Multiple disasters management: Lessons from the Fukushima triple events

Abstract

It has been five and a half years since the Great East Japan Earthquake (GEJE) in March 2011. This study summarize management and policy lessons from the GEJE. The recovery efforts that followed the triple disasters: the earthquake, tsunami and meltdown of the Fukushima Dai-ichi nuclear plant are in progress. The experience of the GEJE and tsunami prompted the building of embankments throughout the Pacific coastal side of the Tohoku region. The Cabinet's Reconstruction Headquarters used at least 19 trillion yen ($158 billion) for intensive reconstruction over five years through 2015. The local government of the affected area accelerated the decontamination of commercial land which is an important action for the recovery. The central government introduced the Electricity Business Act for implementing voluntary energy conservation measures for peak energy seasons. The GEJE has had an indirect effect on the health of the disaster victims via job uncertainty as well. Decontamination is crucial in bringing people and businesses back to the affected area and promoting sustainable economic recovery because it reduces uncertainty about the short and long-term health risks. An efficient health and occupation plan for the victims is essential for the integrated approach to multiple disaster management.

1. Introduction

The aftermath of the meltdown of the Fukushima Dai-ichi nuclear plant has severely complicated the process of recovery from the Great East Japan Earthquake (GEJE). The affected area has suffered from both economic damage and increased health risks due to residual radiation. Decontamination of the affected areas is still underway, but progress in the

recovery is evident. Discussion about nuclear radiation now focuses on pressing local governments to conduct regular environmental radiation monitoring and to update radioactive deposition data. This study summarize management and policy lessons from the GEJE.

Although the debate continues about preparedness before the event and disclosure of its severity, it appears that Japanese authorities have taken actions to mitigate the impact of radiation on human health. These actions include evacuating more than 200,000 inhabitants from the vicinity of the site, monitoring food and water, and systematically scanning evacuees. However, the situation at the Fukushima Dai-ichi nuclear facility remains fluid, and the long-term environmental and health impacts will likely take years to be fully known (Dauer et al., 2011).

The recovery process has two main pillars that are closely entwined. One is decontamination and the associated reductions in health hazards, and the other is the aggregate economic recovery. Economic recovery is possible only if evacuees return to the affected area (see Sanaei et al., 2016), which requires the health risk from radioactive contamination to be reduced. Economic damage from the radioactive contamination is well documented (Tanaka and Managi, 2016; Yamane et al., 2011a, b). An increase of 1μSv/h decreases the land price by 3.39% on average in Fukushima and Miyagi prefectures, and the estimated economic damage due to the radiation-related aftermath of the GEJE to Fukushima is approximately 64.1 billion Japanese yen (U.S. $0.53 billion) (Tanaka and Managi, 2016). However, research shows that the land price decline is only partially explained by increased levels of radiation. Population decreases also have indirectly affected land prices. Thus, population increase, which would result primarily through the return of victims to the area, is crucial for economic recovery (see Shin et al., 2016).

According to the Reconstruction Agency of Japan's annual survey of the victims who have been evacuated from severely contaminated areas, the decision to return to Fukushima depends

foremost on the recovery of infrastructure and public services that directly affect the recovery of their businesses. Another important concern for the evacuees is the speed in which the decontamination process takes place (Reconstruction Agency, 2014).

Decontamination is crucial in bringing people and businesses back to the affected area and promoting sustainable economic recovery because it reduces uncertainty about the short and long-term health risks. To date, more than 1,500 billion yen ($12.5 billion) has been invested in the decontamination process. The *Act of Special Measures Concerning the Handling of Pollution by Radioactive Materials* has provided the legal basis to spend large amounts of money for decontamination, but the process is still incomplete (Yasutaka et al., 2013). The problem is that the Fukushima Dai-ichi nuclear plant has been continuously releasing radioactive substances. Therefore, the very source of radioactive contamination has yet to be stemmed.

Allocating resources to decontamination is difficult given the high cost and the limited budget for recovery from the multiple disasters. In the future, it may be useful to prioritize decontamination by ranking the capacity of the land to generate economic value. One possible solution for the recovery of the affected area would be to accelerate decontamination of commercial land and delay decontamination of farmland. Given budget limitations, commercial land has a relatively higher monetary value, and therefore. the optimal length of the decontamination process for commercial land is 5-10 years as compared to more than 30 years for farmland (Munro, 2013).

2. Lessons in managing and recovering from the triple disasters

2.1 Dealing with energy shortages

The GEJE and the subsequent accidents in the Fukushima Dai-ichi nuclear plant catalyzed the revival of the energy security problem in Japan. Moreover, the accident destroyed the image

of nuclear power as a safe and efficient energy source. As a result, the government shut down all 54 nuclear plants, causing the share of nuclear power in electricity generation to drop from 30% to zero for almost two years until the recent restart of the Sendai Nuclear power plant in Kagoshima on August 11th, 2015. This decline in electricity generated by nuclear plants boosted the share of imported fossil fuels for electricity generation.

Such policy changes increased the import cost of fossil fuels for electricity generation by approximately 3.6 trillion yen ($30 billion) per year as compared to before the earthquake (Ministry of Economy Trade and Industry (METI), 2010). Given that a large share of the additional fossil fuels come from the Middle East and North Africa, where many countries suffer from political instability, the government has restricted electricity consumption during peak demand seasons. The government restricted electricity use in 2011 through the Electricity Business Act, setting specific target numbers for 2011 and 2012, and then implemented voluntary energy conservation measures for peak energy seasons from 2012 to 2015.

Consumption behavior in Japan changed to deal with energy shortages in the short and long term. Restrictions on electricity usage reduced consumption by 8% (Okajima et al., 2015). In the industrial sector, restrictions reduced electricity consumption in both the short and long term. Electricity consumption decreased more in summer than in winter. In the residential sector, restrictions reduced electricity consumption only in the short term and only in summer.

The aftermath of the accidents has induced heated debate domestically and internationally as to whether nuclear power is required to secure energy in the short and long term. The government has developed a nationwide argument that takes into account the factors of safety, efficiency, economy, and environment, but the arguments are based on the future reduction of nuclear power dependency (The Energy and Environment Council (EEC), 2011). The government proposed three options for the energy mix by 2030: a nuclear-power-free society, 15% dependence, and 20% to 25% dependence on nuclear energy (The Energy and

Environment Council (EEC), 2012). Because the dependence in 2010 was 26% and the pre-GEJE target for dependence in 2030 was 45%, all the proposed options have ambitious changes in the level of dependence. As a result of the nationwide discussion, the government in 2012 announced a national strategy that seeks for the country to forego dependence on nuclear energy. The announcement reflects the voice of citizens informed about the impact of all the options on the energy mix, energy costs and the economy. According to The Executive Committee of the Deliberative Poll on Energy and Environmental Policy Options (2012), the majority of citizens support zero nuclear energy in the future.

The results of a hypothetical survey indicate that residential consumers are willing to pay approximately 6% more of the electricity fee for renewable energy, which is less than the increased cost required for a non-nuclear power choice (Morita and Managi, 2015). In this sense, an electricity price increase plays a key role in residential demand, in contrast to the suggestion of the Executive Committee. Consequently, the current government moved to restart the operation of nuclear plants, arguing that nuclear power is an important energy source and that energy policy needs to promote coexistence with nuclear energy. Nuclear energy can increase energy security by reducing dependence on other countries. Without nuclear energy, Japan was 96% dependent on foreign fuels during 1985 to 2011. Despite the risk, nuclear energy is a clean energy source that can mitigate climate change and has other environmental and social benefits. To recover public confidence in its nuclear energy management, the government is reforming nuclear regulation; the first step was the opening of the Nuclear Regulation Authority on June 15, 2012.

2.2 Building embankments

Damages from a tsunami are expected and considered unavoidable, especially in a large-scale tsunami (Taniakwa et al., 2014). The GEJE brought serious damage in terms of human

lives and infrastructure. The tsunami swept over the coast of northeastern Japan, claiming more than 20,000 lives and destroying hundreds of thousands of buildings, along with 60 % of seawalls. The GEJE caused direct economic damage of 300 billion yen ($2.5 billion) by destroying dikes.

Obviously, an adequate protection system can reduce the damages. Infrastructure such as embankments can withstand the tsunami (Tokida and Tanimoto, 2014). After the GEJE, some towns in the region were well protected by the structures in place, even though the tsunami exceeded their design height. In Iwate's Fudai Village, the 15.5-meter floodgate, built in 1984, protected the village and its 3,000 inhabitants (Ishiwatari and Sagara, 2012). The floodgate was constructed because of the mayor's decision to protect the village from a future tsunami. The project cost 3.6 billion yen ($36 million), which was funded by the central and prefecture governments and not by the village. The decision was criticized at the time, but the high cost was justified once mega-disaster struck (Iwata et al., 2014).

Most other cases did not work the same way. The GEJE demonstrated the limitations of Japan's disaster management systems, which relied heavily on dikes (Ishiwatari and Sagara, 2012). From the standpoint of disaster management, mitigating the impact of future tsunamis by building embankments is essential. The government has already invested several hundred billion yen in dike construction around disaster areas (Ishiwatari and Sagara, 2012; Imamura et al., 2016). Badly damaged prefectures such as Fukushima, Miyagi, and Iwate have been constructing dikes and increasing the height, width, and in some cases the length of seawalls since the disaster.

The experience of the GEJE and tsunami prompted the building of embankments throughout the Pacific coastal side of the Tohoku region, and it is expected that embankments will protect Japan's entire coast in the future. It is not clear how much it would cost to build embankments in other regions.

2.3 Economic recovery

The GEJE in 2011 had a negative impact on Japan's economy (see Figure 1), especially in Fukushima. The Tohoku region is showing a positive growth trend because of government investment in the recovery effort, and the offsetting positive effect appeared in Fukushima in 2012. In the past three years, overall Japanese consumption decreased 2-3%, but it declined by more than 18% in the disaster-affected Tohoku region. Damage to building stock is calculated to be 11 to 20 trillion JPY[1] (Saito, 2015).

The Cabinet's Reconstruction Headquarters used at least 19 trillion yen ($158 billion) for intensive reconstruction over five years through 2015. To recover from the damage caused by the GEJE, the Ministry of Health, Labor and Welfare of Japan created a special reconstruction zone for the affected Tohoku region's prefectures (Iwate, Miyagi, Fukushima, Ibaragi) on December 7th, 2011. By this act, the central government paid as much as 75% of the initial costs for the reconstruction of factories and firms in Fukushima. Each prefecture set up its own subsidy system to attract businesses to the prefecture, expecting the effects to spill over and assist in the recovery of industries.

Before the GEJE, the value of shipments of manufactured goods from Fukushima prefecture was 51 billion yen ($425 million) (Ministry of Economy Trade and Industry (METI), 2010). The recovery plan includes reconstructing factories for the manufacturing industry, rebuilding the infrastructures for the agricultural and fishery industries, and constructing a new floating wind-power generating station. So far, the investment in construction has increased. Although the cost effectiveness of the investment is not yet known, a significant amount of the budget has been allocated for reconstruction (Iwata et al., 2014).

[1] Japanese Yen

3. Persistent challenges in managing multiple disasters

3.1 Lack of multidisciplinary sciences

The current need in disaster science is to prepare, adapt and recover from multiple and sequential disasters, a challenge that requires a multi-disciplinary research effort. The Fukushima crisis in March 2011 is an example of multiple disasters because the earthquake, tsunami and radiation leak took place within a short period. This event illustrates the importance of predicting and evaluating large disasters and proves the need for disaster mitigation and adaptation policies (see Islam et al., 2016, Rajapaksa et al., 2016 for perception change after the event).

The multiple disasters produced shocking and unavoidable damage in Japan. The challenges faced by the Japanese government to handle these risks show the extreme importance of managing multiple disasters. Although combined disasters are more dangerous, current disaster management strategies tend to consider the risks of individual disasters, mainly because of the difficulty in understanding uncertainty in the quantitative modeling (see Onuma et al., 2017 for how individuals react to risk and information).

Nuclear reactor accidents are very rare events, and few medical practitioners have direct experience treating patients who have been exposed to radiation or responding to such a public health crisis (Christodouleas et al., 2011). A primary health concern after a nuclear accident is the risk of thyroid cancer. Fukushima evacuees received a much smaller dose of radiation than Chernobyl evacuees did (Tokonami et al., 2012), but health concerns remain because patients contaminated with nuclear radiation also need psychological care, as will be discussed later. Multidisciplinary research is essential to understand the different dimensions of impact and to ensure proper treatment.

The health risk of Fukushima nuclear radiation was evident in Japan as well as in Asia

(Bolsunovsky and Dementyev, 2011), Europe (Masson et al., 2011) and USA (Leon et al., 2011). Large-scale catastrophic events have global consequences, and global effort is essential to mitigate the severity of the crisis. Therefore, a close network of multidisciplinary researchers is needed for efficient decision making in case multiple disasters such as the Fukushima accident in 2011 happen again.

In Europe, Realizing the European Network of Bio-dosimetry (RENEB) has been created to strengthen emergency preparedness and response in the case of a large-scale nuclear accident or radiological emergency. RENEB includes 23 experienced laboratories from 16 European countries with the aim of providing quick, efficient and reliable support (Kulka et al., 2012). In Asia and on other continents, the multidisciplinary research team needs to identify multiple disaster risks from different dimensions.

3.2 Disaster management by domestic institutions

Government handling of large-scale disasters differs by country and by locality within a country. We discuss the difference between the U.S. and Japanese disaster management systems and the actual and probable impacts on the management of the GEJE.

Japan has a unique federal disaster management system in which the disaster experts from different ministries gather in a special agency headed by the Prime Minister to deal with the aftermath of a disaster and set the direction of the recovery process. Under the *Disaster Countermeasure Basic Act*, the Headquarters for the Extreme Disaster Management was formed after other large-scale natural disasters. The system has been improved throughout its history, such as after the Great Hanshin-Awaji earthquake, when the efficiency of decision making was improved by increasing the authority of headquarters and by requiring more timely responses from the bureaucracies and political administration.

According to reports prepared by the Cabinet Office Government of Japan (CO) (2012), the

Federal Emergency Management Agency is composed of bureaucrats with different expertise from different ministries who work together to provide prompt, efficient initial support to the damaged area by working with the affected local administrations. However, the U.S. system is different than that of Japan in that the U.S. Federal Emergency Management Agency plays a central role at the time of all disasters. Unlike Japan, which has a separate headquarters for a nuclear emergency, the U.S. Federal Emergency Management Agency deals with all disasters, including nuclear-related disasters, technological disasters and other national security-related disasters. The U.S. disaster management system is a rather independent and top-down system, whereas the Japanese system requires coordination between the ministries and the administration in office.

One of the strengths of the Japanese coordination system at the time of a disaster is that trained experts in different areas can share expertise and information collected from different perspectives. Headquarters members include not only representatives from different ministries but also experts from the National Police Agency, the Fire and Disaster Management Agency, Japan Coast Guard, and the Self-Defense Forces. Moreover, because the head of the government leads the team, decisions made by the members of headquarters can be implemented quickly. A timely response that considers the tradeoff between security, finances and environment can quicken the recovery process.

In the case of multiple disasters such as with the GEJE, damage from the earthquake and tsunami was dealt with by the Headquarters for the Extreme Disaster Management, whereas the nuclear-related disaster was dealt with by the separate headquarters of the nuclear emergency response. This special headquarters to deal with nuclear emergencies was established under the *Act on Special Measures for Nuclear Disasters*, which was passed shortly after the Fukushima Dai-ichi nuclear plant accident. Despite this quick establishment, there was poor information sharing across the government, the Tokyo Electric Power Company

(TEPCO), which owns the nuclear plant, and the Nuclear and Industrial Safety Agency (Matanle, 2011; Nakamura and Kikuchi, 2011).

We emphasize the difficulties with institutional coordination and with communication between central and local governments during large-scale multiple disasters. After the GEJE, local governments in the affected area quickly set up their own disaster management headquarters, which are established automatically by the prefecture law of the *Local Disaster Management Plan*. The problem, typically, is disagreement between central and local headquarters regarding the allocation of financial and human resources. However, due to the scale of the GEJE, out of 352 municipalities in four affected prefectures, 62 % of municipal facilities were damaged and 12 % of administrative facilities were completely destroyed (Cabinet Office Government of Japan (CO), 2012). Hence, in the case of GEJE, rather than disagreeing or miscommunicating with the central governments, the local government lost its capacity to collect information or act as a disaster manager in its locality. The system beyond the bilateral coordination is indispensable (Norio et al., 2011), and therefore, we need to consider a framework in which it can function during multiple disasters without depending solely on coordination between a few agents at risk of being immobile.

3.3 Global effort in managing

Sharing scientific knowledge about radiation dispersion requires a solid mechanism to build mutual trust among interested parties. Although assistance from other countries is commonly suggested for nuclear radiation, in practice, there are concerns about the leakage of confidential information. Fukushima offers a unique opportunity because Japan is providing access that enables researchers to gain a profound understanding of a nuclear accident, whereas in Chernobyl, researchers were unable to obtain information due to Soviet security.

Nuclear debris is likely to melt with water and transfer through the ocean to nearby shores.

Water samples collected in Russia and Greece show the high-velocity movement of radioactive contamination from the Fukushima nuclear accident and the global effects of this accident, similar to those caused by the Chernobyl accident (Bolsunovsky and Dementyev, 2011). Radioactive fallout from the Fukushima reactor explosion was detected in environmental samples collected in France (Evrard et al., 2012), the Iberian Peninsula (Lozano et al., 2011), the Pacific and Indian Oceans (Nakano and Povinec, 2012), Korea (Kim et al., 2014), Vietnam (Long et al., 2012) and other places around the world.

The effects of the Fukushima Dai-ichi accident on energy security were apparent not only in Japan. The accident resulted in a loss of public support for nuclear energy and led Germany and Italy to shut down some of their nuclear reactors and abandon plans to build new ones (Hayashi and Hughes, 2013). The severity and proximity of Fukushima exposed the Chinese public to the potential risks associated with nuclear power (Huang et al., 2013). Globally, public acceptance of nuclear power decreased significantly after the accident and the popularity of alternative renewable energy sources increased (see Nakada et al., 2016 for discussion on alternative policies on electricity).

Air, water and soil in Austria were monitored for artificial radionuclides released during the accident, but the Fukushima accident did not contribute significantly to the total radio-cesium inventory in Austria (Steinhauser et al., 2013). The Fukushima Dai-ichi release of radionuclides into ocean waters caused significant local and global concern about the spread of radioactive material. Various radionuclides were transported across the Pacific toward Europe, but airborne activity levels pose no concern for public health in Europe (Masson et al., 2011).

The Fukushima accident has increased awareness of nuclear energy risks around the world. Global cooperation and effort is unavoidable under these circumstances (International Atomic Energy Agency, 2015), and ever-increasing energy demand is managed by alternative safe renewable energy. Although Japan has maintained its nuclear reactors safely with regular

inspections, it is struggling to handle the current nuclear crisis. Therefore, developing countries that are embarking on nuclear power may be unable to handle nuclear power plants safely, and an unavoidable occurrence may contribute to a nuclear crisis worldwide.

3.4 Health issues and psychological care

The GEJE damaged not only property but also humans in the disaster area, and some of the health damage may be caused by anxiety, such as about evacuation and unemployment. There are mental health problems among disaster victims as well as issues of compassion fatigue among caregivers and discrimination against Fukushima residents (Yamashita and Shigemura, 2013). Although there is no consensus as to whether and how natural disasters affect suicide rates, suicides have risen in the immediate aftermath of the more harmful natural disasters and even several years later in the case of the Great Hanshin-Awaji earthquake (Matsubayashi et al., 2013).

Evacuees decreased from approximately 470,000 in the aftermath of GEJE to half that number in July 2014. Approximately 10,000 evacuees continue to live in provisional housing (Reconstruction Agency, 2014). The stress of life in temporary housing may be one of the factors harming mental health. Depopulation with rapid aging is occurring, for example, in the city of Minamisoma because of the Fukushima accident (Ishikawa et al., 2012). The aging of society increases the risk of health problems.

Poverty is considered to be another key factor in the health damage (Matsubayashi et al., 2013). More than 100,000 jobs were lost in three quake-stricken prefectures in 2011(Ministry of Health Labour and Welfare (MHLW), 2011), and there were more than 1,400 bankruptcies in the three years after the GEJE (Tokyo Shoko Research Ltd (TSR), 2014). Supply-chain disruptions (Stewart, 2011) and harmful rumors (Haworth, 2013; Koyama, 2012) also damaged the economy. For example, 77.2% of 1,208 consumers refrained from purchasing Japanese

food after the accident because of fears about the food supply (Kim et al., 2015).

Anxiety about employment can make people expect to live an erratic life in the long term, and it is possible that unemployment results in an impairment of mental health (Paul and Moser, 2009). Unemployment is significantly associated with male suicide rates, especially among the demographic of prime age working men (Kuroki, 2010). This implies that the GEJE has had an indirect effect on the health of the disaster victims via job uncertainty as well as a direct influence on the victims through the event itself.

There is another way in which a health condition impacts the labor force for the long term. A significant negative impact of radiation on the labor market was observed in the case of the Chernobyl disaster (Lehmann and Wadsworth, 2011). The impact of radiocesium on human health in the case of Fukushima is expected to be smaller (Evangeliou et al., 2014), but there are various anxiety factors that affect human health (Karz et al., 2014). Although it is still too early to assess the impact of radiation on the local market in areas affected by the GEJE, policy makers need to provide effective labor and general economic recovery policies as well as accelerate the decontamination process to avoid the negative effects of radiation.

4. Conclusion

Since the Chernobyl disaster in 1986, approximately 440 nuclear power reactors in 30 countries have operated without any catastrophic accident until the accident at the Fukushima Dai-ichi nuclear plant. Before the GEJE and the nuclear disaster in Fukushima, developing countries including China, Russia and India have shown growing interest in expanding nuclear energy. China was expected to show the largest growth in nuclear reactor installation. Other developing countries, including Turkey, Bangladesh, Pakistan, Taiwan and other Persian Gulf countries had shown interest in installing nuclear reactors. However, the accident in Fukushima has forced those governments to reassess the risk of nuclear plants and many large-scale projects were cancelled.

The nuclear disaster in Fukushima not only changed the expectations and plans of developing countries regarding expanding nuclear energy, it also initiated a debate on energy policy in the developed countries that already have nuclear plants. The reaction of influential economies varied; U.K., policy makers resolved to proceed with expansion of nuclear power generation, whereas Germany decided to shut down old-generation of nuclear reactors, at least temporarily, and to re-examine the safety of all national nuclear power facilities (Mitchell et al., 2012; Wittneben, 2012). The U.S. government temporarily stopped construction of new nuclear plants but resumed construction in March 2013.

From the different responses of external observers of the accident, Germany's attempt to shift to alternative energy had an impact on current Japanese energy policy (Glaser, 2011). It has been a serious challenge for the Japanese electricity sector to overcome the shortfall in electricity production without nuclear energy. The government has responded to the crisis with a new feed-in tariff to promote renewable energy and has proposed reducing dependence on nuclear power (Huenteler et al., 2012). Despite these efforts, imported fossil fuels are still substituting for most of the energy that used to be produced from nuclear energy.

The shift away from a zero-nuclear policy is important for both economic and environmental reasons. On April 11th 2014, the current cabinet of Japan headed by Prime Minister Shinzo Abe of the Liberal Democratic Party adopted a new basic energy policy that officially abandoned the zero-nuclear policy adopted by the previous administration headed by the current opposition party. The government recently restarted one nuclear plant after it passed the new standard test, and the government and electricity company that owns the plant tried to persuade citizens to support the operation of nuclear plants. Concerns about health risks and the progress of decontamination remain the major obstacles to support for restarting nuclear plants. Prime Minister Abe emphasized energy security as a reason to restart operations in his speech in 2013 and has guaranteed that the radiation risk would not affect the 2020 Olympics in Tokyo.

However, the decontamination process in Fukushima is expected to take another decade, and the current effort to promote nuclear energy has seen little success among citizens. Moreover, the chief of the Nuclear Regulation Authority has remarked that passing the new and stricter requirement does not imply the plants are safe.

More generally, nuclear power has been always controversial because of the tradeoff between possible detrimental accidents and carbon (The Energy and Environment Council (EEC)) efficiency. In addition, initial construction costs are sufficiently high that it becomes difficult to make an economic argument for nuclear power, even before incorporating the external costs (Davis, 2011). Figure 2 shows the discounted per unit electricity generation cost of different energy sources. In the long term, nuclear power generation is cost effective, but in the short term, the cost is relatively high because of the initial construction cost.

The decommissioning of nuclear power plants is another big concern. For Japan, decommissioning would cost about $10 billion. Globally, the cost is estimated to be more than $100 billion, even when excluding the costs of permanent waste disposal (International Energy Agency, 2014). Therefore, when building a plant, countries must consider not only the accident risk but also the long-term decommissioning cost.

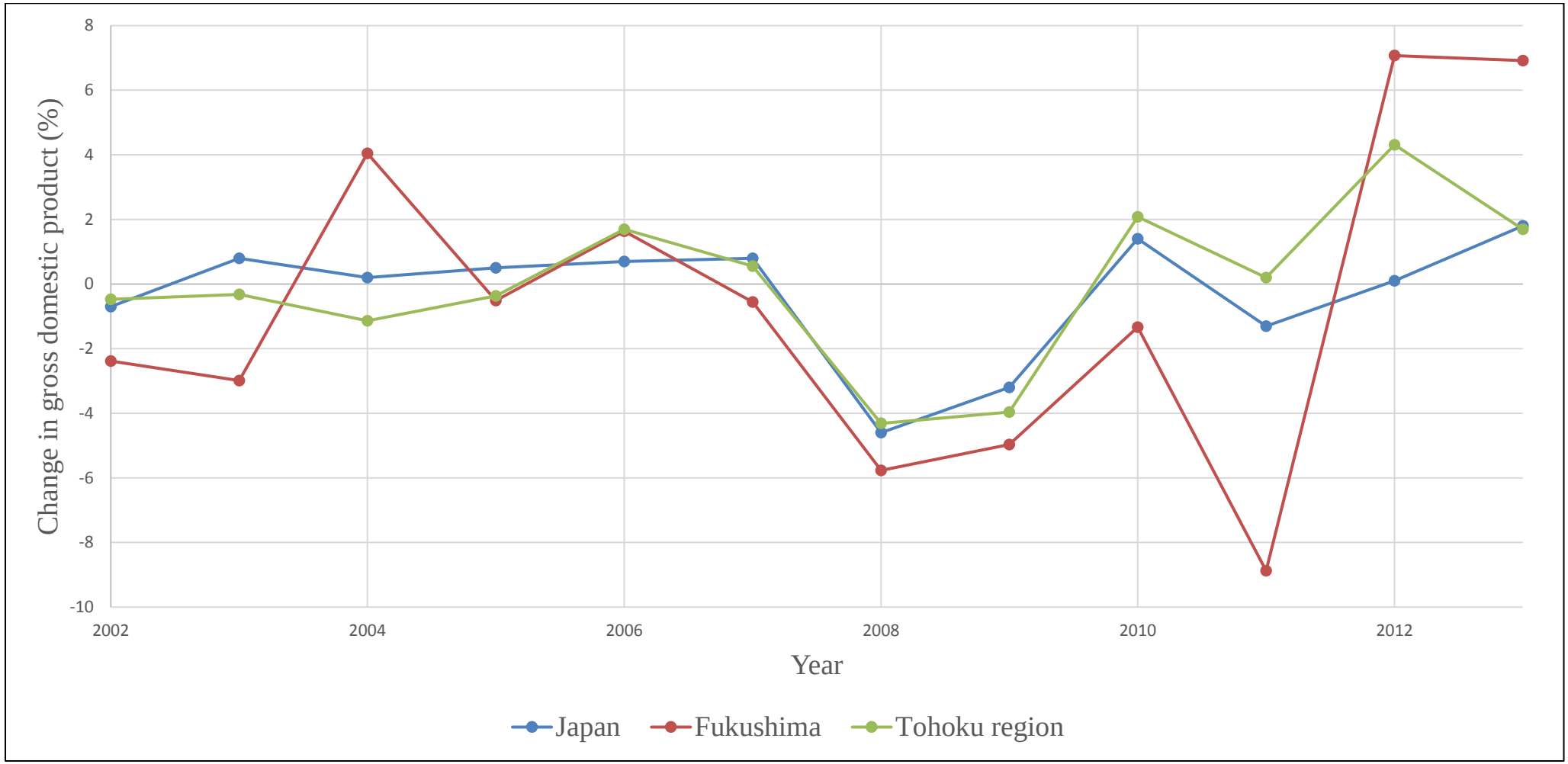
Finally, there is an important accountability question in the case of disaster. Transparency is the key issue when disasters and accidents hit the community. Nuclear energy policy in Japan was supported by the *Myth of Security,* which represents the strong belief that nuclear plants are 100 % safe from accidents (International Atomic Energy Agency, 2015). However, the accident happened and the central government initially told TEPCO to announce that there was not large-scale core melting and melting through (i.e., penetration of nuclear fuel to the pressure and containment vessels) until the news media disclosed the nuclear meltdown (Ryall, 12 May, 2011) and melt-through (Ryall, 9 June, 2011). The administration and related bureaucracies as well as electric companies may have suffered from moral hazard in terms of safety regulation

and preparation for disaster under the blind belief that nuclear plants, especially Japanese plants, are completely safe.

Lack of transparency is not the only problem. The other big challenge is solving the disorganization caused by the division of responsibility among various actors, including the central and local governments, the Nuclear Regulatory Commission, the electric power companies and the nuclear plant crew. Currently, the distribution of responsibility depends upon the scale and type of the accident. For example, a local government might be responsible for evacuation plans for accidents up to a severe level, whereas the central government takes the initiative only in extreme cases. The order of the nuclear plants receiving examinations for restarting is heavily influenced by politics and the METI's interest in restarting nuclear generation.

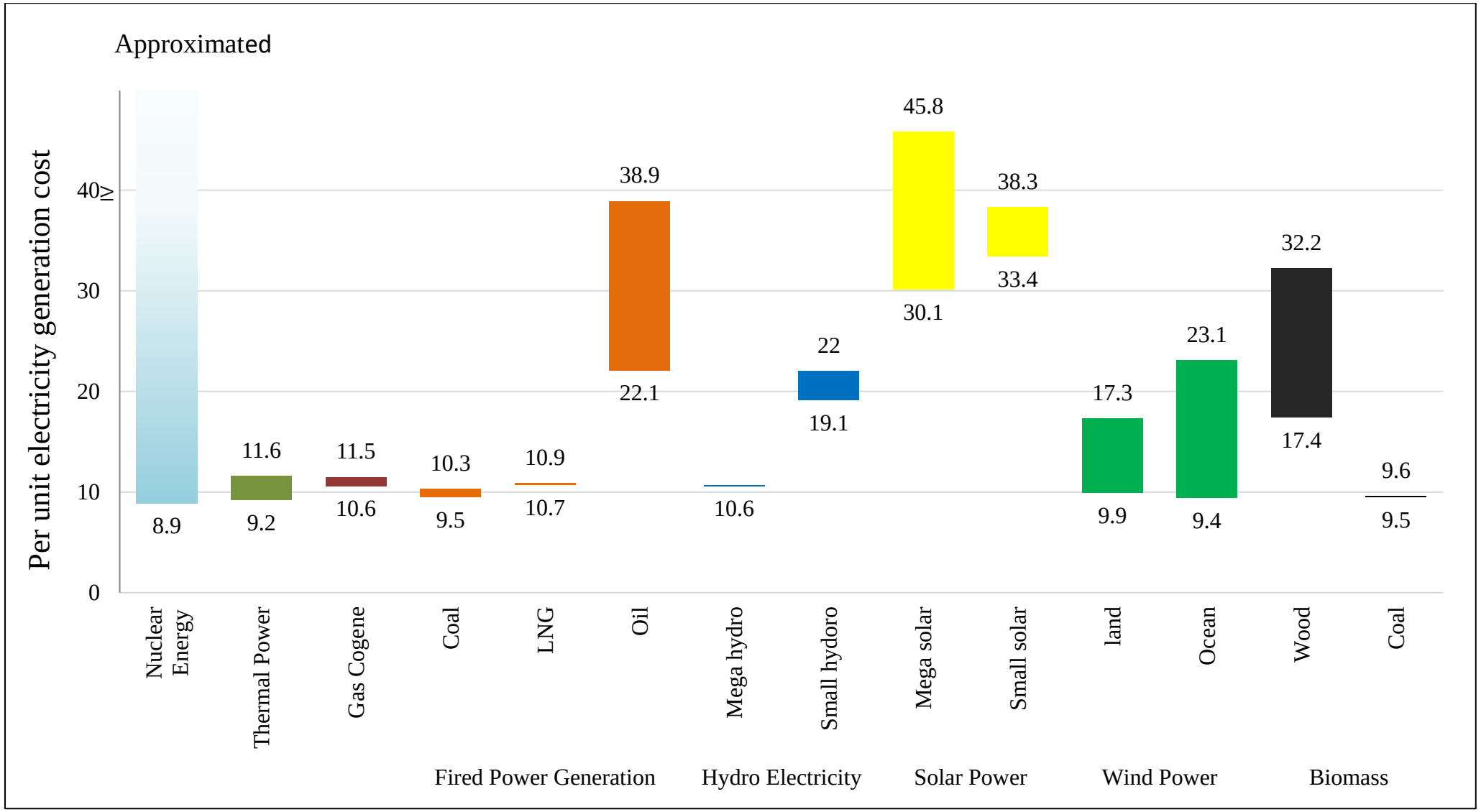
To build an efficient disaster management plan that can be a model for the international community, we need to be transparent and accountable at the time of disasters and accidents. Moreover, the post-disaster management ability of the government could be evaluated by negotiating with local communities and citizens, including some of the victims of the disasters, about (resuming) operation of nuclear plants in the near future. Finally, understanding lessons learned and implementing required policies are essential for Sustainable Development Goals. Technology is one key aspect for better future but management in policy making is essential (Dasgupta et al., 2015; Managi et al., 2016).

Figure 1: Change in gross domestic product (%)



Note: Tohoku region includes Miyagi, Iwate, and Ibaraki prefectures.
Source: Cabinet Office, Government of Japan, 2015, National Accounts of Japan: Quarterly Estimates of GDP; Annual Report on Prefectural Accounts.

Figure 2: Electricity generation cost of different energy sources in Japan after the Great East Japan Earthquake, 2011



Note: Upper limit of nuclear power is unknown

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