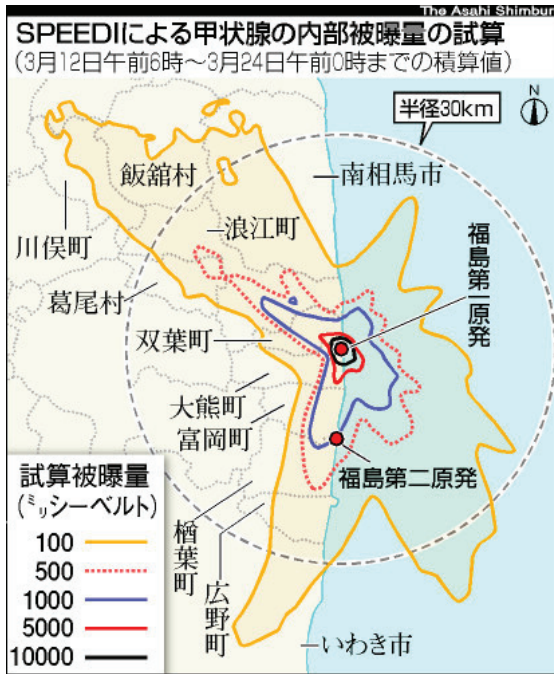


FIGURE 13 SPEEDI Simulations (March 12–24) Showing 30 km Evacuation Radius  
 Source: MEXT.

The issue was that two new simulations of venting the reactor buildings were conducted on SPEEDI (System for Prediction of Environmental Emergency) at about 1:00 a.m. on March 12, about ten hours after the disaster. The simulations take into account the predicted wind and weather patterns for the next six hours, and they clearly showed a spread of radiation in a northwesterly direction. These simulations were sent from NISA to the prime minister’s basement office, but they never made it up to the fifth floor. Kan and his executive team never saw them, and TEPCO’s evacuation map, drawn in concentric circles (and expanded from 20 km to 30 km with astonishing ease at the prime minister’s suggestion) were insufficient in their coverage of areas northwest of the Dai-Ichi plant. (See Figure 12 for contrast between actual radiation spread and evacuation circles.)<sup>61</sup>

Overall, forty-five simulations were conducted between March 11 and March 16, but Kan and his political leader staff were unaware of SPEEDI’s existence, let alone its simulation results.

61 Oshika, *Meltdown*, 74.

Jurisdictional confusion also apparently led to the SPEEDI simulation results not becoming public until weeks after the disaster. MEXT pointed to the local Nuclear Emergency Response Headquarters (NERHQ) as having responsibility to publicize all relevant information to the public, since this is how it interpreted the government's Nuclear Emergency Response Manual's stipulation that the local NERHQ take responsibility for general public information announcements about nuclear emergency measures. However, although the local NERHQ lost functionality due to the devastation and communications network failures, NERHQ and NISA, which are the higher-level organizations, did not automatically take up the responsibility. That they should do so was not stipulated in the handbook, but as the interim report commissioned by the Cabinet notes dryly, "it did not occur to either of these organizations to provide SPEEDI information to the public."<sup>62</sup> Others accuse the government of deliberately concealing the information until it was later revealed by a news magazine.<sup>63</sup>

Information about the plant itself at the *ground level*, such as the location and technical know-how to operate the facilities, was held by subcontractors rather than the power company, TEPCO. Once most contractors evacuated, TEPCO employees were consequently left without sufficient working knowledge of the plant.

The plant manager, in this case Yoshida, was in charge of on-the-ground operations. Yet, it is unclear how much autonomy he had in major decisions, such as to proceed with venting. In extreme cases, such as with the sea water injections, he disobeyed TEPCO headquarters' orders on his own volition to help save the plant. Aoki and Rothwell contend that decision making should be modularized at the plant level, with authority in the plant manager's hands, for swift and critical decision making.<sup>64</sup>

### *Contingency Plans*

TEPCO's own contingency plans, as well as the government's contingency plans for a nuclear disaster, were, in hindsight, woefully inadequate. We only need to extract a partial list from the narrative above.

Other than the obvious but catastrophic design failures of the Fukushima Dai-Ichi plant, the government nuclear emergency plans did not take into account the possibility of *major transportation and communications problems occurring simultaneously with a nuclear disaster*. This reveals the logic

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<sup>62</sup> "Interim Report." 579.

<sup>63</sup> *Meltdown*.

<sup>64</sup> Aoki and Rothwell, "A Comparative Industrial Organization Analysis of the Fukushima Nuclear Disaster: Lessons and Policy Implications."

that earthquakes were considered an improbable (to the point of virtually impossible) source of nuclear catastrophe—a result of the “mythology of safety” discussed later. The inability of TEPCO’s president and chairman to return to headquarters, compounded by mistakes within the SDF, should have been addressed by contingency plans. While critical decision making such as seawater injections and venting may be best left to the plant operator, leadership at the helm of the company should be necessary. Since the SDF was willing to coordinate in returning the TEPCO president on an ad hoc basis, such plans are probably best included in the contingency planning stages.

### *Radiation Emissions Estimates*

Public confusion and mistrust of the government (and TEPCO), were compounded by conflicting announcements about radiation emissions, which varied between the government and TEPCO. TEPCO announced on May 24, 2012, fourteen months after the disaster, that it estimated the amount of radiation released as 900,000 tera becquerels (Tbq)—one-sixth of the Chernobyl accident. In April 2011, a year earlier and a month after the disaster, NISA had announced an estimate of 370,000 Tbq. It then increased the estimate to 770,000 Tbq in June. But eight months later, in February 2012, it decreased its estimate to 480,000 Tbq. JAEA also published the same number the following month.<sup>65</sup> The public increasingly turned to non-governmental organizations that began publishing user-collected data in detailed maps.

### **Regulatory Capture: The Nuclear “Village”**

The fundamental structural problems underlying Japan’s nuclear governance lie in two areas: the concentration of funding and expertise supporting the power industry, and the lack of separation between industry promotion and safety regulation within the government. This has led to a situation of *regulatory capture*, in which regulators/lawmakers and the regulated firms develop mutually beneficial relationships that do not serve the public interest, safety, or economy.

Known as the Nuclear “village” (*mura*), Japan’s power industry is well known for spreading its influence through political, economic, and academic interest groups. We will review the structure of Japan’s power industry in the next section, but the relevant point here is that Japan’s power companies

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65 “Fukushima jiko no houshasei bushitsu, cherunobuiri no roku bun no ichi, seifu suitei no 2 bai [Radioactive material from the Fukushima accident, one sixth of Chernobyl, twice the government’s estimate],” *Nihon Keizai Shimbun*, May 25 2012.

are regulated in a way that guarantees profit. They are allowed to charge customers price levels that exceed total costs by a particular percentage point. As a result, the industry enjoys an extreme concentration of financial resources that fund not only suppliers, but a wide range of activities.

Politicians from both major parties, DPJ and LDP, receive donations from power operators. The TEPCO labor union, among the largest by far, has long been a supporter of the DPJ. The power companies channel massive advertisement fees to mass media, resulting in media reluctant to overtly criticize their benefactors. Power companies also make broad, generous donations to researchers whose work is related to such companies, making those researchers relatively sympathetic to their causes. Post-retirement positions from the government to power companies and nuclear-related foundations is extensive and pervasive. Moreover, personnel from power companies are sent to the government and foundations to support their operations. Power companies also provide direct support, as well as support for government programs and foundations to educate children about the merits of nuclear power. Power companies also make extensive donations, supported by extensive government contributions and support to local communities, to sway their opinions in favor of receiving nuclear power plants.<sup>66</sup> Power companies often donate to localities' cultural facilities and infrastructure.<sup>67</sup>

In sum, the vast financial resources available to power companies enable them to capture policy, shape public opinion, and pressure potential dissent into silence. Only with the nuclear accident did many of these interests split from those of the nuclear power industry—although funding flows continue. In hindsight, the design failures and unheeded warnings about the Fukushima Dai-Ichi plant were influenced by this regulatory capture.

### Design Failures, Unheeded Warnings, and Policy

In hindsight of any disaster, it is almost too easy to point fingers to obvious design failures and information not acted upon. In the case of the Fukushima disasters, the list is long.<sup>68</sup>

To begin with, one could cite *insufficient tsunami preparation parameters and plant design that assumed limited interruptions in external power, and the integrity of backup on-site power sources in the event of external power failures*. Neither vulnerability went unnoticed, but both were rejected

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66 For details, see Daniel P. Aldrich, *Site fights : divisive facilities and civil society in Japan and the West* (Ithaca: Cornell University Press, 2008).

67 "Fukushima Report."

68 Here we focus on the Fukushima nuclear disasters—there is plenty of criticism for tsunami warning systems, and evacuation procedures, beyond the scope of this paper.

as candidates warranting immediate corrective action.

In 2008, an internal TEPCO simulation pointed out that a tsunami of 15.7 meters would critically devastate the Fukushima Dai-Ichi plant. The simulation was conducted after historical research showed that in the year 869, a major earthquake of magnitude 8.4 had occurred in a similar region, triggering a major tsunami that, even 3 kilometers inland, was 3 meters high. Documents from that time cite casualties at over 1000 people in a population of seven million—roughly the same proportion as the 20,000 casualties in a population of 127 million in the March 2011 disaster. An earthquake of 8.4 was six times the strength of TEPCO’s maximum parameter of 7.9.<sup>69</sup> Recent geo-physical research indicated that earthquakes of greater than magnitude 8.0 triggering tsunamis have occurred six times in the Tohoku region over the past 6000 years.<sup>70</sup>

NISA and NSC had actually been asked point blank about the possibility of the plant losing all external and internal power. In 2010, in a Diet meeting of a METI committee, a Japan Communist Party Diet member asked Terasaka, head of NISA, what they would do at a nuclear power plant if the external power lines were destroyed and diesel backup generations became unusable. Terasaka’s answer was that plants were designed with safety in mind to the point that such an occurrence was almost impossible. In 2007, NSC chair Madarame, still a Tokyo University professor at the time, was asked as a witness in court what would happen if the diesel backup generator would not start. His answer was that such an event was beyond their assumption of possible outcomes.<sup>71</sup> The NSC had actually brought up the issue of losing power at nuclear plants in a working group in 1993. However, the issue was not pursued in the final report.<sup>72</sup>

### *Age of the Plant*

Some of the design problems stemmed from the age of the Fukushima Dai-Ichi power plants. It was one of the oldest in operation, at forty years. Table 3 shows all of Japan’s nuclear reactors, their starting date, the power company in charge, and the company that built the plant. Note here the start dates, the size, and the builders. We see clearly that Fukushima Dai-Ichi Reactor 1 was one of the oldest and smallest capacity reactors. The table also clearly shows the outcome of Japan’s industrial policy to foster domes-

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69 Oshika, *Meltdown*, 31–32; Kimura, “Kanei no itsuka kan [5 Days in the Prime Minister’s Residence].”

70 Aoki and Rothwell, “A Comparative Industrial Organization Analysis of the Fukushima Nuclear Disaster: Lessons and Policy Implications.”

71 Quotes based on Diet deliberation minutes. Oshika, *Meltdown*, 47–48.

72 *Ibid.*

tic firms—all early reactors were built by foreign firms, with newer reactors, often within the same plant, built by Japanese companies. We will return to this latter aspect of industrial policy later.

Table 3 shows the decommissioned reactors. Their capacities were smaller than most commercial reactors in use by 2010, and half were operated by the government. Many were newer than Fukushima Dai-Ichi Reactor 1.



TABLE 3

Japan's Active Nuclear Reactors (including maintenance shut-downs), 2010

| Plant Name         | # | Capacity (Mwe) | Operator | Operation Commenced | Reactor Supplier                  |
|--------------------|---|----------------|----------|---------------------|-----------------------------------|
| Fukushima Dai-Ichi | 1 | 439            | TEPCO    | 1971                | GE                                |
|                    | 2 | 760            |          | 1974                | GE                                |
|                    | 3 | 760            |          | 1976                | Toshiba                           |
|                    | 4 | 760            |          | 1978                | Hitachi                           |
|                    | 5 | 760            |          | 1978                | Toshiba                           |
|                    | 6 | 1067           |          | 1979                | GE                                |
| Fushikuma Dai-Ni   | 1 | 1067           | TEPCO    | 1982                | Toshiba                           |
|                    | 2 | 1067           |          | 1984                | Hitachi                           |
|                    | 3 | 1067           |          | 1985                | Toshiba                           |
|                    | 4 | 1067           |          | 1987                | Hitachi                           |
| Genkai             | 1 | 529            | Kyushu   | 1975                | Mitsubishi Heavy Industries (MHI) |
|                    | 2 | 529            |          | 1981                | MHI                               |
|                    | 3 | 1127           |          | 1994                | MHI                               |
|                    | 4 | 1127           |          | 1997                | MHI                               |
| Hamaoka            | 3 | 1056           | Chubu    | 1987                | Toshiba                           |
|                    | 4 | 1092           |          | 1993                | Toshiba                           |
|                    | 5 | 1325           |          | 2005                | Toshiba                           |
| Higashi Dori       | 1 | 1067           | Tohoku   | 2005                | Toshiba                           |
| Itaka              | 1 | 538            | Shikoku  | 1977                | MHI                               |
|                    | 2 | 538            |          | 1982                | MHI                               |
|                    | 3 | 846            |          | 1994                | MHI                               |
| Kashiwazaki Kariwa | 1 | 1067           | TEPCO    | 1985                | Toshiba                           |
|                    | 2 | 1067           |          | 1990                | Toshiba                           |
|                    | 3 | 1067           |          | 1993                | Toshiba                           |
|                    | 4 | 1067           |          | 1994                | Hitachi                           |
|                    | 5 | 1067           |          | 1990                | Hitachi                           |
|                    | 6 | 1315           |          | 1996                | Toshiba                           |
|                    | 7 | 1315           |          | 1997                | Hitachi                           |
| Mihama             | 1 | 320            | KEPCO    | 1970                | Westinghouse                      |
|                    | 2 | 470            |          | 1971                | Westinghouse                      |
|                    | 3 | 780            |          | 1976                | MHI                               |

|          |   |      |          |      |                  |
|----------|---|------|----------|------|------------------|
| Oi       | 1 | 1120 |          | 1979 | Westinghouse     |
|          | 2 | 1120 |          | 1979 | Westinghouse     |
|          | 3 | 1127 |          | 1991 | MHI              |
|          | 4 | 1127 |          | 1993 | MHI              |
| Onagawa  | 1 | 498  | Tohoku   | 1984 | Toshiba          |
|          | 2 | 796  |          | 1995 | Toshiba          |
|          | 3 | 796  |          | 2002 | Toshiba          |
| Sendai   | 1 | 846  | Kyushu   | 1984 | MHI              |
|          | 2 | 846  |          | 1985 | MHI              |
| Shika    | 1 | 505  | Hokuriku | 1993 | Hitachi          |
|          | 2 | 1304 |          | 2006 | Hitachi          |
| Shimane  | 1 | 439  | Chugoku  | 1974 | Hitachi          |
|          | 2 | 789  |          | 1989 | Hitachi          |
| Takahama | 1 | 780  | KEPCO    | 1974 | Westinghouse/MHI |
|          | 2 | 780  |          | 1975 | MHI              |
|          | 3 | 830  |          | 1985 | MHI              |
|          | 4 | 830  |          | 1985 | MHI              |
| Tokai    | 2 | 1060 | JAPCO    | 1978 | GE               |
| Tomari   | 1 | 550  | HEPCO    | 1989 | MHI              |
|          | 2 | 550  |          | 1991 | MHI              |
|          | 3 | 866  |          | 2009 | MHI              |
| Tsuruga  | 1 | 340  | JAPCO    | 1970 | GE               |
|          | 2 | 1110 |          | 1987 | MHI              |

Source: International Atomic Energy Commission [http://www-pub.iaea.org/MTCD/publications/PDF/CNPP2011\\_CD/countryprofiles/Japan/Japan2011.htm#1](http://www-pub.iaea.org/MTCD/publications/PDF/CNPP2011_CD/countryprofiles/Japan/Japan2011.htm#1).

TABLE 4  
Decommissioned Reactors, as of 2010

| Plant Name | # | Capacity (Mwe) | Operator | Operation Commenced    | Facility Retired | Reactor Supplier |
|------------|---|----------------|----------|------------------------|------------------|------------------|
| Fugen      |   | 148            | JAEA     | 1979                   | 2003             | Hitachi          |
| Hamaoka    | 1 | 515            | Chubu    | 1976                   | 2009             | Toshiba          |
|            | 2 | 806            | Chubu    | 1978                   | 2009             | Toshiba          |
| JPDR       |   | 13             | JAEA     | 1965                   | 1976             | GE               |
| Tokai      | 1 | 159            | JAPCO    | 1966                   | 1998             | GE               |
| Monju*     |   | 246            | JAEA     | Constructed<br>1986-94 |                  |                  |

Source: International Atomic Energy Commission [http://www-pub.iaea.org/MTCD/publications/PDF/CNPP2011\\_CD/countryprofiles/Japan/Japan2011.htm#1](http://www-pub.iaea.org/MTCD/publications/PDF/CNPP2011_CD/countryprofiles/Japan/Japan2011.htm#1).

\*Note: Monju was never commercialized.

Economist and nuclear expert Saito points out that the old age of nuclear reactors is not easily captured by the popular imagination, masked by the extreme complexity of nuclear reactors. He points to an analogy of Shinkansen bullet trains. Japan's first trains were in operation from 1964, roughly the same time the technology of the Fukushima nuclear reactor was developed. Since then, the bullet trains have undergone at least four major new models on the Tokaido trunk line, with numerous upgrades in between. None crashed or were damaged by the 9.0 earthquake. It is not obvious that the 1964 model trains, as well as the safety and operations systems, all developed and in continuous use since 1964, would have survived unscathed. The point is that technological and design improvements over the years can significantly enhance the performance of products or facilities when confronted with unexpected disasters.

It should also be noted that for highly complex systems such as nuclear reactors, computer processing power for running simulations is likely to enhance safety. Another dramatic example of the implications of using 40 year old technology is in the expansion of computing power. The onboard computer of the Apollo missions that landed on the moon had processing capacity similar to a simple contemporary digital watch. This was the era in which the early nuclear reactors, including Fukushima Dai-Ichi Reactor 1, were designed.

Saito points to a comparison between the Fukushima Dai-Ichi plant and the Fukushima Dai-Ni plant, roughly ten years newer. Eight kilometers to the South, the Dai-Ni plant was also pummeled by a tsunami far exceeding its design specifications. However, it was able to get external power after

the earthquake. *The emergency diesel generators were located within the nuclear reactor buildings themselves*, a far stronger location than in the Dai-Ichi plant, where they were located underneath the turbine buildings. The primary sea water intake pumps were also better protected, and Reactor 3's pump was not damaged. Therefore, despite damage to the pumps for Reactors 1, 2, and 4, they could be repaired relatively quickly. (It should be noted, though, that since the primary cooling systems for Reactors 1, 2, and 4 were unable to function, emergency cooling systems were used. These systems were insufficient to bring the reactors to a cold stop though, causing temperatures within the pressure chambers to rise. However, in the early hours of March 14, the sea water pumps motors were successfully replaced, bringing the primary systems cooling systems back online.) By the fifteenth, all reactors in the Dai-Ni plant were brought to a "cold stop," with dependable sustained cooling mechanisms in place.<sup>73</sup>

### *The Government's "Radical" Approval of Extending Plant Life*

In hindsight, since the Dai-Ichi plant's Reactor 1 in particular had such an old design, the logical question is why TEPCO had continued to use such an old reactor with a far higher risk of losing control with a strong earthquake or tsunami. Saito points to what he characterizes as a *radical* government decision to *extend reactors' lifespans from forty to up to sixty years*.

Japan's nuclear reactors were initially regulated to have a maximum lifespan of forty years. After thirty years of operation, a technical evaluation would be undertaken, which would determine whether they could operate a final ten years. However, in new policy guidelines published by NISA in 2005, following a U.S. move to extend the lifespan of its reactors meeting safety standards, Japan's reactors could apply for two additional ten-year extensions.<sup>74</sup>

The TEPCO Dai-Ichi plant Reactor 1 had just recently received approval in March 2010, just before it turned forty years old in 2011, to extend another ten years. It was preparing to apply for extensions of Reactors 2 and 3 as well. In short, by the March 11 2011 disaster, *the Fukushima Dai-Ichi Reactor 1 had transformed from an asset at the end of its useful lifespan facing imminent decommissioning, into one with up to twenty years of productive capacity*.

Saito surmises that this may have substantially delayed the decision to inject seawater to prevent overheating. At a time when TEPCO needed to

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73 Saito, *Genpatsu Kiki no Keizaigaku* [The Economics of the Nuclear Crisis], 39–40.

74 *Ibid.*, 47.

take decisive action to save the plant by destroying the reactor with seawater, it was inhibited by a cost-benefit analysis—even if it were implicit—of essentially scrapping a 100 trillion yen (1.2 trillion dollars at 1 USD=82 yen) capital asset.<sup>75</sup>

It is not clear that plant manager Yoshida himself had authority to inject seawater and thereby scrap the reactor. Given that the emergency cooling system could provide only temporary relief, Saito contends that it should have been an immediate decision to inject sea water. We now know that the top leadership of TEPCO was not present at the time, and if procedures are not in place to make decision making, the large cost-benefit calculations may have critically delayed the decision.

The cost-benefit calculation was altered by government policy, bringing into question the governance structure of nuclear oversight during non-emergency situations as well.

Somewhat incredibly, on June 6, 2012, NISA approved a ten-year extension to the forty-year-old Mihama nuclear plant Reactor 2, built in 1971. The policy of allowing extensions to the 40 year lifespan of nuclear reactors was under debate in the Diet at the time, but NISA's approval fell under the existing regulations.<sup>76</sup>

### TEPCO's "Mythology of Safety"

Power companies, supported by the government, aggressively marketed a "mythology of safety," originally to assure local communities and broader public opinion about the safety of nuclear power. *Underlying this mythology was the design philosophy of setting maximum disaster parameters, and designing within them.* When disasters exceeded these parameters, the catastrophe was made all the worse because there were no means to cope with the unexpected—loss of all external power to the power plant, for example.

The "mythology of safety" became a design constraint for the power operators through the following logical inconsistency: If nuclear facilities were designed and operated with maximum safety, how could safety enhancements be undertaken without admitting that they were not safe to begin with?<sup>77</sup>

Out of this self-perpetuating, and ultimately self-defeating logic, the power companies considered "beyond-design-basis" safety precautions as

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<sup>75</sup> Ibid., 48.

<sup>76</sup> "Genpatsu, 40nen koe "datou" Mihama 2 gouki, Hoanin ga younin [Over 40 years is "reasonable": NISA approves Mihama Reactor 2], *Asahi Shimbun* (2012), <http://www.asahi.com/national/update/0606/TKY201206060600.html>.

<sup>77</sup> "Fukushima Report."

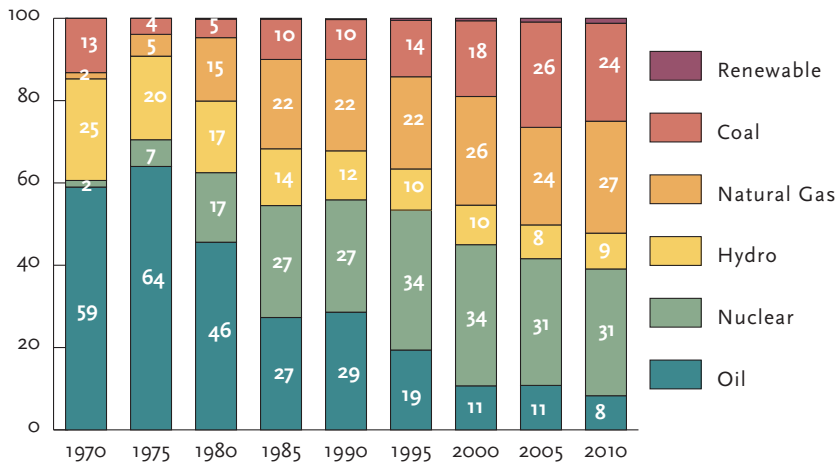


FIGURE 14 Distribution of Japan's Power Sources, 2010

Source: METI

unnecessary and undesirable. This is in direct opposition to the principle of “defense in depth” widely advocated by the international nuclear safety community.<sup>78</sup>

The mythology of safety did, however, come under increasing scrutiny in the 1990s. Most severe was the 1999 accident at a uranium reprocessing facility operated by JCO in Tokaimura in Ibaraki prefecture, in which a chain reaction resulted in two deaths, hundreds of hospitalizations, and a limited evacuation.

TEPCO's biggest scandal came in the early 2000s, sparked by a whistleblower from GE, based in the US, who was involved in maintenance of the Fukushima Dai-Ichi reactor. He had seen several cracks in the steam dryer of Reactor 1, but was silenced by GE's top management, in response to heavy pressure from TEPCO (213). In August 2002, NISA reported that TEPCO had hidden twenty-nine “incidents” in its reactors over the span of several decades. This led to the resignations of TEPCO's chairman, president, advisor, and head of its nuclear division, as well as other demotions and suspensions – the largest corporate damage TEPCO had experienced until 2011.<sup>79</sup> Yet, this damage clearly did not translate into rapid improvements in the Fukushima Dai-Ichi plant's vulnerabilities.

In sum, TEPCO's *philosophy of safety* that was meant to undergird nuclear power operations, probably best encapsulated by the notion of “defense-in-depth,” *was replaced by a mythology of safety*—a mythology that came crashing down in catastrophic form in March 2011.

78 Miller et al., “U.S. NRC.”

79 Oshika, *Meltdown*, 213–14.

# ADDRESSING JAPAN'S ENERGY CHALLENGES

We now turn to addressing Japan's energy challenges moving forward. This section draws heavily from the conference, *One Year After Japan's 3/11 Disaster: Reforming Japan's Energy Sector, Governance, and Economy*, held at the Walter H. Shorenstein Asia-Pacific Research Center at Stanford University on February 27, 2012, where a wide range of scholars and experts brought issues to the table.<sup>80</sup>

This section proceeds as follows:

- An overview of Japan's energy challenges, short-medium term and medium-long term
- An overview of the industry structure and historical business orientation
- A search for solutions that covers the potential for dynamic pricing and industry restructuring, with an overview of the political forces at work

## Japan's Short-Medium-Term Energy Challenges: Supply, Prices, Energy Sources

In the short term, Japan faces an acute electricity capacity crisis during the summer peak months. The immediate challenges are ensuring stable supplies of electricity, and maintaining electricity prices low enough to ensure industrial competitiveness.

Following the disaster, most of Japan's nuclear reactors, which provided up to approximately thirty percent of the country's electricity, went offline, many for "scheduled maintenance." Yet, due to local political opposition they did not come back online. In early May 2012, the last of Japan's fifty-three nuclear reactors went offline, and the country faces the impending summer peak of electricity usage with minimal nuclear power.

Electricity supply *stability* is critical not only for hospitals and other lifeline services, but also for a wide range of industrial processes. Industrial processes such as heat furnaces for small-medium semiconductor compo-

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80 For the agenda, slides, and video of the presentations, see [http://aparc.stanford.edu/events/one\\_year\\_after\\_japans\\_311\\_disaster/](http://aparc.stanford.edu/events/one_year_after_japans_311_disaster/).

nent firms, and numerous other processes depend critically on uninterrupted power. While some large manufacturers such as steel and petrochemical companies have their own power plants, small-medium firms are at the mercy of power companies. For a significant group of small-mediums firms that are critical—and often globally dominant—suppliers of essential high tech components such as condensers, resins, and films, access to sustained electric power is a fundamental necessity.<sup>81</sup>

Electricity *price levels* are also significant in international competition. For firms facing competition against firms in countries with lower factor prices, a spike in electricity prices could lead to decisions to move production offshore. For smaller firms with thin margins in sectors such as retail, new disadvantages are incurred against larger firms that can bargain for lower prices through scale. Carlos Ghosn, CEO of Renault and Nissan, told the Nihon Keizai Shimbun that imposing consumer austerity measures and hiking industrial power prices were not viable medium-term solutions. He noted that the up to 17 percent rise of electricity prices charged by power companies beginning April 1 raised the price of domestically assembled cars by 2000–3500 yen overnight.<sup>82</sup>

A challenge in the short-medium term is the mix of resources to generate electricity in Japan. Before the disaster, Japan's total electricity output was 1002 million megawatts per hour. Of this, approximately 28 percent was from Liquid Natural Gas (LNG), 25 percent from coal, and 25 percent from Nuclear power.

Japan has virtually no natural resources of its own, so all energy is imported. An increase in its dependence on oil and LNG to replace nuclear power thrusts Japan further into the uncertainties of international oil prices. Moreover, Japan's current negotiated price for LNG is pegged to the price of oil, and it pays approximately 10 times the prevailing market value.<sup>83</sup>

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81 The author wishes to thank Ulrike Schaede for detailed insights at her presentation at the Japan Studies Program Colloquium Series at the Walter H. Shorenstein Asia-Pacific Research Center, Stanford University. [http://jsp.stanford.edu/events/phoenix\\_rising\\_from\\_the\\_ashes\\_japans\\_response\\_after\\_the\\_tohoku\\_disaster/](http://jsp.stanford.edu/events/phoenix_rising_from_the_ashes_japans_response_after_the_tohoku_disaster/).

82 “Carlos Ghosn: Tough Choices for Japan, Inc,” Nikkei Online (2012), [http://www.nikkei.com/article/DGXNASFK0500K\\_V00C12A6000000/?df=2](http://www.nikkei.com/article/DGXNASFK0500K_V00C12A6000000/?df=2).

83 This takes the market value to be the Henry Hub (large natural gas trading hub in Gulf of Mexico) price.



## Japan's Medium-Long-Term Energy Challenges: Governing Japan's Energy Sector for Disaster/Crisis Prevention and Reaction

A longer-term challenge facing Japan is how to *reconstruct the institutions governing the energy industry*. The government's oversight of TEPCO, and TEPCO's oversight of nuclear safety, clearly failed. They failed in both the longer-term safety measures, as well as the immediate crisis response. Better long-term safety measures could have averted the crisis, given what we now know of the chain of events leading to the catastrophe. The immediate crisis response itself was characterized by confusion, mistrust, and information coordination problems between the government, TEPCO leadership, and within TEPCO.

A longer term, massive, but uncertain cost will be incurred by Japan society in some form due to the damage compensation for displaced residents and industries, and the decommissioning of nuclear reactors. The Government Commission for the Management and Financial State of TEPCO ("the commission") estimates \$33.9 billion (USD) as a one time compensation, with annual compensations of \$13.2 billion for FY 2011, followed by \$11.6 for subsequent years. For the decommissioning cost of the Fukushima Daiichi reactors, the commission estimates \$17.2 billion, derived by the cost of the three mile Islands case, multiplied by the scale of the Fukushima plants, with some added costs such as contaminated water.<sup>84</sup>

### Japan's Power Industry Structure: Regulated Regional Monopolies, Residential-Driven Profit

It is clear that Japan's energy industry must be restructured. In order to consider the options, we must first examine the configuration of the country's electricity industry.

There are two major characteristics: first, Japan's electricity industry consists of *regulated regional monopolies*. This is not the case in the United States and in many parts of the developed world. There are ten utilities in Japan, and although they were partially deregulated in the 1990s, each region is still served by a regulated monopolist.

Second, Japan's electricity industry is *vertically integrated* between generation, transmission, distribution, and retailing. This was common in most developed countries before the 1990s. A wave of deregulation since then led

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84 Keita Nishiyama, "An Insider's View on Policy Processes and Policy Recommendations on Japanese Electricity Industry," in *One Year After Japan's 3/11 Disaster: Reforming Japan's Energy Sector, Governance, and Economy* (Stanford, CA: Walter H. Shorenstein Asia-Pacific Research Center, 2012).

to transmission and distribution becoming unbundled in a variety of countries, but not in Japan.

In terms of profits, the power companies rely more heavily on households than on industry. A METI report shows that TEPCO provided 62 percent of the electricity it produced to industry, with 38 percent to households, matching the national average. For profit sources, however, TEPCO drew 91 percent from households, with only 9 percent from industry, compared to 69 percent and 31 percent as the national average. (See Figure 16) This data, not made readily available until 2012, will fuel political debates over how to distribute the costs of the Fukushima disaster.<sup>85</sup> For example, will consumers shoulder a proportionally higher burden than industry by incurring higher electricity prices? If this is politically unpalatable, could industry shoulder the cost? However, the proportion of TEPCO's profits from industry is low, implying a higher rate increase would be needed to obtain the same amount of extra revenue vis-à-vis raising prices for consumers.

### *Business Orientation: Supply-Side Management*

The implicit bargain in allowing regional monopolies was that in exchange, they would ensure stable supplies of electricity. Essentially free from cost constraints, the power companies built their capacity to meet any peak demand. Therefore, much of their heavy investment into supply capacities was to serve a relatively small number of peak hours during the year. It was a supply-side solution rather than measures to balance demand to off-peak times and thereby reduce the peak in demand. Demand-side solutions, such as dynamic pricing, in which prices vary in real time, were not pursued.

## **Searching for Solutions: The Potential for Dynamic Pricing, and Restructuring the Industry**

### *The Potential for Dynamic Pricing in Managing Supply and Demand*

Japan's electricity industry structure of regional monopolies has led to supply side building rather than demand management to meet electricity needs, as noted above. This is not only highly costly, but faces a crisis as the

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<sup>85</sup> "Denryoku Rieki Katei Kara 7 wari [Power Company profits, 70 percent from households]," *Asahi Shimbun*, May 23 2012.

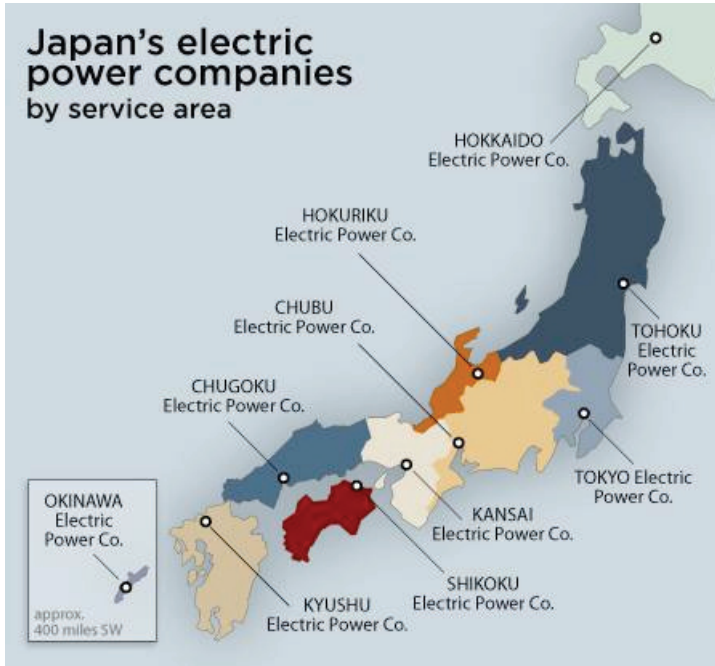


FIGURE 15 Japan's Electric Power Companies by Service Area  
 Source: Global Energy Network Institute.

stable supply of nuclear power is eliminated or drastically reduced for the time being.<sup>86</sup>

Japan is actually ideally suited for dynamic pricing. It has a large peak demand relative to average demand, suggesting that measures to offset the peak will substantially reduce excess generation supply.<sup>87</sup> Moreover, there is a large amount of capacity in pumped storage facilities (approximately 10,000 megawatts), which are quite costly, to meet peak demand.

Implementing dynamic pricing does not necessarily require a thorough industry overhaul. What is required is the construction of a market that can set prices slightly ahead of use, dispatch centers that have the information and market clearing mechanism, and deploy metering technology to collect data on demand.

86 Frank Wolak, "Restructuring the Japanese Electricity Supply Industry in the Aftermath of Fukushima," in *One Year After Japan's 3/11 Disaster: Reforming Japan's Energy Sector, Governance, and Economy* (Stanford, CA: Walter H. Shorenstein Asia-Pacific Research Center, 2012).

87 Its load factor, which is the average to peak demand ratio, is quite low, at 0.6. See Wolak, "Restructuring."

For example, hourly measures of demand can be collected, and the market can set hourly dynamic prices for retail electricity on a day-ahead basis. Imbalances can be corrected by a short term spot-market. Experience from “critical peak pricing” in the United States and UK are encouraging.<sup>88</sup>

*Restructuring the Industry: Previous Attempts at Liberalization*

There have been multiple previous attempts at liberalizing Japan’s electricity industry. However, at each juncture, the political opposition mounted by the power companies exceeded the political power of the reformers. Partial liberalization occurred in three phases: 1995, 2000, and 2003.<sup>89</sup>

In 1995, the main objective for each of the measures was to lower electricity prices rather than to fundamentally restructure the industry. Electricity generation was partially deregulated, with new players allowed to enter the market by generating power to the wholesale market. In 2000, the retailing market was opened for some customers, mostly large industries and commercial users for using extra-high-voltage power. This included large scale

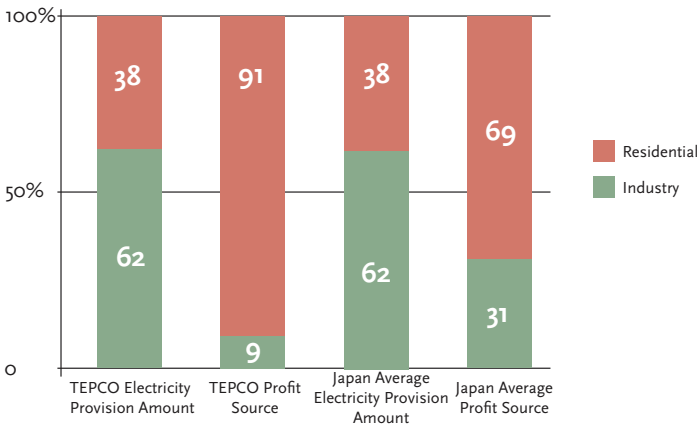


FIGURE 16 Electricity Provision and Profit Source, TEPCO and Japan’s National Average (2006-2010 average)

Source: METI, cited in “Denryoku Rieki Katei Kara 7 wari [Power Company profits, 70 percent from households],” *Asahi Shimbun*, May 23 2012.

88 Ibid.

89 This section is based on the following presentations: Koichiro Ito, “Reforming Japan’s Power Industry,” in *One Year After Japan’s 3/11 Disaster: Reforming Japan’s Energy Sector, Governance, and Economy* (Stanford, CA: Walter H. Shorenstein Asia-Pacific Research Center, 2012), [http://iis-db.stanford.edu/evnts/6977/Ito\\_Presentation.pdf](http://iis-db.stanford.edu/evnts/6977/Ito_Presentation.pdf) and Nishiyama, “An Insider’s View on Policy Processes and Policy Recommendations on Japanese Electricity Industry,” combined with “Fukushima Report,” and Oshika, *Meltdown*.

factories, department stores, and office buildings, covering approximately 26% of total power.<sup>90</sup>

In 2003, reformers attempted to unbundle transmission and distribution. This failed, however, due to opposition from power companies, combined with a lack of political leadership. In reforms that came into effect in 2004 and 2005, the liberalized market segments were expanded to include high voltage (rather than extra-high-voltage) industrial and commercial users, such as small-medium factories and office buildings, and supermarkets. The total share of liberalized segments led to 63 percent.<sup>91</sup>

During these political debates, some arguments against deregulation included critiques of the California electricity crisis, pointing to the state's experience deregulating its energy markets, which led to power shortages, high prices, and rolling blackouts. As will be discussed later, however, this argument was based on a misunderstanding of the California situation. Other arguments pointed to the need to ensure a stable supply of electricity, with the prevailing equilibrium consisting of a trade off of fewer hours of blackout per person in exchange for higher electricity bills.

### *Unbundling and Creating Markets*

The key issues around reforming the industry can be sorted into several analytically distinct categories, revolving around structuring the new industry, and shaping the actors that own and operate the systems.

The first issue is *unbundling*—breaking apart the vertically integrated structure in some form—to open the electricity markets for new entrants. The question is how to do this. In telecommunications, for example, the former state-owned monopoly, NTT, was reorganized under a holding company, with competition introduced in each area (local, long distance, and mobile) that it had previously monopolized. In the case of electricity, the power grid itself would likely need to be managed by a specialized operator, since the networks are more costly, with fewer technological alternatives compared to telecommunications.

A second issue is how to create *inter-regional markets*. The current levels of inter-regional transactions of electricity are very low, with a notable lack of investment in inter-regional transmission. Japan is one of the few industrialized countries with essentially two separate power grids—one that runs at 50 Hz in eastern Japan, with another that runs at 60 Hz in western Japan.

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<sup>90</sup> Nishiyama, "An Insider's View on Policy Processes and Policy Recommendations on Japanese Electricity Industry."

<sup>91</sup> Ibid.

This was the result of Tokyo's adopting German-manufactured generators in the initial days of electrification, while Osaka adopted U.S. equipment.

The rolling blackouts in Tokyo in the summer of 2011 are the clearest evidence of this lack of inter-regional transmission, since sufficient electricity supplies from Western Japan could not be transferred to Tokyo. (Even within a single prefecture, Shizuoka, which straddles two electric power utilities, consumers experienced rolling blackouts in the Eastern part controlled by TEPCO, due to the lack of inter-regional transmission capacity.) A group of reform-minded industry leaders and academics, part of an independent group known as the Japan Policy Council, have even raised the possibility of a trans-Asia power grid, with underwater power lines to Korea and Taiwan—technologically feasible now—to facilitate international electricity markets.<sup>92</sup> This would put Japan in a situation more similar to that of Europe, with electricity markets reaching beyond national borders.

The third issue is one of *creating a competitive marketplace*. Japan's existing wholesale and retail markets are far from competitive. The monopoly utilities generate over 70 percent of total power, and despite the 1995 deregulation allowing independent power providers to enter the market, the independent share remains small. Moreover, most transactions are long-run bilateral contracts between providers and users rather than through a spot-market. Transactions through the Japan Electric Power Exchange (JEPX) account for less than 1 percent of the total volume of electricity transactions. Even after the 2000 liberalization that allowed independent power providers access to 63 percent, the volume remained at 2 percent. The potential for independent producers is extremely large, however. METI estimates put the total amount of potential electricity producible by non-power company producers at 43 million kW, somewhat less than TEPCO's 65 million kW (including nuclear reactors), but greater than that of KEPCO, Japan's second largest power utility, capable of 34 million kW.<sup>93</sup>

Finally, there is the issue of the *Smart Grid*—what it may look like, who will own and operate it, and how it can function. A smart grid of some sort, which sends data along with electricity, is a precondition for the supply-demand balancing solutions noted above. Beyond simply managing supply and demand, smart grids have great potential for innovation, entrepreneurship, and disaster relief. For example, with the appropriate configuration, electric vehicles and plug-in hybrid automobiles can be used for household power generation in times of emergency. They can also be used in aggregate as storage of electricity to help manage peak demand.

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92 <http://www.policycouncil.jp/pdf/propo1/siry02.pdf>.

93 [http://www.meti.go.jp/committee/summary/0004660/23\\_007\\_06\\_00.pdf](http://www.meti.go.jp/committee/summary/0004660/23_007_06_00.pdf).

## *The Politics of Restructuring TEPCO*

Several government organizations and interest groups are currently engaged in debates over how to reorganize TEPCO. TEPCO certainly wields substantial leverage over a wide range of industries through its purchasing power. Its annual revenue of \$70 billion dwarfs that of PG&E (\$14 billion).<sup>94</sup>

Yet, TEPCO is as vulnerable as it has ever been. The Government Commission for the Management and Financial State of TEPCO ("the commission") and NDLFF are able to deploy sufficient resources, including outside professionals, and regulators have a better understanding of the efficiency and real operations of utilities. TEPCO faces serious financial constraints, an unprecedented opportunity for reform.

In early May, 2012, the government agreed upon a restructuring plan that would inject 1 trillion yen in public funds to TEPCO, with the company put under temporary government control. It was focused on paying compensation, decommissioning the Fukushima nuclear plant, and providing stable electricity supplies to the areas it serves, notably Tokyo.

New management was installed, with Shimokobe Kazuhiko, a lawyer and member of the NDLFF, becoming the chairman and Naomi Hirose, a TEPCO managing director in charge of compensation, becoming president, subject to approval in the June TEPCO shareholder's meeting.

Interest groups have mobilized along different lines regarding reform of TEPCO. Japan's largest business association, Keidanren, has also been supportive of TEPCO. Japan's largest industrial firms were major beneficiaries of TEPCO's investments: Hitachi, Toshiba, and Mitsubishi Heavy industries were suppliers of the nuclear reactors (See Table 3); major construction firms such as Kashima and Shimizu were hired to build the plants; steel producers such as Nippon Steel, major cement producers, engineering firms, and the like were all major customers of the power industry. Reflecting this, the vice chairman of Keidanren was almost always from TEPCO.

Doyukai, an organization in which Japan's managerial elite are members on an individual basis, advocated that smart-meters give users information about their usage and pricing, and that specifications for smart-meters should have standardized interface and data formats. They also called for

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<sup>94</sup> Nishiyama, "An Insider's View on Policy Processes and Policy Recommendations on Japanese Electricity Industry."

establishing a power exchange market that will enable market-based transactions.<sup>95</sup>

METI released a similar statement, focusing on two key concepts: efficiency and stable smart-rule based competition. Yet, METI was split, with some portions favoring the early restarting of nuclear plants to help the power industry, while others attempted to seize the opportunity to drive major reforms.<sup>96</sup>

The Ministry of Finance (MOF)'s primary concern was about the government's financial obligations in nationalizing TEPCO. MOF became involved in the debate over the government's ownership ratio, fighting against owning more than half.<sup>97</sup>

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95 Kazuhiko Toyama is a member of Doyukai, and was involved in preparing this statement. Kazuhiko Toyama, "Innovation of the Electric Power Industry in Japan's post-Fukushima Era," in *One Year After Japan's 3/11 Disaster: Reforming Japan's Energy Sector, Governance, and Economy* (Stanford, CA: Walter H. Shorenstein Asia-Pacific Research Center, 2012).

96 Oshika, *Meltdown*.

97 *Ibid.*; Toyama, "Innovation of the Electric Power Industry in Japan's post-Fukushima Era."



# THE MISSED POLITICAL OPPORTUNITY

The nuclear disaster, combined with the broader earthquake and tsunami catastrophes that devastated wide areas of the Tohoku region, was clearly a time of crisis. As such, it was a prime opportunity for bold reform and decisive action. There was a pervasive sense within and outside Japan that a critical juncture in the broader trajectory of the country's politics, economy and society had arrived, requiring action. However, almost everyone was disappointed. At a time that presented opportunities to put aside smaller political squabbles in favor of decisive and bold action, Japanese politics descended into exactly the type of smaller political squabbles that the public did not want to see. Kan was vilified in the media—sometimes based on erroneous information<sup>98</sup>—for excessive meddling in the Fukushima nuclear disaster. The focus among Diet politicians shifted from reform and recovery to power struggles within the DPJ and between the DPJ and LDP. Other topics, such as raising the consumption tax, came to the fore. Why did this occur? Several factors at the deeper structural political levels help to explain.<sup>99</sup>

## A Mandate of Transforming Politics, not Policy

The first issue is how the DPJ came to power in the first place. Its assumption of power in 2009 was the first true electoral alternation of power since 1955. Voters essentially threw out the LDP—a moment that had the potential to transform Japanese politics. The transition presented the possi-

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<sup>98</sup> The Yomiuri reported that Kan's order to halt seawater injections had contributed to the disaster. However, it was later revealed that not only did Kan not order a halt of seawater—with the order instead issued by TEPCO headquarters based on a report by TEPCO's Takekuro based on his reading of the situation more than anything else, but that plant manager Yoshida had disobeyed the order to halt seawater injections, continuing with them while giving the façade of complying with headquarters. Oshika, *Meltdown*. Yoshida later testified to the Diet committee that it was a matter of life and death, so he continued.

<sup>99</sup> This section is primarily based on Steven Vogel, "Japanese Politics After March 2011," in *One Year After Japan's 3/11 Disaster: Reforming Japan's Energy Sector, Governance, and Economy* (Stanford, CA: Walter H. Shorenstein Asia-Pacific Research Center, 2012). It has been supplemented by the author with appropriate references.

bility of altering the basic logic of politics of the postwar era, which entailed permanent incumbent and opposition parties, with interest groups aligned around those expectations. Japan faced potential for more competition for policy substance, with some observers predicting the emergence of a two-party, more policy-oriented political logic.

However, the DPJ gained its power with the promise of transforming politics, rather than on a particular set of policy platforms. Critically, a major component of its promise to transform politics was to attack those who should have been natural allies—the bureaucrats who understood substantive issues. The DPJ increased the number of political appointees in each Ministry, and in the early days of policymaking, bureaucrats were often explicitly excluded from meetings between the political leaders of ministries, and between ministries.

In the context of the Fukushima disaster, Kan's background as the Ministry of Welfare in 1994 led to his overall mistrust of bureaucrats. While Minister of Welfare, Kan had uncovered a major scandal in which pharmaceutical companies, which employed retired MoW bureaucrats, covered up the neglect in undertaking procedures to filter HIV-tainted blood, leading to a number of hemophiliacs and pregnant women contracting HIV. MoW had known about the problem, and a deliberation committee reported the need for urgent and immediate change, but the Ministry had not taken heed. TEPCO's relationship with NISA and METI was somewhat similar: METI bureaucrats often took post-retirement positions in the power industry, and the Ministry in charge of safety was also responsible for advocating development of the industry. Some of Kan's initial crisis response of micromanagement stems from this experience—but was anchored in the broader context of the DPJ's stance toward bureaucrats.

### **DPJ, the Dual-Headed Monster**

Returning to the lack of bold leadership and reform following the disaster, another structural problem with the DPJ was in its internal hierarchy. Put simply, from the beginning, the DPJ had two heads. Ozawa Ichiro, the stronger political force in the party, had long held a vision of the prime minister and Cabinet actually running the country. To this end, he had moved to strengthen the cabinet. However, this vision was hard to execute when he was ousted as party leader (and therefore potential prime minister-ship) due to campaign financing scandals. The DPJ was therefore a dual-headed monster in which the strongest figure, Ozawa, was in the party but not in the government, while the prime minister, Hatoyama Yukio, was not necessarily

the most powerful figure in the party. And Hatoyama fell from power when the party realigned to oppose the Ozawa-controlled portion of the party.

In the aftermath of the crisis, Kan came under attack from within the DPJ, with the Ozawa supporters pulling the rug out from under him. While in France at an OECD meeting, where Kan announced a new energy policy that would drastically reduce the proportion of nuclear energy and focus on increasing renewables, Ozawa's group within the DPJ joined forces with some DPJ members calling for a vote of non-confidence. On June 1, Ozawa gathered seventy DPJ members loyal to him to announce the vote of non-confidence. The previous prime minister Hatoyama publicly announced his support of Ozawa's move. Since the minimum number of members needed for a decisive party vote was eighty-one, this was a very serious split. After a meeting between Kan and Hatoyama the following day, Kan announced that he would resign after completing the tasks currently underway.<sup>100</sup> This diffused pressure from the vote of non-confidence, but he became a lame duck and was unable to push through major legislation or bold reform.

### Japan's "Un-Westminster," "Non-Party Polarized" System

A more basic structural reason that bold reform led by the prime minister is difficult in Japan stems from the division of power between the political leadership and the bureaucracy. In theory, a Westminster system—upon which Japan's political system is based—gives the prime minister and Cabinet authority over the party and bureaucracy. In Japan, however, the actual power center was shared between the party and bureaucracy for most of the postwar era—not the prime minister and Cabinet. Therefore, while Great Britain engaged in dramatic and bold reforms under the Thatcher administration, Japanese political leaders were unable to enact similar levels of bold reform.

Moreover, Japan has been characterized by its non-polarized party system. It is difficult to tell, in policy terms, the exact demarcations between the LDP and DPJ's policies. In 2007, Ozawa attacked the LDP in rural areas quite successfully—so even in areas where we might have expected differentiation between urban DPJ and rural LDP, the DPJ went rural.

There are a few additional factors. Japan suffers what many have identified as a leadership deficit. The Koizumi Junichiro prime ministership from 2001 to 2006 was a period in which he was able to use his personal charisma and electoral popularity to drive reforms. However, since then, prime ministers have not assumed strong leadership roles.

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<sup>100</sup> Oshika, *Meltdown*, 309–10.

Finally, the issue of the so-called “twisted” Diet, in which the ruling party has a majority in the lower house, but not the upper house, has slowed decisive policymaking. It might be considered Japan’s version of a divided government, but it is not conducive to rapid or decisive policy.

## A CALL TO AVOID “GALAPAGOS”

This report closes with a call to unleash the potential of Japan’s emerging new electricity grid to its international advantage.<sup>101</sup>

Many aspects of the pending reform of TEPCO, and Japan’s power utilities companies more generally, resemble that of liberalizing the telecommunications market in the 1980s. Both TEPCO and NTT were former state-owned companies, and both wielded extreme levels of capital resources, with Japan’s major industrial firms benefiting considerably from their relationships with TEPCO and NTT. Both were politically powerful, with unions that were among Japan’s very largest.

The liberalization of NTT was a politically messy affair. It involved an activist Prime Minister Nakasone driving an ambitious reform agenda that privatized Japan’s railroads and tobacco companies. Turf wars between the Ministry of International Trade and Industry (MITI) and the Ministry of Posts and Telecommunications over the emerging role of Information Technology (IT) were underway, and the Ministry of Finance (MOF) was involved in the privatization process from the vantage of regulating the government’s ownership of shares in the privatized entity. *Zoku* politicians in the LDP—those specializing in particular issue areas—were heavily involved, and the NTT labor union was active in mobilizing the opposition socialist party, the core of which eventually became the DPJ. The result of a complex political battle was liberalization in the form of deregulation as well as a plethora of new rules to govern competition. MPT governed the new regulated industry, gaining a broad range of regulatory powers. NTT, however, backed by strong support of both the incumbent LDP and opposition socialist party, as well as major suppliers of NTT, was not completely broken up as in the analogous case of AT&T in the United States.<sup>102</sup>

The end result of Japan’s decision not to break up NTT eventually led to a domestic market, particularly in mobile phones, that was innovative

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<sup>101</sup> This section is based on Kenji E. Kushida, “Visions for moving forward: a Vantage from IT,” in *One Year After Japan’s 3/11 Disaster: Reforming Japan’s Energy Sector, Governance, and Economy* (Stanford, CA: Walter H. Shorenstein Asia-Pacific Research Center, 2012).

<sup>102</sup> “Entrepreneurship in Japan’s ICT Sector: Opportunities and Protection from Japan’s Telecommunications Regulatory Regime Shift,” *Social Science Japan Journal* 15, no. 1 (2012).

and sophisticated, but isolated from global markets. The financial resources of NTT, combined with dynamism introduced by a set of new competitors, enabled a new range of sophisticated features and handsets—in particular a set of Internet content platform services that debuted in the late 1990s. Vibrant content markets flourished, as did hardware that took advantage of new features that are now familiar to users across the world, but had debuted in Japan several years before hitting global markets. Examples include polyphonic ring tones, color displays, Internet-based email and web browsing, camera phones, the ability to email pictures from handset cameras, and GPS. Other services, such as electronic money transferred by physically touching the phone to a payment terminal, and simplified terrestrial digital broadcasting tuners, are still far more advanced in Japan. I have argued that this “leading without followers” was the result of a particular set of competitive dynamics that drove firms winning in the domestic market to lose in global markets. The Japanese domestic press has dubbed the phenomenon as “Galapagos,” after the Pacific islands where Darwin made the observations that led to his theory of evolution: islands where geographic isolation led to a proprietary trajectory of evolution.<sup>103</sup>

As Japan moves towards Smart Power Grids as a sophisticated lead user, it must avoid treading the same path as its IT sector. Smart Grids by definition require managing flows of high volumes of information along with flows of electricity. The management of such information will entail competition over who provides the platforms and IT systems for Smart Grid networks. Traditional Japanese IT suppliers such as NEC and Fujitsu will be interested, as will Silicon Valley firms such as Cisco Systems. The ability of electric vehicles or plug-in hybrids to plug into power grids also ushers in players such as Toyota who are interested in helping manage flows of electricity as well.

What Japan does not want, and indeed cannot afford, is to roll out an advanced but proprietary Smart Grid, which can act as a platform for various innovations—new, decentralized power sources plugged into the grid and the ability for fleets of vehicles to sell back electricity into the grid during peak demand, for example—but which can exist only in Japan. All standards around information flows should be designed with an eye towards global markets. Narrowly defined proprietary standards that might advantage domestic manufacturers in the short term are likely to backfire in the long term, just as the Apple iPhone and Google Android platform are wip-

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103 “Leading Without Followers: How Politics and Market Dynamics Trapped Innovations in Japan’s Domestic “Galapagos” Telecommunications Sector,” *Journal of Industry, Competition and Trade* 11, no. 3 (2011).

ing out Japan's "Galapagos" feature-phones. The power companies, which dominate the resources in the sector, should not be the ones in charge of setting the standards. A neutral, third party organization should be in charge, comprised of members from a variety of foreign as well as domestic players. Of all the lessons learned from the Fukushima Dai-Ichi nuclear disaster, this area should be considered one of the key issues outside of direct nuclear safety and governance concerns, which is likely to have significant ramifications for Japan's future economic development.





# CONCLUSION: A CALL FOR AN INDEPENDENT NUCLEAR REGULATORY BODY

This report provides one of the first readable and detailed accounts of Japan's Fukushima nuclear disaster in English. Only by understanding the magnitude of what went wrong can we point to the urgent need for reform.

The clearest lesson to be learned is that the promotion and safety regulation of nuclear power should not reside in the same institution. The nuclear safety regulatory body should also be independent from monetary and political influence of the power companies to avoid regulatory capture. In short, a truly independent nuclear safety regulatory body is needed.

Japan's political reform of nuclear safety regulation is moving in the right direction, but as of yet does not go far enough. NISA is being moved out of METI, which gained the agency during political debates of the late 1990s when the government structure was reorganized. Current plans call for NISA to be placed under the Ministry of the Environment. However, the latter is not known to be a strong Ministry, having been created in 2001 from the Environmental Agency during the same government reorganization that shifted NISA to METI. Recent agreements by local governments to restart a number of nuclear reactors to cope with summer peak demand often include calls to create an independent safety regulator.

Now that the "mythology of safety" has been permanently punctured, it is time to institute a *philosophy of defense-in-depth*, preparing for the possibility of beyond-design-parameter events. The heterogeneity of reactor designs and ages should be re-examined, with safety-enhancing measures put in place. With not only Japan's neighbors, but developing countries around the world, moving quickly to increase their dependency on nuclear power, Japan should take the lead in creating institutions that can provide models for elsewhere. This may even facilitate plans for the international expansion of nuclear plant businesses for Japanese manufacturers. Japan could potentially take the position of "we learned from our mistakes, and are therefore now better at safely operating nuclear plants" rather than being seen as a

country that, even in the future, provides an example of how not to organize one's nuclear governance structures and contingency plans.

From the perspective of civil society activism, the realities and challenges of Japan's international strategic situation and energy needs should be understood before ideologically-based blanket calls for zero nuclear energy are put forward; policymakers will be balancing calls to depart from nuclear energy with potential costs of economic growth prospects that reverberate into employment and other concerns. The effectiveness of such calls is likely to be enhanced by positions that take into account the real challenges that a non-nuclear energy Japan would face, to create a stance of solving problems together.

The potential for creating international electricity markets, such as connecting Japan to South Korea, is an interesting one that merits serious consideration. A deeper economic integration in the most basic sense may be one of the steps to address international security and policy concerns. Within Japan, it may also facilitate reform if external power supplies are available, and may even give power companies leverage in international negotiations over LNG prices.

In conclusion, since lessons from the Fukushima disaster can only be learned by understanding what happened, I sincerely hope that this report is the first step in providing a detailed, easily accessible narrative that can be used broadly in analyses to come. Luckily, as bad as the Fukushima nuclear disaster was, there were no immediate deaths or serious injuries from the radiation alone. Numerous lessons can be gleaned from the experience, and we call for experts in all fields and popular support to help channel nuclear power in the world, which is unlikely to give it up any time soon, towards the maximum safety possible.

## **Appendix A: A Note on Sources**

In the year after the disaster, a number of reliable sources have been published by the Japanese government, media, and academia, and the U.S. Nuclear Regulatory Commission. The Japanese sources have interviewed many of the key participants in the disaster as it unfolded, and the accounts documented in the publications agree for the most part with National Diet testimonies. Where there was disagreement in interpretation, particularly between TEPCO and the political leadership, this disagreement has been noted in the text.

The Japanese sources include: a series by a special investigative report-

ing unit within the Asahi Newspaper;<sup>104</sup> a book published by the editor of AERA, a major investigative news magazine;<sup>105</sup> an investigation and analysis report by a private think tank;<sup>106</sup> the midterm report of a an investigation commission appointed by the Cabinet Office.<sup>107</sup>

The government appointed two investigative commissions. The first, “The Investigation Committee on the Accident at Fukushima Nuclear Power Stations of Tokyo Electric Power Company” was appointed by the Cabinet Office under Prime Minister Kan’s direction, with a University of Tokyo Emeritus Professor of Engineering, Hatamura Yotaro as chair. Commissioned on June 2011, it submitted a midterm report in December 2011 based on interviews with 456 people.<sup>108</sup>

The second, “The National Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission (NAIIC” was formed by a statutory law by the National Diet in October 2011, with Kurokawa Kiyoshi, Professor Emeritus at the University of Tokyo Faculty of Medicine and professor at the National Graduate Institute for Policy Studies (GRIPS), and the Science Advisor the Cabinet. The final report was published during the summer of 2012, and many of the testimonies were public, and widely reported in the media.

## Appendix B: Creating Electricity Markets: A Technical Recommendation

A thorough restructuring of the industry is a potentially effective method to balance demand and supply.

A short-term wholesale electricity market could improve the efficiency of generating power.<sup>109</sup> Independent system operators can submit curves to supply energy for each hour of the day. Transmission and distribution networks would be open, on an open-access basis. Therefore, the issue of which suppliers produce and which retailers purchase electricity is settled in the

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104 *Prometheus*.

105 Oshika, *Meltdown*.

106 “Fukushima Report.”

107 “Interim Report.”

108 *Ibid*.

109 Recommendations from Wolak, “Re-structuring the Japanese Electricity Supply Industry in the Aftermath of Fukushima.”

market, with offer and demand curves submitted the market manager.<sup>110</sup>

For such a market, some measures would be needed to ensure sufficient demand for suppliers to invest in facilities, such as mandated forward contracting levels for retailer, enforced by regulators. The mandated contracting overcomes the limits in the incentive of retailers to hedge short-term price risks in cost-based short term dispatch. A focus on developing the forward market for energy can ensure competitive short-term market outcomes, since everywhere in the world, large fractions of final demand are covered by fixed-price forward contracts.

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<sup>110</sup> There are multiple ways to operate such a market, including a bid-based market, in which suppliers submit their willingness to supply energy with the price becoming the highest bid necessary to meet demand, and the cost-based market in which suppliers submit information about their variable costs to the independent system operators, with the pricing becoming the highest variable cost necessary to meet demand. Ibid.

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