Impacts on International Energy Market of Unplanned Shutdown of Kashiwazaki-Kariwa Nuclear Power Station[1]

Tomoko Murakami, Leader, Nuclear Energy Group, Strategy and Industry Research Unit, Institute of Energy Economics, Japan

Michihito Watanabe, Senior Researcher, International Strategy Analysis Group, Strategy and Industry Research Unit, IEEJ

Shusaku Sato, Researcher, International Strategy Analysis Group, Strategy and Industry Research Unit, IEEJ

Kentaro Shida, Researcher, International Strategy Analysis Group, Strategy and Industry Research Unit, IEEJ

Introduction

Due to the Niigataken Chuetsu-oki Earthquake that occurred at around 10:13 a.m. on July 16, 2007, the Unit 3 reactor (a 1.1 GW BWR[2]), the Unit 4 reactor (a 1.1 GW BWR) and the Unit 7 reactor (a 1.356 GW ABWR[3]) in commercial operation at the Kashiwazaki-Kariwa nuclear power station of Tokyo Electric Power Co. were automatically shut down. The Unit 2 reactor (a 1.1 GW BWR), which was starting up after a periodic inspection, was also automatically shut down. The Unit 1, 5 and 6 reactors were under a periodic inspection.

Although the safety protection system worked as designed to secure safety for all reactors, various instruments were broken. Many minor troubles occurred, though falling short of affecting the safety of nuclear reactors. As of December 2007, therefore, no schedule was in sight for restarting the nuclear power station. The seven-reactor nuclear power station has a total capacity at 8.212 GW amounting to some 16% of Japan's nuclear power generation capacity and had been planned to operate at some 75% of its capacity in FY 2007. Its shutdown thus means that TEPCO has been forced to depend on thermal power stations for about 40 TWh in power generation in FY 2007 alone and 50-60 TWh annually until the Kashiwazaki-Kariwa nuclear power station resumes its operations. If its shutdown is prolonged, additional demand will emerge for LNG, crude oil and

1 This report is a translation of the original report written and published in Japanese version on 8 January 2008.

2 BWR stands for boiling water reactor. The BWR is one of the world's most widely used light water reactors. It directly transfers heat extracted from fuel to turbines through coolant water. Japanese companies that have adopted the BWR include Tohoku Electric Power Co., Chubu Electric Power Co., Hokuriku Electric Power Co., Chugoku Electric Power Co., Japan Atomic Power Co. and Electric Power Development Co., as well as TEPCO.

3 ABWR stands for advanced boiling water reactor. The ABWR is the latest practicable BWR. It has been adopted not only for the Unit 6 and 7 reactors of the TEPCO Kashiwazaki-Kariwa power station but also for the Unit 5 reactor at Chubu Electric Power Co.'s Hamaoka nuclear power station and the Unit 2 reactor at Hokuriku Electric Power Co.'s Shika nuclear power station.

fuel oil for power generation. The unplanned shutdown of the large-capacity nuclear power station is expected to exert significant impacts on international crude oil and gas markets. The extraordinary shift to fossil fuels will also work to increase greenhouse gas emissions (CO2). In this respect, the unplanned nuclear power plant shutdown may affect the CO2 emission reduction goals.

The objective of this report is to look into and analyze various effects of the unplanned shutdown of the large nuclear power station on the international energy market and to derive implications about the significance of nuclear power generation and its impacts on markets for other energies. Specifically, Chapter 1 reviews the chronology and present situation of the nuclear power plant shutdown and summarizes key points for restarting of the nuclear power station. Chapter 2 examines the shutdown's real effects on the electricity supply/demand balances, and oil and gas markets. Chapter 3 discusses future prospects of impacts on oil and gas markets. Chapter 4 gives a conclusion.

1. Chronology and Present Situation of Shutdown of Kashiwazaki-Kariwa Nuclear Power Station

1-1 Chronology of Shutdown of Kashiwazaki-Kariwa Nuclear Power Station

Due to the Niigataken Chuetsu-oki Earthquake that occurred at around 10:13 a.m. on July 16, 2007, the Unit 3, 4 and 7 reactors in commercial operation at the nuclear power station were automatically shut down. The nuclear reactor scram[4] sign stated "seismic monitoring trip," making it clear that the earthquake directly caused the shutdown. It was also clear that the safety protection system worked soundly. The Unit 2 reactor in start-up operation after a periodic inspection was also shut down automatically due to the seismic monitoring trip. The Unit 1, 5 and 6 reactors were under a periodic inspection. Even when several aftershocks jolted the region, a series of safety operations including the nuclear reactor decay heat removal after the shutdown have been carried out normally. Each reactor has remained in a cooled shutdown condition. It is clear that key safety functions for nuclear reactors, including the shutdown, cooling and containment, were maintained as designed even during the epicentral earthquake that greatly damaged Kashiwazaki City and its vicinity.

But the earthquake caused a number of troubles. Water spattered from spent fuel pools on operating floors[5] for all reactors. At the Unit 6 reactor, water including a tiny amount of radioactive substances leaked through a non-controlled area to the sea. Minor injuries, shears, oil leaks and the like were seen in instruments. During checkups inside nuclear reactors that started in August, some control rods failed to be pulled out of the Unit 6 and 7 reactors (at present, all rods have already been

[4] The nuclear reactor scram means a nuclear reactor is shut down as a control rod is inserted into the reactor in emergency.

[5] Operating floor: The operating floor is a nuclear reactor building's highest floor where heavy substances are conveyed. With a spent fuel pool, the floor is a radiation controlled area.

pulled out). Small holes were found on the well[6] of the Unit 7 reactor. No other problems have been discovered during the checkups.

By December 13, 2007, TEPCO confirmed and announced five earthquake-caused troubles involving radioactive substances. Including minor troubles involving no radioactive substances, TEPCO reported 3,107 troubles by November 30. The following two are relatively significant radioactive substance releases:

- Releases to the sea accompanying water leaks from a spent fuel pool of the Unit 6 reactor
- Detection of radioactive iodine, cobalt 60 and chrome 51 in the main exhaust stack monitor for the Unit 7 reactor

Troubles other than radioactive substance releases included deviations from safety regulations[7] (lowered water levels in spent fuel pools at Unit 1, 2 and 3 reactors, dislocation of a blowout panel for the Unit 3 reactor building, etc.). These deviations were immediately solved and fell short of being interpreted as safety regulation violations. No action running counter to the Nuclear Regulation Law or any other law has been confirmed.

The two troubles involving radioactive substance leaks are summarized below, based on TEPCO explanations and media reports. While they did not affect the environment, every nuclear power plant operator had many lessons[8] to learn from these troubles. We expect that the lessons will be utilized for prevention of similar troubles and be shared widely.

1-1-1 Radioactive substance releases to the sea through water leaks from a spent fuel pool of the Unit 6 reactor

Around 12:50 p.m. on July 16, water leaks were confirmed at the operation (third) floor and the non-controlled mezzanine floor of the Unit 6 reactor building. Around 6:20 p.m., radioactive substances were confirmed in the water leaks. On the third floor, water leaks totaled some 0.6 liter with the amount of radioactivity at 2.8×10^2 becquerels[9]. On the mezzanine between the second and third floors, water leaks came to 0.9 liter with the amount of radioactivity at 1.6×10^4 Bq. TEPCO has explained that water flew out of the spent fuel pool to the operating floor on the quake and leaked to the non-controlled area through the fuel exchanger cable and through the wall separating the radiation controlled area from the non-controlled area.

---

6 Nuclear reactor well: The well filled with water is used for such operations as refueling. It is a well-shaped space between the top of the nuclear reactor container and the refueling floor.

7 Nuclear reactor operators are legally required to keep coolant water, pressures and temperatures within standard ranges. Deviations from safety regulations mean operations or shutdowns deviating from these standard ranges.

8 A report by an IAEA survey team that visited the power station in early August 2007 stated that nuclear power plant operators would have precious lessons to learn from the incident for the future.

9 Becquerel: The becquerel (Bq) is a unit of radiation, representing the number of atomic disintegrations per second. An adult man has 2 grams of potassium per kilogram body weight. In terms of K-40 as the radioisotope of potassium, the amount is described as about 60 Bq/kg.

Later, water releases to the sea through an outlet were confirmed. Water released to the sea was estimated at some 1.2 square meters with the amount of radioactivity at about 9×10^4 Bq. Water releases had stopped before their announcement. The sea water monitoring data for the Unit 6 reactor indicated no significant change, confirming there was no impact on the environment.

The spent fuel pool and fuel racks in the pool are given top priority in seismic design and feature relatively tougher seismic standards among nuclear facilities. But the standards concern integrity of the spent fuel assembly and does not prevent water leaks from spent fuel pools. An analysis by nuclear plant makers indicates that water in the spent fuel pool may flow out to the operating floor and leak through to non-controlled areas. It would be important to install some filtering systems to prevent radioactive substances (including nuclear fission products in fuel and rust of cladding tubes contaminated with such products) from being released out of the building. It should be solved hereinafter that Kashiwazaki-Kariwa and other nuclear power stations would keep sound containment function of reactor buildings and other facilities to prevent radioactive substances from being released out of these facilities. We hope that sufficient consideration would be given to this point in regard to all nuclear power stations.

1-1-2 Detection of radioactive iodine and particles in the main vent stack monitor for the Unit 7 reactor

Around 1 p.m. on July 17, radioactive iodine, cobalt 60 and chrome 51 were detected at the filter of the main exhaust stack of the Unit 7 reactor during its regular measurement. During a later measurement, iodine-131 and 133 were detected. The radiation dose from radioactive iodine was announced as about 2×10^{-7}mSv and that from radioactive particles (including chrome and cobalt) as about 7×10^{-10}mSv. Each dose is sufficiently lower than environmental radioactivity of 2.4mSv/year, having no impact on humans.

Usually, however, no radioactive substances are detected from the main vent stack filter. Such substances are contained in reactor coolant water. After investigations, TEPCO has estimated that radioactive substances staying in the condenser were drawn into the ventilator and reached the vent stack, as the ventilator, connected to a system for extracting steam from the turbine, failed to be suspended promptly on the automatic reactor shutdown in response to the earthquake on July 16.

The problem emerged from a shutdown procedure failure. Stricter implementation of shutdown procedures including a valve shutdown and suspension of various systems may help prevent such problem[10].

---

[10] Thorough diffusion of right procedures is cited as a measure for prevention of this kind of problems in a TEPCO report, "an analysis of fundamental causes of radioactive gas waste (including iodine) releases from the main exhaust stack at the Unit 7 reactor of the Kashiwazaki-Kariwa nuclear power station," which was given at the third meeting of an operation management and equipment soundness assessment working group of an investigative panel on nuclear facilities affected by the Niigataken Chuetsu-oki Earthquake at the Nuclear and Industrial Safety Subcommittee, Advisory Committee for Natural Resources and Energy, on November 1, 2007.

1-2 Consideration on Seismic Design Review Guideline for Nuclear Facilities and Their Seismic Performance

Table 1-1 shows the maximum seismic spectrum value for each reactor of the Kashiwazaki-Kariwa nuclear power station during this earthquake.

The maximum horizontal value for the Unit 1 reactor was the highest among the seven reactors, standing at 680 gal[11], 2.5 times as high as the design floor response spectrum [12] at 273 gal. The maximum horizontal seismic spectrum value came to 606 gal (against the design floor response spectrum at 167 gal) for the Unit 2 reactor and to 492 gal (against 194 gal) for the Unit 4 reactor. At each of these reactors, the maximum horizontal seismic spectrum value more than doubled the design floor spectrum response.

Table 1-1 Maximum Value at Each Unit of Kashiwazaki-Kariwa Nuclear Power Station

(Unit: Gal)

Unit	Meridional			Horizontal			Vertical		
	Observed maximum value (A)	Design floor response spectrum (B)	A/B	Observed maximum value (A)	Design floor response spectrum (B)	A/B	Observed maximum value (A)	Design floor response spectrum (B)	A/B
1	311	274	1.14	680	273	**2.49**	408	235	1.74
2	304	167	1.82	606	167	**3.63**	282	235	1.20
3	308	192	1.60	384	193	1.99	311	235	1.32
4	310	193	1.61	492	194	**2.54**	337	235	1.43
5	277	249	1.11	442	254	1.74	205	235	0.87
6	271	263	1.03	322	263	1.22	488	235	**2.08**
7	267	263	1.02	356	263	1.35	355	235	1.51

Source: TEPCO-published data

The present seismic design review guideline is a revised version of the 1981 guideline, reflecting the latest earthquake engineering knowledge and seismic design technology progress for light water reactors. The revisions include a thorough survey on the presence or absence of active faults at a nuclear power station site and its vicinity before setting the design basis earthquake ground motion[13]. In response to the revisions, the Nuclear and Industrial Safety Agency (hereinafter referred as "NISA") has required electric power utilities to conduct seismic safety reassessment

[11] The gal is a unit of acceleration used to indicate the strength of an earthquake. 980 gal is equal to 1G (earth gravity).

[12] The design acceleration response is an analysis-based design acceleration response, representing a response that an acceleration meter at each reactor would make on a standard seismic ground motion based on the seismic design review guideline, as indicated through a model analysis. The real data's excess over the standard hints that the real earthquake was stronger than a standard one assumed in the guideline.

[13] For revisions to the seismic design review guideline, see the September 19, 2006 Nuclear Safety Commission decision on "Revisions to the seismic safety review guidelines including 'the seismic design review guideline for nuclear reactor facilities for electricity generation.'"

(seismic back check) based on literature and on-site inspections for a 30-kilometer radius of each nuclear power station[14]. As instructed by the NISA, TEPCO had conducted a geological survey on the Kashiwazaki-Kariwa nuclear power station and its vicinity again. On the ground area, TEPCO had looked into the underground conditions with artificial quakes. But it has fallen short of implementing any new survey on undersea faults under a conclusion that data collected by other research institutions would be sufficient[15]. In response to the Niigataken Chuetsu-oki Earthquake, the Ministry of Economy, Trade and Industry (hereinafter referred to as “METI”) instructed all electric power utilities including TEPCO on July 20 to review their seismic back check plans[16]. On July 26, TEPCO announced that it would conduct a geological survey of waters surrounding each nuclear power station using marine seismic profiling in addition to the planned seismic back check. On August 17, TEPCO stated that it would expand ground areas for underground condition surveys to reconfirm and reassess active faults.

On July 19, the Nuclear Safety Commission announced its Chairman Atsuyuki Suzuki's "Statement on the Safety of the Kashiwazaki-Kariwa Nuclear Power Station after the Niigataken Chuetsu-oki Earthquake." Chairman Suzuki said that the present seismic design review guideline was basically effective. It was important for electric power utilities and regulatory authorities to consider design conditions (including the design basis earthquake ground motion and the analytical model) in detail and confirm seismic safety, he said. In response to the METI instruction on July 20, 2007, all electric power utilities including TEPCO submitted and published their seismic back check implementation plans on August 20[17]. According to these plans, the electric power utilities would implement geological surveys at all nuclear power station sites within FY 2007 and conduct seismic safety assessment in FY 2008 and 2009. Needs for geological surveys have been discussed above. All electric power utilities are now required to reconsider whether the present design basis earthquake ground motions and analytical models are appropriate under the guideline and whether analytical results are satisfactory enough to maintain the integrity of facilities. In this sense, analytical results should be fed back promptly.

1-3 Key Points for Restarting Kashiwazaki-Kariwa

It is difficult to predict the time for restarting the Kashiwazaki-Kariwa nuclear power station at present. In addition to safety and quake resistance conditions as discussed in Sections 1-1 and 1-2, there are some other conditions for restarting the nuclear power station. While having published a schedule for reactor inspections, TEPCO has not discussed any prediction for restarting

[14] See the METI and NISA document dated September 20, 2006.
[15] Source: asahi.com news bulletin on July 19, 2007
[16] See the METI and NISA document dated July 20, 2007.
[17] See the METI and NISA document dated August 20, 2007.

the power station based on assessment of inspection results. We here would like to discuss key points for restarting the power station from safety, quake resistance and other perspectives.

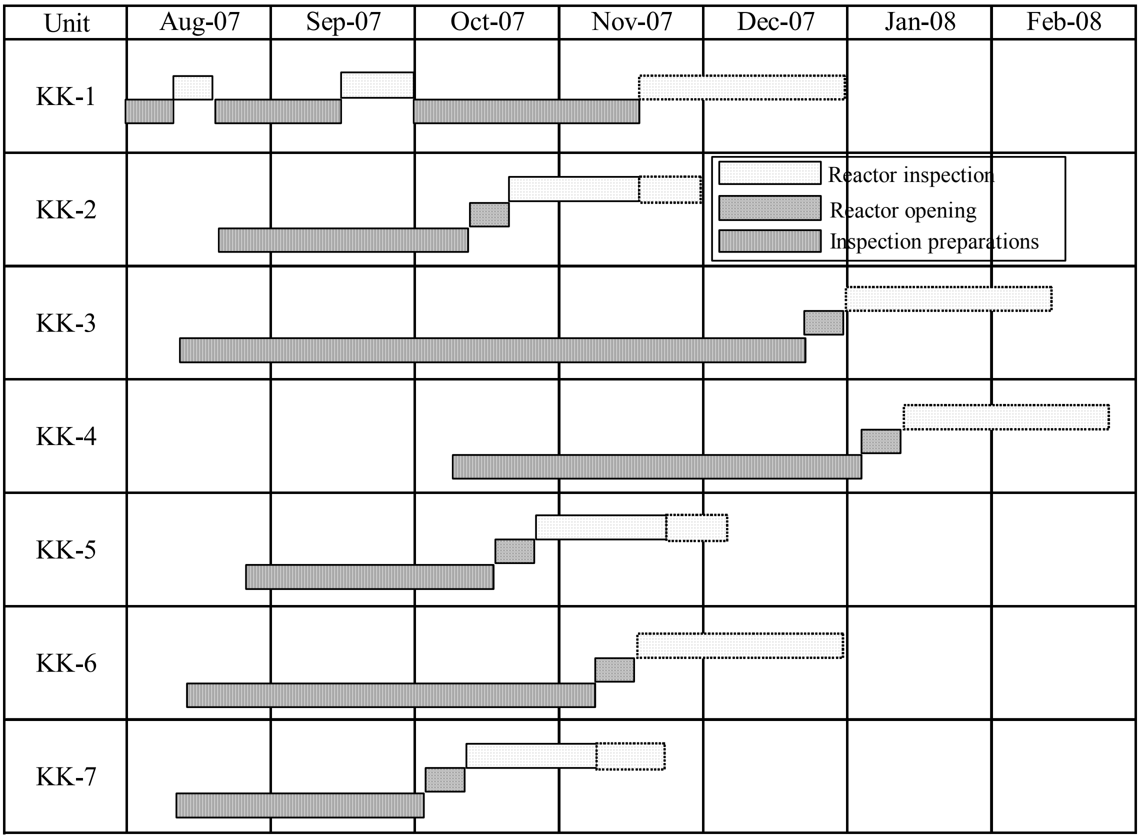
1-3-1 Securing seismic safety of facilities

On July 20, TEPCO announced a report on how to secure safety of the Kashiwazaki-Kariwa nuclear power station in response to the Niigataken Chuetsu-oki Earthquake. The report stated that TEPCO had submitted its inspection results and future policy to NISA and would analyze earthquake observation data to confirm seismic safety of the power station. Later, TEPCO disclosed restoration conditions and problems found through inspections in its weekly reports. By the end of November 2007, confirmed problems including minor ones numbered more than 3,000. We here would like to consider seismic safety conditions for restarting the power station and the lead time for meeting the conditions.

Earthquake observation data must be analyzed before assessment of seismic safety. TEPCO puts seismic ground motion data gained through the analysis into each reactor model to conduct seismic response analyses and seismic safety assessment. The company submitted the first report on model-based seismic response analyses to METI on July 30 and the second one August 22. These reports were also made public. The period of time required for seismic safety assessment for all equipments is estimated at six to 10 months without antiseismic reinforcement, given the period between the shutdown and restart of Tohoku Electric Power Co.'s Onagawa nuclear power station after the Miyagiken-oki Earthquake in August 2005. As noted in Sections 1-1 and 1-2, however, TEPCO has been conducting geological surveys based on the revised seismic design review guideline, as well as the seismic safety assessment. Depending on the survey results, the design basis earthquake ground motion may have to be revised. Therefore, the seismic safety assessment period can be longer than estimated above. Antiseismic reinforcement may also be required for less quakeproof structures and machines that cannot resist any earthquake registering "6 upper" or higher on the Japanese seismic intensity scale of 7. Many injuries have been found for less quakeproof structures and machines, although no major injury has been detected for highly quakeproof machines. Even if the standard seismic ground motion does not have to be revised, more than 12 months may be required before any of the reactors is restarted at the Kashiwazaki-Kariwa nuclear power station. Much longer time could be required before the last reactor resumes commercial operation as the restart operation will be implemented one by one. For reference, TEPCO's published reactor inspection schedule is shown in Table 1-2.

In addition to the confirmation of seismic safety, TEPCO will have to establish measures for prevention of water leaks to an outlet on the operating floor as discussed in Section 1-1 and procedures for stopping such water leaks to help secure the safety of facilities. While conducting seismic safety assessment, TEPCO may reform operation manuals, obtain government approval on the reform and brief local governments on the reform.

Table 1-2 Reactor Inspection Schedule for Kashiwazaki-Kariwa Power Station



Source: TEPCO-published data

1-3-2 Contingency plan

Although no radioactive release was identified at the Kashiwazaki-Kariwa nuclear power station upon the earthquake, there were some troubles that led experts to conceive the possibility of radioactive substances being released. Therefore, possible emergency evacuation of residents has attracted attention. The severe criticality accident at a nuclear fuel conversion plant in Tokai, Ibaraki Prefecture, in 1999, prompted nuclear facility operators to set up off-site centers to deal with severe accidents. Manuals for operation of such centers have been placed at local governments, nuclear facilities and regional public facilities.

The All Japan Council of Local Governments with Atomic Power Stations requested METI, the Nuclear Safety Commission and the Federation of Electric Power Companies of Japan on July 23 to secure seismic safety of each nuclear power station and promptly provide information upon any troubles[18]. In response, TEPCO considered enhancing its contingency arrangement while conducting restoration and checking operations. On October 15, TEPCO established the "Niigata-Chuetsu-Oki Earthquake Restoration Management Center" at its Nuclear Asset Management Department to integrate contingency systems at nuclear power stations and secure their quality and safety[19]. The Kashiwazaki and Kariwa municipal governments will hold sufficient talks with TEPCO on functions and operations of the off-site center. Further enhancement of contingency plans as well as reconfirmation of seismic safety would be a key prerequisite for restarting the nuclear power station. The period of time for enhancing contingency plans is uncertain, but TEPCO may be able to enhance contingency plans while conducting seismic safety assessment as discussed in Section 1-3-1.

Given the above considerations, we can conclude that the critical technical path to restarting the nuclear power station is "reaffirmation of seismic safety." The essential point is that the seismic safety should reach a certain level from a technological viewpoint. However, relevant parties including the central government, local governments, local residents and TEPCO may find it not easy to reach agreement on decision of restarting the nuclear power station. Even if the plants are technologically ready to restart, some of the parties may find it hard to allow the restart from the different point of view. TEPCO will naturally do its best to promptly restart the nuclear power station while meeting safety requirements, however, there is uncertainty over the timing for restarting the nuclear power station.

2. Review of Impacts on Electricity Supply/Demand and Oil/Gas Markets

The previous chapter covered the chronology and present situation regarding the unplanned shutdown of the Kashiwazaki-Kariwa nuclear power station. Based on the previous chapter, this chapter reviews the impacts of the unplanned shutdown on electricity supply/demand balance in the summer of 2007 and those of TEPCO's extra oil and gas procurement on fossil fuel markets.

2-1 Summer 2007 supply/demand adjustment review

TEPCO's FY 2007 power supply plan had set the maximum daily demand (in terms of generated and received power)[20] at 61.10 GW, the maximum three-day daily average at 60.37 GW, supply capacity[21] at 65.62 GW and the reserve margin[22] at 8.7% for the summer of 2007. Just

[18] "Request Regarding Seismic Safety of Nuclear Power Stations," as released by the All Japan Council of Local Governments with Atomic Power Stations on July 23, 2007.

[19] TEPCO press release dated October 15, 2007

[20] For usual summer heat conditions, an average of maximum temperatures for maximum power demand days in the past 10 years is assumed. The generated and received power covers generating-end output at TEPCO-owned power stations and sending-end output (generating-end output minus power consumption at stations) for other power stations.

[21] Supply capacity is given as a monthly average.

before the Kashiwazaki-Kariwa nuclear power station shutdown, TEPCO had secured 65.27 GW as supply capacity for August and expected no supply problem for the summer. Upon the nuclear power station's shutdown triggered by the earthquake on July 16, TEPCO lost 7.26 GW out of the average supply capacity planned for August. The maximum supply capacity thus plunged to 58.01 GW just after the earthquake, forcing TEPCO to urgently secure extra summer supply capacity. The company was required to cover the planned supply capacity of the Kashiwazaki-Kariwa nuclear power station with extra power generation including thermal generation. At the end of March 2007, TEPCO's power generation capacity totaled 61.83 GW[23] -- 8.99 GW in hydroelectric power generation, 35.53 GW in thermal power generation and 17.31 GW in nuclear power generation. Including power received from other companies, TEPCO's total capacity stood at 75.52 GW[24]. The 8.212 GW Kashiwazaki-Kariwa nuclear power station accounted for 13.1% of TEPCO-owned capacity or 10.9% of total capacity including power received from other companies.

We here would like to review power supply/demand adjustment measures within the TEPCO service area for the summer of 2007. In early July 2007 before the earthquake, TEPCO had reopened two thermal power units[25] in long scheduled shutdown with capacity totaling 440 MW, including power received from others, in order to address drought and other risks. After the earthquake, the company was forced to secure more additional supply capacity. Additional supply capacity that TEPCO secured by its July 30 announcement totaled 4.44 GW including 1.66 GW in power provided by other power utilities, 2.08 GW through operational capacity increase at existing powers stations (over load operation by mainly thermal power stations) and changes to periodic inspection schedules, and 700 MW in purchases from private power generators. Later, it changed[26] a periodic inspection schedule for the Unit 3 reactor of the Fukushima Daiichi nuclear power station to further increase additional supply capacity to 4.74 GW by August 20 before the summer's peak demand day. TEPCO's total supply capacity including additions stood at 62.75 GW then. Against an anticipated peak demand at 61.10 GW, TEPCO then planned its reserve capacity at 1.65 GW and the reserve margin at 2.7% (see Figure 2-1 for changes in capacity and Figure 2-2 for additional supply capacity). Furthermore, TEPCO obtained an emergency permission to make its 900 MW Shiobara hydroelectric power station available for operation between July 30 and September 7, 2007. A one-year ban on water intake from May 2007 had been imposed on the station following its illegal water intake from an upper reservoir.

Figure 2-1 Changes in Power Supply/Demand for TEPCO in 2007

---

22 The ratio of reserve capacity to maximum demand. Reserve margin (%) = (supply capacity - maximum demand) / maximum demand x 100

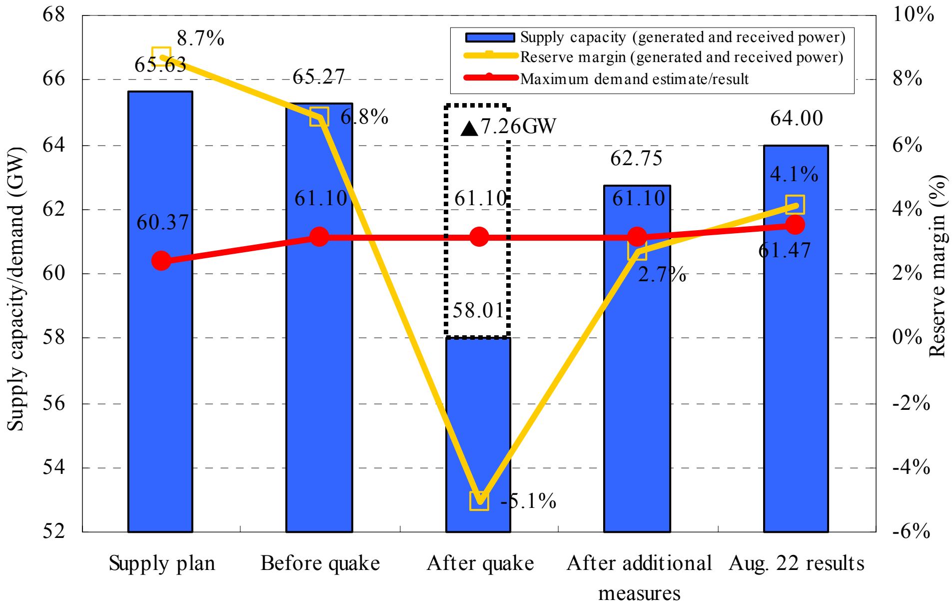
23 FY 2007 Electric Power Industry Handbook

24 FY 2007 TEPCO Power Supply Plan

25 Goi thermal power station's Unit 2 (265 MW) and Joban joint thermal power station's Nakoso Unit 6 (175 MW).

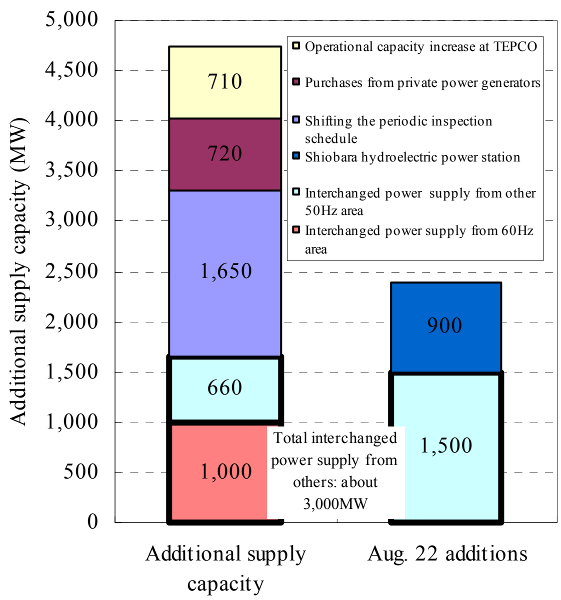
26 The first day for a periodic inspection was moved from August 20, 2007 to August 31, 2007.

(in terms of generated and received power)



Sources: FY 2007 TEPCO Power Supply Plan, TEPCO press releases

Figure 2-2 Additional TEPCO Supply Capacity in Summer of 2007



Sources: Electric Power Industry Panel data, TEPCO press releases

TEPCO considered restarting thermal power stations in long scheduled shutdown[27]. But it

[27] According to the FY 2007 TEPCO supply plan, six thermal power generation units with a total capacity at 1.93 GW had been scheduled to be in shutdown as of July 2007. (Of them, the Goi thermal power station's 265 MW Unit 2 had been restarted before the earthquake.)

eventually gave up on their operation for the summer of 2007 because of some time required for preparations. When TEPCO was ordered to shut down nuclear power stations due to its coverup of troubles in 2003, it had time to make preparations for restarting thermal power stations in scheduled shutdown. Since the peak-demand day came a little more than one month after the surprise earthquake in July 2007, TEPCO had to make maximum use of existing reserve capacity and secure additional supply capacity within a short period of time.

Regarding demand, TEPCO increased contract-based flexible electricity demand cuts by some 200 MW from the pre-earthquake level to 1.27 GW (by August 20). Under special demand adjustment contracts, TEPCO would ask certain large customers to reduce electricity demand in response to a tight supply/demand balances.

Next, we would like to review the electricity supply/demand situation upon the demand peak in the summer of 2007.

As for weather conditions in the summer of 2007, the seasonal rain front stayed close to Japan in July. The rainy season ended 12 days later than the historical average. Temperatures remained below average levels. After the rainy season ended around August 1, however, heat waves hit Japan in the middle of August. There were many extremely hot days where the peak temperature exceeded 35 degrees C. Temperatures hit the highest levels on record at various points[28]. In Kumagai, Saitama Prefecture, on August 16, the peak temperature rose to 40.9 degrees C, the highest on record in Japan. Temperatures thus exceeded average-year levels. The average peak temperature for the Tokyo region in August stood at 33.0 degrees C, the fourth highest on record[29].

Under such weather conditions, heat waves grew severer from August 20 after the Obon festival holidays in Tokyo. Peak demand within TEPCO's service area reached 60.13 GW on August 21, exceeding 60 GW for the first time in the summer. As air conditioning demand rose fast on high temperatures in the morning of August 22, TEPCO revised an anticipated demand peak upward to 61.50 GW and added the 900 MW Shiobara power station to its supply capacity. The station, which was available for emergency operation under special permission, began operation with the maximum output at 300 MW at 1 p.m. Interchanged power supply totaled some 3 GW as some 1.5 GW from the Tohoku and Hokkaido regions with lower temperatures[30] came in addition to 1.66 GW as secured under existing contracts with other utilities. Supply capacity for the TEPCO service area thus aggregated 64 GW. Regarding demand, TEPCO requested 23 customer plants under existing prompt demand adjustment contracts[31] to reduce demand by some 140 MW. TEPCO implemented

[28] In Japan, 101 points saw their respective highest ever maximum temperatures on record.
[29] The highest ever monthly average peak temperature for the Tokyo region was 33.7 degrees C in August 1995.
[30] The average maximum temperature for the seven prefectural capitals within Tohoku Electric Power Co.'s service area on August 22 dropped by 2.8 degrees C from 31.8 degrees C on August 21 to 29.0 degrees C.
[31] These contracts with large industrial customers provide for discounts in electricity charges in exchange for demand cuts implemented some 20 minutes after notification.

such demand adjustment for the first time in 17 years. The 23 plants were among customers that had special demand adjustment contracts with TEPCO. These supply and demand adjustment measures allowed TEPCO to clear the demand peak of 61.47 GW[32] with a reserve capacity at 2.5 GW or a reserve margin of 4.1% (see Figures 2-1 and 2-2.).

About 3 GW in interchanged power supply[33] from other utilities on the peak-demand day of August 22 amounted to 4.9% of the demand peak at 61.47 GW. The percentage exceeded the day's reserve margin of 4.1%. This means that TEPCO would have failed to achieve a supply/demand balance at the demand peak without interchanged power supply from other companies. In August, nationwide bilateral electricity transactions through interconnected transmission lines[34] totaled 11.35 TWh and spot transactions came to 220 GWh[35]. Transactions through interconnected transmission lines thus hit the highest level since relevant data began to be compiled in April 2005. Transactions through bilateral bargaining exceeded those through the Japan Electric Power Exchange. The reason behind this may be because TEPCO, in anticipation of a tightening supply/demand balances, chose to secure electricity supply through bilateral transactions with other power utilities that are reliable and have abundant supply capacity. Eventually, wide-area bilateral electricity provision contributed to stable supply at the summer's demand peak. Additional interchanged power supply secured just before the demand peak from the 50Hz area was made available thanks to the day's weather conditions. Additional supply from the 60Hz area came at 100% of the maximum capacity at 1 GW for the relevant frequency changer. There was no reserve capacity. The event has triggered discussions about the need for expansion of interconnected transmission lines and the reconsideration of reserve margins. How to secure stable electricity supply in the face of a large capacity loss on a shutdown of a large power station has been left for future consideration.

2-2 Impacts on LNG Market in and before September 2007

Thermal power stations played a key role in making up for the lost nuclear power generation capacity. Particularly, LNG and oil thermal power stations played a central role, indicating that additional demand might have emerged for LNG and oil for power generation. We here would like to discuss such additional demand, additional procurement from international

[32] The highest ever demand peak for TEPCO was 64.30 GW on July 24, 2001. TEPCO cited electricity-saving efforts, an increase in separated demand and the peak temperature below the record level as factors behind the August 22 demand peak that fell short of exceeding the past record.
[33] TEPCO received a total of 32.43 GWh in interchanged power supply from other companies in August.
[34] The following are interconnected transmission lines between TEPCO and other power utilities:
- Tohoku-Tokyo Soma Futaba line with transmission capacity at 6.31 GW (network stability constraints limit maximum transmission from Tohoku to Tokyo to 5 GW and that from Tokyo to Tohoku to 1.1 GW).
- Tokyo-Chubu frequency changers with transmission capacity at 1 GW (including the 300 MW Sakuma FC, the 600 MW Shin-Shinano Substation and the 100 MW Higashi-Shimizu Substation)
[35] Source: Statistics from the Electric Power System Council of Japan

markets and their impacts.

2-2-1 Analysis of procurement indicated by LNG delivery and consumption data

First, we would like to review the impacts of the unplanned nuclear power plant shutdown on the LNG market in the July-September quarter for which the latest real data have been available. Usually, we compare the July-September data with past data to find any conspicuous changes in the quarter. It is conceivable for us to compare the July-September 2007 data with the July-September data for the past five years or the previous year, or the January-June 2007 data. We have chosen to compare the July-September 2007 data with year-before data for the following reasons:

- In the July-September quarter of 2006, there was not any accident similar to the unplanned nuclear power plant shutdown having great impacts on LNG supply/demand.
- The July-September LNG delivery and consumption data are different from those for other quarters because the TEPCO service area's electricity consumption reaches an annual peak in the July-September quarter[36].

These reasons will stand for analyzing impacts on the oil market as discussed in Section 2-3.

How much additional LNG had to be procured? Table 2-1 indicates LNG delivery and consumption at TEPCO in the July-September quarter of 2006 and 2007. This shows substantial increases in July-September 2007 LNG delivery and consumption from year-before levels. In the quarter, consumption exceeded delivery, indicating that TEPCO consumed any increase in delivery without accumulating LNG inventories.

Table 2-1 TEPCO's LNG Delivery and Consumption

(July-September quarter of 2006 and 2007)

(1,000 tons)

	2006			2007			2007－2006			
	July	August	September	July	August	September	July	August	September	July-September
Delivery	1,531	1,631	1,407	1,742	1,972	1,596	211	341	189	741
Consumption	1,424	1,512	1,469	1,631	1,998	1,681	207	486	212	905

Source: TEPCO Website

Next, we would like to examine how the additional volume of LNG could be procured. Since LNG is characteristically different from oil, additional draw down from domestic storage inventories is basically inconceivable[37]. Therefore, additional supply might have been covered by

[36] FY 2003-2006 data showed the monthly average LNG acceptation for the July-September quarter tended to exceed such average for any other quarter (according to the TEPCO website).

[37] Given LNG's characteristics (including ultralow temperatures and emergence of boil-off gas), LNG inventories are

increased imports. Specific additional procurement options include making use of upward quantity tolerance under existing long-term LNG import contracts[38], expansion of joint LNG procurement with Mitsubishi Corp. from Oman[39], and purchases at spot markets. TEPCO's existing LNG import contracts are estimated to cover some 18 million tons in annual imports. Upward quantity tolerance may allow TEPCO to secure some additional procurement[40]. A media report stated that TEPCO had decided before the shutdown to take delivery of 600,000 tons out of 800,000 tons in Mitsubishi's annual procurement form Oman and eventually accepted the remaining 200,000 tons as well[41]. Finally, we look at Japan's LNG procurement from spot markets. Table 2-2 indicates LNG arrivals at Japanese ports in the July-September quarter of 2006 and 2007. An increase in spot purchases was seen in 2007. But the following factors have made it difficult to attribute the increase to the unplanned nuclear power plant shutdown:

- No published data exist on TEPCO's spot LNG procurement in the quarter. (TEPCO and Tokyo Gas Co. jointly own some LNG terminals.)
- Given the usual lead time for spot procurement (including price negotiations, port coordination and maritime transportation), any LNG purchases resulted from the loss of nuclear power right after the earthquake were estimated to arrive in Japan in late September at the earliest.
- It is difficult to estimate TEPCO's additional LNG procurement, including upward quantity tolerance and spot purchases, from existing long-term contract partners.

Any additional LNG purchases after the earthquake might have not arrived in Japan in time for an August power demand peak. Nevertheless, spot LNG purchases in the July-September quarter of 2007 increased from the year-before level. This could be interpreted as indicating electric power utilities had secured an increase in LNG procurement even before the earthquake in anticipation of summer heat waves.

---

too costly to maintain. It is therefore difficult to hold massive inventories.

[38] LNG contracts usually set some flexibility of delivery to fill gaps between anticipated and real demand (all contracts do not necessarily have such options). An upward quantity tolerance is usually set at around 5%.

[39] TEPCO and Mitsubishi Corp. have agreed that their 50-50 joint venture would accept 800,000 tons in annual LNG procurement by Mitsubishi from Oman and allocate LNG between the two according to supply/demand and market conditions.

[40] If all contracts have 5% high elasticity options, TEPCO may acquire up to 900,000 tons in additional procurement.

[41] Source: The Nihon-Keizai Shimbun on September 24, 2007

Table 2-2 LNG Arrivals in Japan (July-September quarter of 2006 and 2007)

(1,000 tons)

		2006			2007			2007-2006		
		July	August	September	July	August	September	July	August	September
Major long-term contract partners	Malaysia	1,040	1,153	960	1,214	1,040	1,056	174	-114	96
	Brunei	524	562	522	582	517	581	57	-45	60
	Indonesia	1,054	1,156	1,228	1,099	1,150	1,037	45	-6	-191
	Qatar	541	719	730	726	726	672	185	8	-59
	Oman	187	376	187	186	375	315	-1	-1	128
	UAE	448	547	426	491	487	426	43	-60	0
	U.S.	107	108	72	81	83	48	-26	-25	-24
	Australia	1,238	1,320	811	1,138	1,108	647	-101	-212	-164
	Subtotal	5,140	5,942	4,936	5,516	5,487	4,782	377	-455	-153
Partners for spot contracts alone	Trinidad & Tobago	-	54	56	56	-	104	56	-56	48
	Algeria	-	66	-	-	53	117	-	-14	117
	Egypt	-	-	-	61	236	60	61	236	60
	Nigeria	-	-	-	-	57	118	-	57	118
	Equatorial Guinea	-	-	-	-	-	118	-	-	118
	Subtotal	-	120	56	116	345	517	116	225	461
Total		5,140	6,062	4,991	5,632	5,831	5,299	493	-230	308

Source: Trade Statistics, Ministry of Finance

2-2-2 Impacts on prices

Next, we would like to review the impacts of additional LNG procurement on LNG prices. Table 2-3 indicates prices of LNG arrivals in Japan in the July-September quarter of 2006 and 2007. Prices under long-term contracts and spot deals in the two periods are not so remarkably different. Spot prices showed no particular changes during the July-September quarter of 2007.

Table 2-3 Prices of LNG Arrivals in Japan (July-September quarter of 2006 and 2007)

($ per million Btu)

		2006			2007			2007-2006		
		July	August	September	July	August	September	July	August	September
Major long-term contract partners	Malaysia	6.36	6.52	6.98	7.83	8.38	8.37	1.47	1.86	1.39
	Brueni	6.01	6.00	6.01	5.63	5.97	6.00	-0.38	-0.03	-0.01
	Indonesia	8.54	8.39	8.86	8.24	8.64	8.57	-0.30	0.25	-0.29
	Qatar	7.33	8.18	8.36	8.04	8.28	8.81	0.71	0.10	0.45
	Oman	5.95	8.45	9.90	6.70	7.05	7.44	0.75	-1.40	-2.46
	UAE	6.78	7.00	7.17	6.72	7.43	7.63	-0.06	0.43	0.46
	U.S.	6.64	7.02	7.13	5.79	5.97	6.09	-0.85	-1.05	-1.04
	Australia	6.89	6.60	6.86	6.37	6.52	7.93	-0.52	-0.08	1.07
	Average	6.81	7.27	7.66	6.92	7.28	7.61	0.10	0.01	-0.05
Partners for spot contracts alone	Trinidad & Tobago	-	10.53	9.66	11.93	-	8.68	-	-	-0.98
	Algeria	-	9.46	-	-	8.45	8.51	-	-1.01	-
	Egypt	-	-	-	7.27	10.28	10.89	-	-	-
	Nigeria	-	-	-	-	8.59	10.38	-	-	-
	Equatorial Guninea	-	-	-	-	-	9.08	-	-	-
	Average	-	10.00	9.66	9.60	9.11	9.51	-	-0.89	-0.15

Source: Trade Statistics, Ministry of Finance

2-3 Impacts on Oil Market in and before September 2007

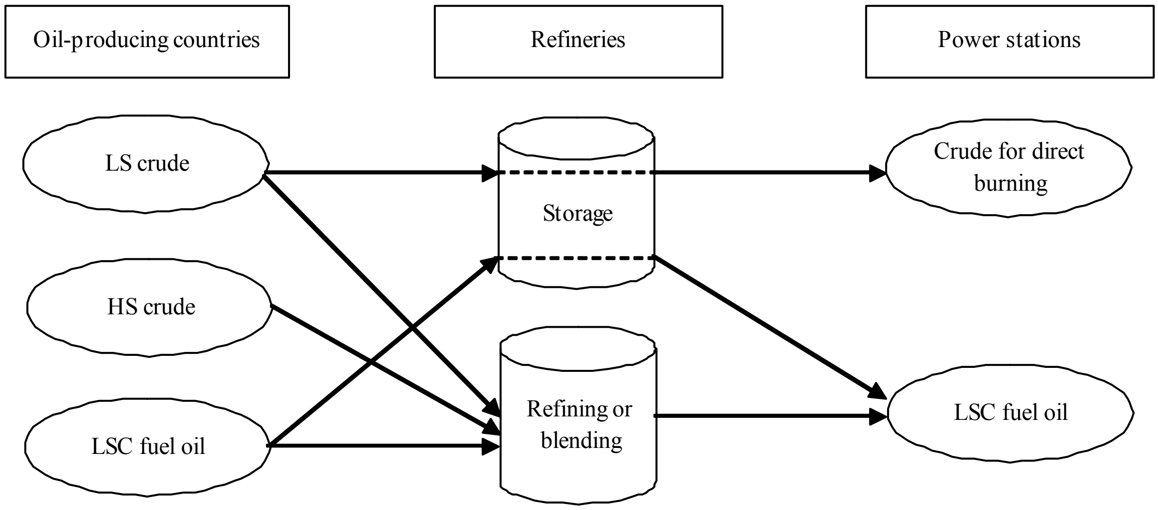
This section looks into the impacts that the unplanned shutdown of the nuclear power station exerted on the oil market.

Since categories and distribution channels for oil are more complicated than those for LNG, we may have to overview how oil as power generation fuel is classified and arrives at power stations before looking into specific developments regarding procurement of oil for power generation[42].

Crude oil that is used for direct burning at power stations is limited to low-sulfur crude. The low-sulfur crude oil is procured by oil companies or trading companies from oil-producing countries. Then the crude oil is delivered to power stations via oil refineries or directly. Fuel oil for power generation is basically limited to low-sulfur fuel oil.[43] The low-sulfur fuel oil is also procured by oil or trading firms and then delivered to power stations via oil refineries or directly. In some cases, crude and fuel oil is refined or blended at refineries to produce low-sulfur fuel oil for delivery to power stations[44]. Figure 2-3 indicates ordinary channels for distribution of oil for power generation from oil-producing countries to power stations.

Based on the above basic facts, we would like to look into additional procurement of oil for power generation between July's unplanned shutdown of the nuclear power station and September.

Figure 2-3 Distribution Channels for Oil for Power Generation from Oil-producing Countries to Power Stations



Source: IEEJ

[42] Oil for power generation includes crude and fuel oil for power generation.
[43] Some power stations burn high-sulfur fuel oil.
[44] In some recent cases, power utilities directly import low-sulfur crude and fuel oil from oil-producing countries.

2-3-1 Additional procurement methods

As is the case with LNG, oil procurement in the quarter and a year-before period is compared to find any addition procurement required in July-September 2007.

Table 2-4 indicates TEPCO's delivery and consumption of oil for power generation in the July-September quarter of 2006 and 2007. This shows a substantial increase in delivery and consumption of both crude and fuel oil. The gap between delivery and consumption in July-September 2007 is almost equal to the year-before level. This means no particular inventory build was carried out.

Table 2-4 TEPCO's Delivery and Consumption of Oil for Power Generation (July-September quarter of 2006 and 2007)

(1,000 kl)

		2006			2007			2007-2006			
		July	August	September	July	August	September	July	August	September	July-September
Crude	Delivery	117	123	95	177	233	249	60	110	154	324
	Consumption	59	72	83	160	195	209	101	123	126	350
Fuel oil	Delivery	314	258	190	395	726	633	81	468	443	992
	Consumption	243	269	236	403	775	604	160	506	368	1,034

Source: TEPCO Website

Next, we would like to look into Japan's imports and shipments of low-sulfur crude oil[45] (LS crude) and low-sulfur fuel oil C[46] (LSC fuel oil) in a bid to quantitatively analyze procurement of crude and fuel oil procurement. Table 2-5 indicates Japan's LS crude imports and shipments in the July-September quarter of 2006 and 2007. This shows that imports in July-September 2007 increased from a year earlier while shipments declined.

Table 2-5 Japan's LS Crude Imports and Shipments (July-September quarter of 2006 and 2007)

(1,000 kl)

		2006			2007			2007-2006			
		July	August	September	July	August	September	July	August	September	July-September
LS crude	Imports	1,435	1,003	1,146	1,715	1,229	1,227	280	227	82	588
	Shipments	581	577	456	514	364	574	-67	-213	118	-162

Source: Petroleum Association of Japan

Comparison of LSC fuel oil imports, production, exports and shipments in July-September 2007 with year-before levels, as shown in Table 2-6, indicates that imports remained almost unchanged while production increased by 721,000 kl. Exports remained almost unchanged while shipments expanded by 586,000 kl. Production and shipments thus increased substantially. Japan's

[45] LS crude here covers 10 brands that are generally used for power generation -- Sumatra Light (Minas), Cinta, Duri, Widuri, Light Seria, Bach-Ho, Sutuden, Nile Blend, Wandoo and Stag.

[46] In Japan, LSC fuel oil is mostly used for power generation.

total oil refining throughout in July-September 2007 totaled 58.25 million kl[47], almost unchanged from 58.38 million kl a year earlier.

Table 2-6 Japan's LSC Fuel Oil Imports, Production, Exports and Shipments (July-September quarter of 2006 and 2007)

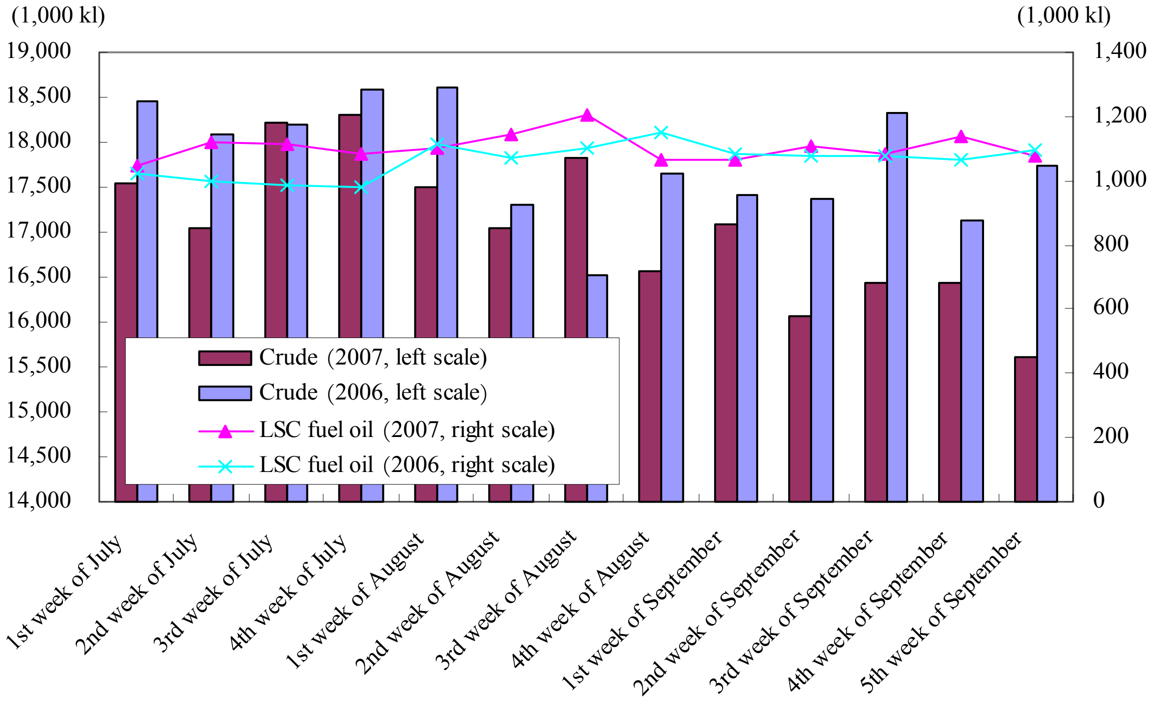
(1,000 kl)

	2006			2007			2007-2006			
	July	August	September	July	August	September	July	August	September	July-September
Imports	308	354	303	347	223	381	40	-131	78	-13
Production	325	535	507	418	744	926	93	208	419	721
Exports	0	0	0	6	3	6	6	3	6	15
Shipments	658	718	854	643	884	1289	-15	166	435	586

Source: Petroleum Association of Japan

Figure 2-4 compares crude[48] and LSC fuel oil inventories in July-September 2007 with their respective year-before levels. Crude inventories in 2007 decreased slightly, while LSC fuel inventories remained almost unchanged.

Figure 2-4 Japan's Crude and LSC Fuel Oil Inventories



Source: Petroleum Association of Japan

The above data indicate the following conditions regarding procurement of oil for power

[47] Source: Petroleum Association of Japan statistics
[48] Crude here covers all brands.

generation between July's unplanned shutdown of the nuclear power station and September:

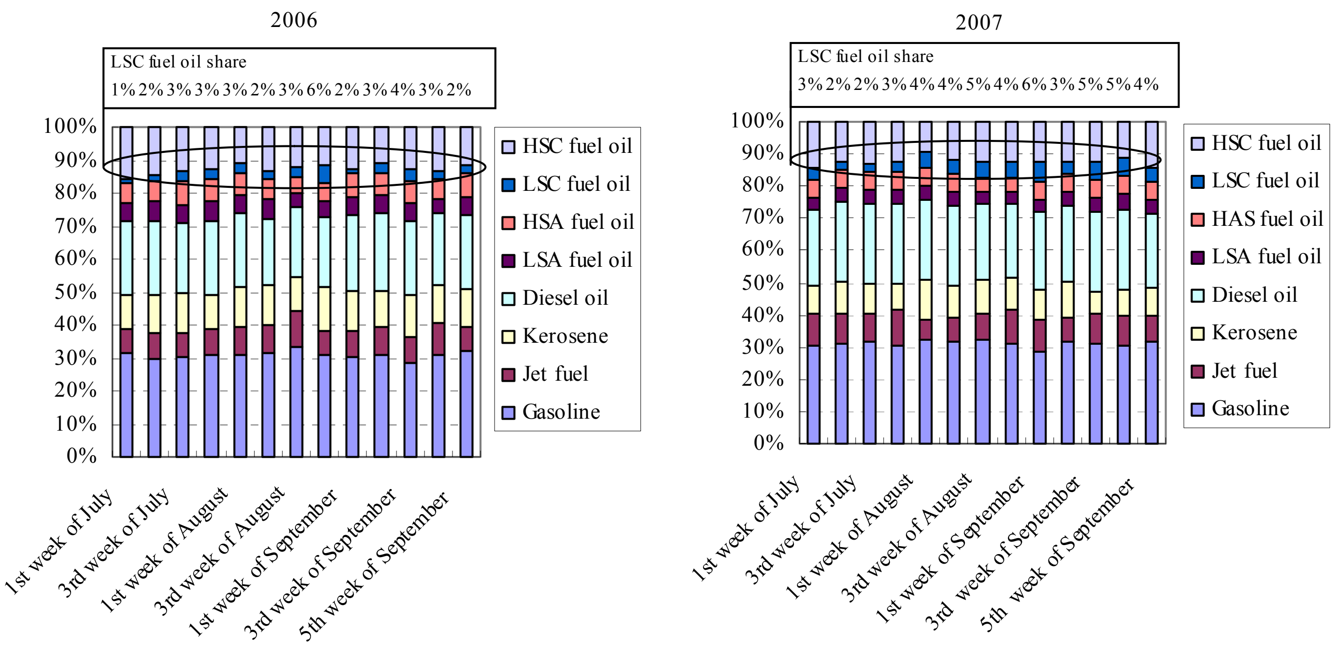
LS crude imports in the period increased from a year-earlier level, suggesting that the increased requirement basically supplied by imports for additional procurement. Given the lead time for procurement from oil-producing countries, however, it might have been difficult to arrange new imports after the July earthquake for arrivals in or before September. Therefore, oil companies and trading companies might have drawn down inventories[49] to cover the additional procurement.

As is the case with crude, LSC fuel oil imports are put under lead time constraints. Imports, exports, crude oil refining and inventories in July-September 2007 remained almost unchanged from their respective year-before levels, while production and shipments increased substantially. This indicates that oil refineries gave priority to LSC fuel oil production while cutting output of other petroleum products.

Figure 2-5 breaks down petroleum products[50] produced at Japanese refineries in the July-September quarter of 2006 and 2007. This also indicates that refiners boosted LSC fuel oil's share of total output while lowering shares for other products.

Figure 2-5 Breakdown of Output at Japanese Refineries

(July-September quarter of 2006 and 2007)



Source: Petroleum Association of Japan

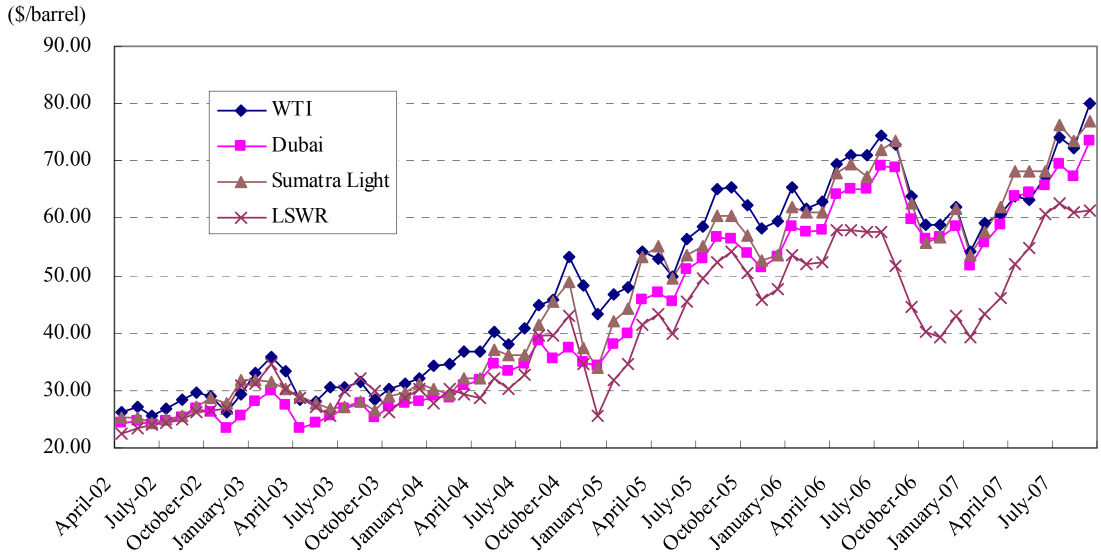
2-3-2 Impacts on Prices

49 Inventories here include crude that oil and trading companies procure from oil-producing countries for direct delivery to power stations, without bringing imports to oil refineries.

50 Naphtha is excluded.

We have so far examined the quantitative aspect of procurement of oil for power generation. As noted above, it is estimated that TEPCO may have depended on domestic crude inventories and increased fuel oil output at refineries for additional procurement of oil for power generation. We here would like to confirm impacts of such additional procurement on oil prices. Figure 2-6 indicates price changes for the West Texas Intermediate, Dubai[51], Sumatra Light[52] and LSWR[53] between April 2002 and September 2007.

Figure 2-6 Price Changes for WTI, Dubai, Sumatra Light and LSWR (between April 2002 and September 2007)



Source: IEA Weekly Oil Market, etc.

First, attention must be paid to the fact that WTI and Dubai crude oil prices are more likely to be affected by the supply/demand balances for total oil products than products for power generation only, as crude is used to produce various products[54]. As well as real supply/demand conditions, fund flows and other factors can also affect crude oil prices. TEPCO's additional oil procurement accounted for a limited share of the oil market[55] and had far weaker influences on the market than its additional LNG procurement's effects on the LNG market[56]. Therefore, any new requirement from TEPCO, oil firms or trading companies for additional oil procurement might have

[51] Dubai is the benchmark Middle Eastern crude oil for Asia.
[52] Sumatra Light is traded mainly as LS crude for power generation. It is a representative brand for power generation.
[53] LSWR stands for low sulfur waxy residue. It means LSC fuel oil or heavy distillate as a material for LSC fuel oil. LSWR serves as the benchmark for international LSC fuel oil prices in Asia.
[54] In fact, fuel oil C production in Japan in FY 2006 accounted for only some 15% of petroleum products output (oil statistics by the Agency for Natural Resources and Energy).
[55] TEPCO's additional oil procurement amounted to some 6 million kl in terms of crude oil. The amount is equivalent to only 0.3% of the world's annual crude oil trade (some 2.3 billion kl in 2006, according to BP Statistics 2007).
[56] TEPCO's additional LNG procurement amounted to about 2.5 million tons, equivalent to 1.7% of the world's annual LNG trade (about149 million tons in 2006, according to BP Statistics 2007).

had only limited impacts on the market. Thus, although crude oil prices rose in September, the price hike has had little direct link with TEPCO's additional oil procurement accompanying the unplanned shutdown of the nuclear power station.

However, since Sumatra Light and LSWR are primarily used for power generation and their market size is fairly limitable, the additional procurement from these fuels by TEPCO, oil firms or trading companies could lead to a tighter supply/demand balances and higher prices for these fuels. As far as Figure 2-6 indicates, however, Sumatra Light and LSWR prices posted no conspicuous hikes after July's unplanned shutdown of the nuclear power station. This is reasonable, given that our analysis has indicated that TEPCO depended on inventories for additional crude oil procurement and on increased production for additional fuel oil purchases until September. As far as the price trends indicate, any additional crude or fuel oil procurement by TEPCO might have had only limited impacts on the market for the period examined by this paper[57].

3. Estimated Impacts on International Markets

The previous chapter reviewed the impacts of the unplanned shutdown of the nuclear power station on electricity supply and demand in the summer of 2007 and those of TEPCO's additional oil and gas procurement on the fossil fuel market. This chapter analyzes the unplanned nuclear plant shutdown from the viewpoint of the whole of Japan since the entire electric power industry was involved in interchanged power electricity supply to TEPCO. Based on some preconditions, the impacts of the shutdown of the 8.21 GW power station are estimated in terms of substitute power generation, additional fuel consumption and carbon dioxide emissions. These estimates are used for analyzing the impacts of the shutdown on the international energy market.

3-1 Estimation of substitute power generation, additional fuel consumption and CO2 emissions accompanying the 8.21 GW nuclear power plant shutdown

This section deals with estimation of substitute power generation, additional fuel consumption and CO2 emissions accompanying the shutdown of the 8.21 GW nuclear power station. The estimation is based on capacity utility factor for the Kashiwazaki-Kariwa nuclear power station under the FY 2007 electricity supply plan and real data for the past three years (FY 2004-2006). Estimates will be made for the following two cases -- (A) electricity output loss is estimated on the assumption of the capacity utilization rate of 74.7% for the relevant nuclear power station (= the amount of electricity lost on the shutdown) and (B) electricity output loss is estimated on the assumption of the capacity utility factor of 84% for the relevant nuclear power station (= the amount of electricity lost on the shutdown). Estimates results are shown in Table 3-1.

[57] The Nikkei Shimbun on September 8, 2007, stated that TEPCO's additional LS crude demand accompanying the unplanned shutdown of the nuclear power station was less than expected by the market. The International Energy Agency's Oil Market Report (September 2007) made a similar comment regarding LSC fuel oil.

Table 3-1 Estimated Substitute Power Generation, Additional Fuel Consumption and CO2 Emissions Accompanying the 8.21 GW Nuclear Power Plant Shutdown

Estimate	Unit	Estimated FY 2007 impacts	Estimated impacts of year-long shutdown	
			Case A	Case B
Power generation lost on the 8.21 GW nuclear power plant shutdown	TWh	40.4	53.6	61.1
Percentage of Japan's power generation for utility services (FY 2006)	%	4.2%	5.5%	6.3%
Substitute oil thermal power generation	TWh	24.3	32.1	36.7
Substitute LNG thermal power generation	TWh	16.2	21.4	24.5
Additional oil consumption (in fuel oil)	1,000 kl	5,790	7,671	8,756
Percentage share of Japan's crude and fuel oil consumption for power generation (FY 2006)	%	39.0%	51.6%	58.9%
Additional LNG consumption	1,000 tons	2,542	3,367	3,843
Percentage of Japan's LNG consumption for power generation (FY 2006)	%	6.7%	8.8%	10.1%
Additional CO2 emissions	million tons	23.7	31.5	35.9
Percentage of Japan's CO2 emissions (1990)	%	1.9%	2.5%	2.8%

Source: Estimated by IEEJ with FY 2007 TEPCO Electricity Supply Plan, etc.

（Note） The power generation loss from shutdown of the 8.21 GW nuclear power plant was estimated on the assumption of the following two capacity utility factor:

・Case A: If there is no unplanned shutdown, the average capacity utilization rate of 74.7%. (The rate is equivalent to the actual average rate of the past three years (FY 2004-2006) at Kashiwazaki-Kariwa.)

・Case B: If there is no unplanned shutdown, the average capacity utilization rate of 85%.(This value is based on the plan by electric power utilities for four years from FY 2011.)

Estimated impacts in FY 2007 are those after the unplanned nuclear power plant shutdown.

The electricity loss on the shutdown was estimated at 40 TWh for FY 2007. The shutdown of the 8.21 GW nuclear power station means an annual loss of 53 billion to 61 TWh. The loss amounts to 5-6% of electricity generation by utilities in FY 2006.

In FY 2007, TEPCO's electricity supply capacity for thermal power stations included about 12 GW for oil thermal plants and about 24 GW[58] for LNG thermal plants. These power plants' capacity utility factor differs depending on their respective thermal efficiencies. The average capacity utility factor is some 20% for oil thermal plants and about 50% for LNG thermal plants. As far as the required substitute power generation amount is concerned, TEPCO can achieve the substitute generation by raising capacity utility factor at thermal plants. But coal thermal power plants are not taken into account since their capacity utility factor is already high with additional generation potential limited.

Regarding substitute power generation, it is reasonable to give priority to LNG thermal plants rather than oil thermal plants because the economic factors and less emission of lCO2. But

[58] FY 2007 TEPCO Electricity Supply Plan, FY 2007-end Power Mix.

additional LNG procurement is put under various constraints. Although spot LNG transactions have increased over recent years, long-term contracts are still dominant with the limited supply flexibility. LNG delivery and gasification capacities are also limited. It may be reasonable to assure there is an upper limit for additional LNG procurement. Based on the market facts, LNG thermal plants are assumed to cover 40% of the substitute power generation, given realistic additional LNG procurement. The remaining 60% is assumed to come from oil thermal plants that burn fuel featuring greater supply flexibility than LNG.

Based on these shares of the substitute electricity generation, additional consumption is estimated at about 5.8 million kl for oil (fuel oil, the same hereinafter) and at about 2.5 million tons for LNG for FY 2007. If the shutdown continues for one year, additional consumption may total 7.6 million to 8.8 million kl in oil and 3.3 million to 3.9 million tons in LNG. The annual additional oil consumption is equivalent to about 51-59% of crude oil consumption for power generation in Japan in FY 2006. The estimated annual additional LNG consumption amounts to about 8-10% of Japan's LNG consumption for power generation in FY 2006.

Additional fossil fuel consumption boosts CO2 emissions. Based on the estimated additional fuel consumption, additional CO2 emissions are estimated at about 24 million tons[59] for FY 2007. If the shutdown continues for one year, annual additional CO2 emissions may total about 31 million to 36 million tons. The estimated additional emissions are equivalent to about 2-3% of Japan's total CO2 emissions in 1990.

According to an interim report by the Global Environment Subcommittee, Environment Committee, Industrial Structure Council, and the Global Environment Committee of the Central Environment Council, greenhouse gas emissions in 2010 may rise by 0.9-2.1% from 1990 if nuclear power stations operate at some 88% of their total capacity. If nuclear power stations' capacity utility factor decline, emissions may increase further.

According to the World Bank's projections[60], demand for emission credits under the Kyoto Mechanism for the first Kyoto Protocol commitment period between 2008 and 2012 would total about 1.6 billion to 2.6 billion tons in CO2. Emission credit supply through CDM[61] and JI[62] may come to about 1.7 billion tons in CO2. But this figure does not include emission credits held by Central East European countries. Therefore, there exists a certain degree of uncertainty about the future carbon market supply/demand balance. Japan may have to take advantage of emission credit

[59] TEPCO has estimated additional CO2 emissions at about 28 million tons in FY 2007 for a case where oil thermal plants alone would cover the whole of the substitute power generation.
[60] "State and Trends of the Carbon Market 2007" by the World Bank
[61] CDM stands for the Clean Development Mechanism representing greenhouse gas emission reduction projects between industrial and developing countries.
[62] JI stands for the Joint Implementation representing greenhouse gas emission reduction projects between industrial countries.

trading to achieve its emission reduction goal under the Kyoto Protocol while taking account of extra CO2 emissions resulting from the nuclear plant shutdown. The problem should be regarded as a national issue. The entire nation is now required to make decisions and take measures to achieve the goal.

As indicated by the above discussions, the impacts that a shutdown of a large-capacity nuclear power station on fossil fuel consumption and CO2 emission reduction are not small. This means that smooth operations of nuclear power stations at high capacity utility factor would make substantial contributions to reducing dependence on fossil fuels and CO2 emissions. On the contrary, an unplanned shutdown of a large-capacity nuclear power station could result in increase in fossil fuel procurement and CO2 emissions, the extent of the impacts being dependent on the duration of the shutdown and its capacity utility factor.

The next section deals with the impacts of additional fossil fuel procurement on the international energy market and future prospects.

3-2 Future LNG market outlook

The previous chapter looked into additional LNG procurement in the July-September quarter and such procurement's impact on LNG prices in the period. At present, we have found that the additional LNG procurement has fallen short of causing any sharp LNG price hikes as far as quantitative data are concerned. On the LNG market in the summer of 2007, spot procurement by Europe and the United States was not as much as usual. Additional procurement might have been possible to some extent depending on pricing agreements. Under such conditions, additional volume might have procured by spot procurement while minimizing any impact on prices.

In the meantime, some information[63] stated that Asian market spot prices rose above $11 per million Btu for arrivals in Japan in October and November. Prices could rise further if buyers other than Japanese utilities increased purchases toward the winter LNG demand season. For example, Korea Gas Co. (KOGAS), an LNG user as large as TEPCO, purchases 2.6 million tons on a spot basis usually toward the winter. For 2007, however, KOGAS began to take delivery of LNG from Qatar under a new long-term contract (for 2.1 million tons in annual imports) in March. At present, the coming winter in South Korea is forecast to be warmer than usual. Under such conditions, KOGAS is forecast to limit spot purchases for this winter to about 1 million tons. If the forecast turns on correct, Japanese utilities may be able to stably secure additional procurement.

If severe cold waves hit South Korea and Japan, however, spot prices may rise fast on a tighter supply/demand balance. Spot purchases are expected to have some spillover impacts on negotiations to renew long-term contracts. Japanese companies will have to pay attention to LNG

[63] Source: The Denki Shimbun, September 28, 2007

prices and supply/demand balance changes toward the winter in proceeding with LNG procurement.

3-3 Future oil market outlook

The previous chapter looked into additional procurement of crude and fuel oil as well as LNG in the July-September quarter and such procurement's impact on oil prices in the period. At present, we have found that the additional procurement of crude and fuel oil as well as LNG has fallen short of causing any sharp price hikes as far as quantitative data are concerned. As noted above, constraints regarding the lead time for procurement might have prompted the additional requirement to be covered by domestic inventories for additional crude oil procurement and on increased domestic production for additional fuel oil supply in the July-September quarter of 2007. In and after October, any large-scale additional oil procurement might have been refrained from implementing in view of smooth spot LNG procurement and oil price hikes.

On the other hand, LS crude inventories are limited. As kerosene production increases toward the winter demand season, LSC fuel oil production may be affected. In the fiscal second half from October, therefore, additional requirement for LSC fuel could depend on imports for additional oil procurement. Such moves could exert pressures on LS crude and LSC fuel oil prices to go up. Japanese utilities may examine and implement procurement while watching prices of both oil and LNG. If spot LNG prices rise substantially, their procurement may shift to oil. Such development may then exert pressures on oil prices to increase.

Electric power utilities, which have developed various electricity sources to diversify risks and prevent price hikes for one fuel from causing substantial rises in overall power generation costs, may have to keep close watch on market trend while considering such a variety of cases.

4. Conclusion and Implications

The unplanned and prolonged shutdown of the Kashiwazaki-Kariwa nuclear power station caused by the Niigataken Chuetsu-oki Earthquake on July 16, 2007 has exerted great impacts on various areas. As noted in Section 1-2, electric power utilities had been implementing seismic back check regarding the revision of the seismic design review guideline under instructions from METI and the Nuclear and Industrial Safety Agency before the earthquake, that forced them to substantially reform back check details and procedures. Although the seismic back check reform does not directly affect operation plans of nuclear reactors in operation, it would be effectively difficult to expect a restart of any nuclear power station in the unplanned shutdown status without getting relevant parties' understanding about the station's seismic safety. Therefore, it is difficult to forecast when the current shutdown is over. At the same time, nuclear facility operators' contingency procedures and information provision in emergency are now being examined. Nuclear facility operators may have to take a wide range of measures. In the future, nuclear facility operators will have to mobilize massive human and financial resources to address these problems.

Although TEPCO managed to maintain the electric power balance in the summer of 2007 with a reserve margin of 4.1% on peak by taking supply and demand adjustment measures, wide-area power provisions between electric power utilities which played a key role at 2007 peak demand time are not always guaranteed, as noted in Chapter 2. In emergency situation, it is possible that stability of electricity can be at risk. Although electricity network operations, including emergency interchanged power supply to TEPCO from other electric power utilities, were implemented smoothly in the summer of 2007, whether emergency interchanged power supply and network balancing between transmission lines connected through frequency changers or DC-AC inverters could be smoothly implemented would be a key problem regarding stable electricity supply in emergency.

It is important for energy industry people that the unplanned nuclear plant shutdown will have spillover impacts on the international energy market beyond the domestic electricity market. Energy industries always keep certain level of fuel inventories and can change in the product mix of refineries to prepare for sharp changes in supply and demand. Thanks to these efforts, any market turmoil (including price hikes) on a tighter supply/demand balance was avoided for the 2007 power demand peak in Japan that came a little more than one month after the earthquake. In case the shutdown is prolonged, the impacts of the shutdown of the power station which accounts for a large share of Japan's power generation cannot be ignored, as noted in Chapters 2 and 3.

The unplanned nuclear plant shutdown has indicated Japanese nuclear power generation's linkage to the international energy market by demonstrating how nuclear power generation affects fossil fuel markets and procurement, and CO2 emissions. In view of the impacts of the shutdown on fossil fuel markets and CO2 emissions, relevant parties should maximize their efforts to restart the nuclear power station as early as possible while giving top priority to safety. All energy industry players including electric power utilities should recognize the potential risk of a prolonged shutdown of a large-capacity power station like the Kashiwazaki-Kariwa nuclear plant, understand impacts of such shutdown on the global or Asian energy market and take advantage of such knowledge for future risk management.

Contact: report@tky.ieej.or.jp