Energy Outcomes of the Fukushima Daiichi Nuclear Disaster

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Abstract

Decades before the Great East Japan Earthquake and the Fukushima Daiichi nuclear disaster of 2011, the United States of America was influential in establishing nuclear energy in Japan as the island nation attempted to assert greater autonomy over its domestic energy supply. But the 2011 disaster had a tremendous impact on Japan's ability to maintain energy security. Contingency measures were implemented to mitigate a severe lack of power as Japan was forced to supplement its electrical grid with expensive, emission-heavy imports. In the process of revising its energy policies, Japanese civilians and local governments exerted great pressure on the national government to shy away from nuclear energy and reform its business as usual approach. Many new policies and regulatory changes came about in the aftermath of the Fukushima nuclear disaster, including renewable energy policies aligned with other developed countries. While Japan was forced into making countless near-term and long-term decisions having a great impact on its economy and energy supply, the country remains committed to nuclear energy as it vies to establish a stronger and more balanced electricity system. A comprehensive analysis of the actions taken both before and during this energy crisis is completed.

Keywords: Japan energy policy, nuclear disaster, nuclear energy, Fukushima

Introduction

This paper will investigate the energy crisis that developed in the aftermath of the Great East Japan Earthquake and Fukushima Daiichi nuclear disaster of 2011. In its World Energy Assessment, the United Nations Development Programme (UNDP) defines energy security as "the availability of energy at all times in various forms, in sufficient quantities and at affordable prices, without unacceptable or irreversible impact on the economy and the environment" (2004). Since at least 2011, Japan has wholly failed to meet the UNDP energy security definition as the country attempts to overcome a seemingly insurmountable energy challenge. Historically, Japan has been paralyzed by a lack of natural resources and fossil fuels, which makes attaining energy security in the island nation quite difficult (Vivoda, 2012). The Post-World War II nuclear era was particularly influential in bolstering Japan's domestic supply of energy, and this era will be thoroughly examined to better understand the country's development of nuclear energy. After the Fukushima Daiichi disaster, the government suspended the operation of all nuclear power facilities across Japan, which previously supplied 30% of the nation's electricity (DeWit, 2011). This rapid loss of generating capacity and the government and utility provider response in coping with such a significant loss of power is historic. In the years that followed the disaster, Japan introduced a plethora of economic, regulatory, and voluntary policies designed to mitigate damages suffered to its electricity system. Current energy research on the Fukushima Daiichi nuclear disaster will be used to analyze the intricacies of these many policies, and garner an understanding of the energy predicament that Japan now finds itself in as the nation attempts to establish energy security.

Japan's Nuclear Background

To gain a full and comprehensive understanding of the Japanese energy situation, it is necessary to first reflect on the post-World War II nuclear era, which unfolded in the half century prior to the 2011 nuclear disaster. It presents perhaps one of the most complex and challenging energy issues in the entire developed world because Japan has nearly no access to a domestic supply of natural resources, and the country has virtually no fossil fuels (Hayashi & Hughes, 2013). After World War II, Japan's nuclear energy program grew to supply 30% of the nation's energy supply, which was fuelled by a coalition of government and nongovernment organizations that advocated for a Japanese nuclear industry, including Japan's Ministry of Economy, Trade and Industry (METI), domestic energy regimes, political actors that received financial support from energy companies, the government of the United States of America, as well as major news outlets in Japan (Shin, 2017). Many powerful government and energy industry leaders worked tirelessly to expand nuclear power generation in Japan, proclaiming that nuclear is both safe and necessary. By framing a strong and cohesive counterargument designed to suppress anti-nuclear voices, Japan positioned itself to become a nuclear energy leader.

After General Electronics (GE) installed the first reactor at the Fukushima Daiichi Nuclear Power Plant (NPP), which went online in 1971, GE, Toshiba, and Hitachi joined Japan's budding pro-nuclear coalition, and the consortium was hired by the Tokyo Electric Power Company (TEPCO) to design and construct the first two reactors at the Fukushima-I NPP in 1978 (Shin, 2017). Private companies like GE, Toshiba, and Hitachi had their interest piqued because of lucrative and profitable contracts to design and build NPPs. The Japanese government and energy regulators also favoured this form of energy

because it offered a predictable amount of electricity and enabled Japan to gain greater autonomy in its domestic energy supply. Decades later, GE, Toshiba, and Hitachi established Global Nuclear Fuel in the year 2000, manufacturing and distributing Boiling Water Reactor NPPs around the world, in addition to offering strong support for the Trans-Pacific Partnership Agreement (TPAA), despite local Japanese businesses being against the TPAA (Shin, 2017). In order to bolster revenue and increase profits, these pro-nuclear companies possessed an unwavering desire to expand the domestic and international supply of nuclear energy. Long before greenhouse gas emission concerns surfaced, nuclear energy was a burgeoning industry because of an agenda that was largely driven by the biggest empire in the history of the world, the United States of America. More than anything else, capitalism and American influence helped to ensure NPPs sprouted around the globe, serving as a means to both secure a new source of energy and to deter non-conformance from less powerful nations that would never dream of attacking a nuclear United States. The ties between Japan and the United States grew stronger and stronger, and consequently, nuclear energy firmly planted its roots in the island nation.

Japan's Energy Policy in the 1990s and Early 2000s

By the early 1990s, the world came to realize the real threat imposed by pollution and widespread environmental travesties caused by industrialization and capitalism. But by this time, monolithic socioeconomic structures were firmly entrenched in society, and massive transnational corporations wanted no part in downsizing that would impact revenue. Japan became the world's most energy-efficient country by reducing its reliance on oil from a high of 72% of total energy consumption in 1979, to a low of 40% by 2010, despite being the fifth highest energy consumer globally (Vivoda, 2012). Energy

efficiencies and a reduced reliance on fossil fuels aligned with a new global mission to minimize greenhouse gases. But in Japan, local energy action did not emanate from developing and investing in renewables. In 2008, solar and wind power production accounted for less than half a percent of national electricity generation, and Japan had big plans to increase reliance on nuclear energy as part of its 2010 Basic Energy Plan, envisioning nuclear energy generation that would increase from 30% in 2010, to 50% of the national supply by 2030 (Huenteler, Kanie, & Schmidt, 2012). This plan enticed Japan's pro-nuclear coalition, which was advocating for increased reliance on nuclear energy that would enable their corporations to grow, thereby guaranteeing economic success in energy. Furthermore, nuclear energy is touted as clean energy, enabling Japan to reduce its CO2 emissions. However, the Japanese had witnessed nuclear incidents throughout the twentieth century, including NPP fatalities in 1999, causing many to grow apprehensive about nuclear energy (Vivoda, 2012). But no incident was as powerful as the events of March 2011.

The Fukushima Daiichi Nuclear Disaster

In 2011, catastrophe struck the east coast of Japan in the largest release of radionuclides since the 1986 Chernobyl nuclear accident (Brandl, Johnson, & Steinhauser, 2014). As *Figure 1* illustrates, Japan's spread of land bound radionuclides was not as widespread as Chernobyl, but it was still enough to register as a major event on the International Nuclear Event Scale (INES), ranking the Fukushima event among the worst possible (Atomic Energy Society of Japan, 2015). At 3:38pm (local time), on March 11, 2011, an estimated 14-meter high tsunami flooded the Fukushima Daiichi NPP

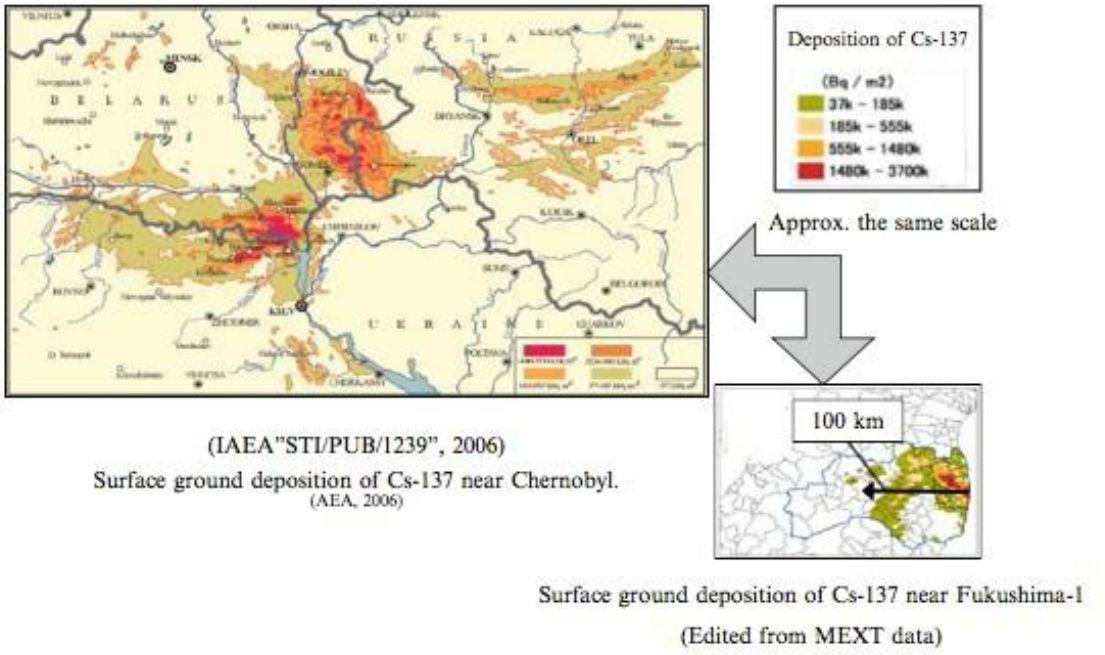

Figure 1. Spread of Chernobyl and Fukushima radionuclides on land. This figure shows the spread of landfall radionuclides in Japan and the Ukraine after each of their major nuclear disasters (Atomic Energy Society of Japan, 2015).

approximately one hour after the magnitude 9.0 Great East Japan Earthquake in the Tohoku Region (Thielen, 2012). More than 20,000 civilians lost their lives because of the earthquake and tsunami, and the event resulted in more than $220 Billion USD in economic damages to the Tohoku Region, making it the most expensive natural disaster in human history, and also one made far worse because of human activity (DeWit, 2011). TEPCO's Fukushima Daiichi NPP sustained over $45 Billion USD in damages (Heffron, Ashley, & Nuttall, 2016). Approximately 350,000 homes were damaged, in addition to total power failure at the Fukushima Daiichi NPP, which incapacitated the site's cooling systems, leading to a nuclear meltdown, hydrogen explosions, and extensive damage to three reactor buildings (Fukushima et al., 2013). Unlike the Chernobyl disaster, which occurred in a landlocked area of Europe, the Fukushima Daiichi disaster was not as severe because of its location, as seen in *Figure 2*, enabling the Pacific Ocean to dilute

over 80% of the radiological releases (Brandl et al., 2014). Despite this, the Fukushima nuclear disaster is a reminder of how dangerous and uncontrollable nuclear energy can be when systematic failures occur.

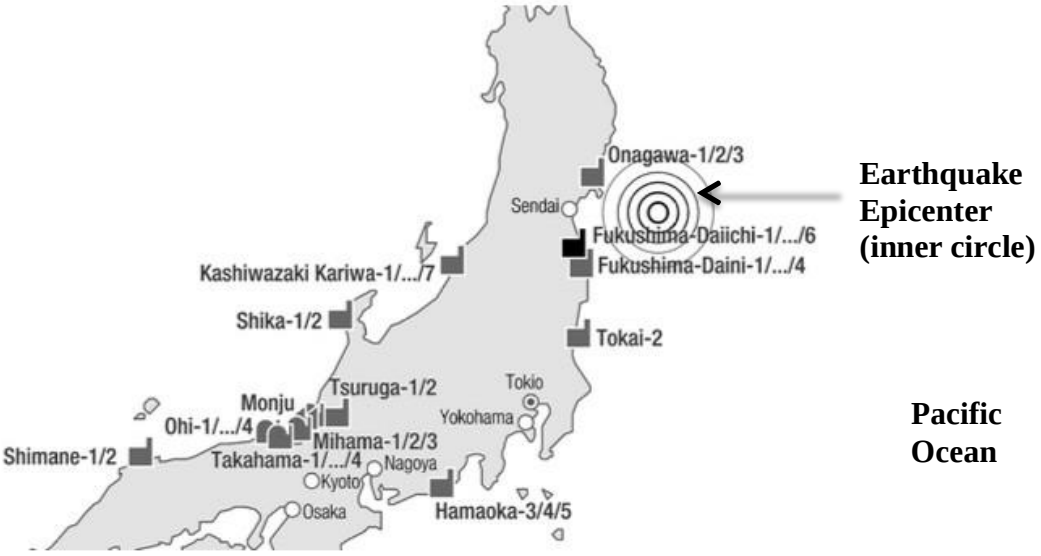

Figure 2. 2011 Earthquake epicenter and major NPP locations in Japan. This figure shows the location of the Great East Japan Earthquake epicenter off the northeast coast of Japan, as well as the locations of nationwide NPPs, including the six reactors at TEPCO's Fukushima Daiichi NPP (Thielen, 2012).

Japan's 2011 Nuclear Disaster & Energy Crisis

The catastrophic events of March 11, 2011, had a colossal impact on Japan, resulting in immediate or expedited actions that were designed to mitigate the energy crisis posed by the Fukushima Daiichi nuclear calamity. When the disaster struck, an electricity shortage was exacerbated by Japan's historical east-west splitting of its electricity grid that runs on different frequencies; the outcome was an attempt by utility companies to reduce peak demand, institute rolling blackouts, and bring recently retired thermal plants out of retirement (Huenteler et al., 2012). The government and regional utility providers took swift action in order to generate as much electricity as possible.

Through various policies, including regulatory by-passes to re-start aging thermal power plants, emergency gas turbine installations, electricity imports, grants for private power generators to sell surplus electricity back to the grid, encouragement of reduced usage on a voluntary basis, and an emergency regulatory cap on consumers with high energy demands, Japan was able to curtail electricity demand by up to 18% for TEPCO, and by nearly 16% in the Tohoku Region during the 2011 summer peak season (Hayashi & Hughes, 2013). These measures helped Japan to successfully meet electricity needs during the post-disaster summer and winter peak seasons. This success is largely attributed to Japan's ability to rapidly increase thermal power generation, which increased supply by 11,300 Gigawatt hours (GWh) from March 2011 to August 2011, representing a 23% increase in thermal power generation, and a 45% average increase in fossil fuels required to fuel thermal generators, including imported fuels such as oil, liquefied natural gas (LNG) and coal (Hayashi & Hughes, 2013). Of course, these temporary countermeasures helped Japan meet its immediate electricity needs, but these practices were economically and environmentally unsustainable in the long-term. Additionally, the Fukushima nuclear crisis prompted parallel actions to further enhance protections to safeguard Japanese civilians.

Just months after the disaster, the government mandated all utility providers to complete a stress test on each of the nuclear reactors across the country (Takeda & Yamazaki, 2016). This was the first of many hurdles that nuclear energy producers faced in the aftermath of March 2011. By the fall of that year, the Japanese government committed to a major revision of the nation's nuclear policy that was published just months before the disaster that shook the nation (Huenteler et al., 2012). Big changes

were coming as Japan faced enormous economic damages. Increased fossil fuel imports led to a near-$10 Billion USD trade deficit in August 2011, and TEPCO required initial government bailouts exceeding $43 Billion USD to cover compensation payouts for leaking radiation, which resulted in increased electricity prices and a public takeover of the utility provider (Hayashi & Hughes, 2013). Aside from TEPCO, all Japanese utility companies lost huge sums of money. In 2011, Japan's energy companies faced a total net financial loss in excess of $20 Billion USD because of increased expenditures related to importing fuels, which came at a price increase of over $29 Billion USD in comparison to the previous year (Hayashi & Hughes, 2013). As utility companies suffered financially and struggled to meet energy demands throughout 2011, the government began to systematically rollout a suite of nuclear industry policy changes and regulations.

Nuclear Regulatory Changes & The Anti-Nuclear Movement

As exhibited in *Figure 3,* all of Japan's NPPs were significantly impacted by the events of March 11, 2011. Eventually, the country was reduced to zero nuclear power generation on May 5, 2012, and this lack of electricity put a substantial strain on the nation that required immediate action. After the national government forced a halt on all nuclear energy production in the Fukushima aftermath, local governments across Japan were charged with the final decision as to whether NPP reactors inside of their districts would be permitted to power on again, and many local governments had become completely adverse to accepting nuclear energy in their backyards (Huenteler et al., 2012). The Fukushima Daiichi nuclear catastrophe led to the formation of a robust and unified movement that advocated for a nuclear-free Japan, regulatory and structural

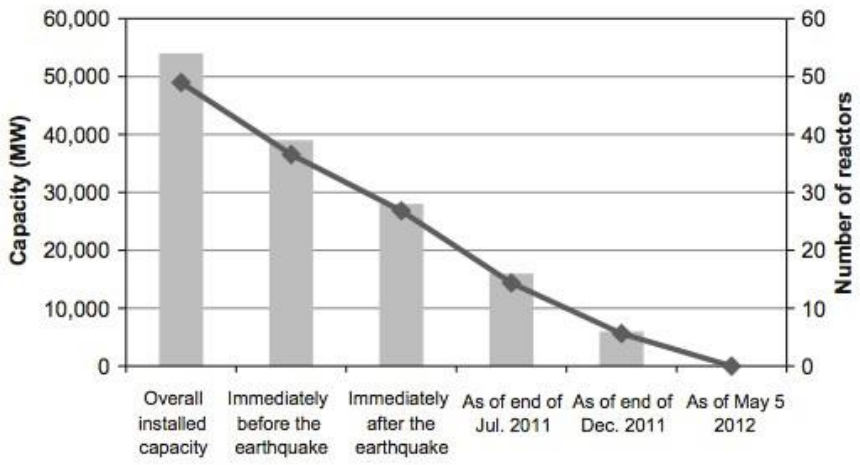

Figure 3. Total loss of nuclear power in Japan. This figure illustrates Japan's nuclear capacity loss resulting from the Great East Japan Earthquake, tsunami and Fukushima Daiichi nuclear disaster (Hayashi & Hughes, 2013).

changes to Japan's energy industry, and a transformative mindset focused on de-centralization of the electricity grid. The people of Japan became reluctant to support the nuclear regimes that had been entrenched in their society since the 1950s, and nearly 60% of survey respondents supported the complete abolishment of Japan's nuclear energy program in September 2011 (Hayashi & Hughes, 2013). Quite simply, the government and utility providers lost the trust of Japanese civilians, and the disaster spurred a new grassroots movement amidst energy industry turmoil. While Japan had previously toyed with an insignificant and ineffective Feed-in-Tariff (FIT) program in 2009, business leader Son Masayoshi, Softbank CEO, kept Japan's renewable FIT program on the government agenda in the months following the Fukushima disaster, and he advocated against nuclear by enrolling 35 out of 47 Japanese prefectures in the Natural Energy Council, as well as a similar system for cities with more than 500,000 people, of which Masayoshi enlisted all but two of Japan's most populous cities (DeWit, 2011). These

moves put an exorbitant amount of pressure on the Government of Japan, and the traction-gaining anti-nuclear movement forced the government into further action.

Whereas pre-2011 government policy and the METI regulatory framework was set-up to ensure growth of the Japanese nuclear industry and utility monopolies, a new energy framework emerged in the years after the Fukushima nuclear disaster. In September 2012, Japan created a new agency called the Nuclear Regulatory Authority (NRA), which changed the course of Japan's nuclear industry when the organization exerted its newfound authority by implementing a suite of changes that included some of the highest nuclear safety standards in the world, ranging from the institution of a 40-year lifespan on all nuclear reactors, increased engineering requirements for the construction of buildings occupied by would-be emergency evacuees, as well as replacement wiring, enhanced ventilation systems, and NRA inspections based on the new criteria (Takeda & Yamazaki, 2016). All of these changes were designed to enhance the safety of Japan's NPPs. Undoubtedly, the pro-nuclear regime was unhappy about the new operating restrictions. Even after re-starting two nuclear reactors in July 2012, which provided 2.4 GW of electricity, the government shut them down again in September 2013, leading to zero nuclear energy for a second time in Japan's post-World War II nuclear era (Oztuk & Radindadi, 2016). Something had to give. After months of directly battling explosions and uncontrollable radiation leaks from the Fukushima Daiichi NPP, and several years of transformative, 180-degree policy changes, enhanced nuclear safety regulations, and transfers of power in the energy industry, Japan needed to become a trailblazer for re-affirming its authority over national energy security.

Japan Moves to Incorporate Renewable Energy

To think that major changes to Japan's energy infrastructure could occur overnight is impractical. The logistics of revolutionizing energy policy, programs, and infrastructure is highly complex. But Japan had no choice but to look outward to nations that already implemented renewable FIT programs to investigate the plausibility of creating a similar energy framework in Japan. Another purpose was to avoid making the same mistakes that other renewable FIT nations had made, such as policies leading to high electricity prices. Prior to implementation in July 2012, draft FIT legislation incorporated these lessons learned and was proposed by the governing Democratic Party of Japan, but after it was reviewed and amended by the opposition Liberal Democratic Party in 2011, the Japanese FIT bill that was ultimately passed resulted in increased electricity bills for consumers, increased financial guarantees for utility providers, less financial risks for the electricity industry, and a decreased ability to make prompt changes to the tariffs charged to consumers should high-costs become an issue (Chapman, Sakurai, Tanaka, & Tezuka, 2017). Japan's 2012 FIT legislation followed a similar path to early-FIT adopters like Germany, resulting in high costs to ratepayers in the name of new renewable capacity. While the new FIT program resulted in a quadrupling of the nation's renewable energy capacity from 6.6GW in 2012, up to 28.4GW in 2015, the annual price tag ballooned to $17 Billion USD in 2016, and was paid entirely by Japanese ratepayers (Komiyama & Fujii, 2016). Rather than avoid FIT nations' mistakes from the previous decade, Japan implemented a FIT program that mirrored the same ones that led to extortionate electricity bills globally. To further complicate matters, Japan's progress has been severely impeded by the fractured post-Fukushima electricity supply, which has

led to a 3.6% contraction of Japan's economy, causing the country to fall into a deep recession with a debt load equivalent to 240% of the country's GDP (Oztuk & Radindadi, 2016). So while the nation has implemented a FIT program and increased its renewable capacity, economic and energy turmoil have impeded Japan's ability to quickly adapt and implement a new energy mix.

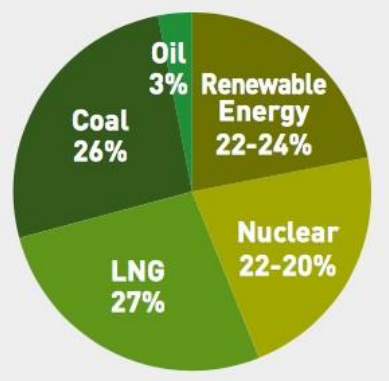

Figure 4. Japan's future energy mix. This pie chart provides a visual of the energy mix proposed by Japan in its first post-disaster energy policy, which remains the proposed energy mix to present (METI, 2017).

Japan's Current Energy Situation

Since the country only supplies an unsustainable 7% of its current energy needs from internal power generation, the government released the first national energy policy following the Fukushima nuclear disaster; released in April 2014, the Strategic Energy Plan of Japan calls for nuclear power to fuel 20-22% of its energy demands, in addition to 27% reliance on LNG, 26% on coal, 3% on oil, and 22-24% of total energy to be sourced from renewable resources (Komiyama & Fujii, 2016). *Figure 4* is a visual of this proposed mix. Somewhat unsurprisingly, nuclear is again part of Japan's future. Similar to the Fukushima disaster, all Ukrainian NPPs were taken offline in the years following Chernobyl, but nuclear power has again risen in the Ukraine, supplying nearly 50% of that nation's electricity needs (Kuramochi, 2015). While nuclear energy has crept back

into Japan's energy mix, the present plan cites inherent nuclear safety issues, and calls for reduced long-term use. Equally complex is the rapid expansion of renewable energy because even though there are comparatively low overall cost related risks, land is scarce and expensive, materials and labour are costly, and the total price to generate renewable electricity is actually estimated to be more expensive than nuclear energy (Konidari, Matsumoto, Mavrakis, & Morita, 2017). The post-Fukushima proposed balance of low or non-emitting energy aligns with other developed nations that have elected to generate significant power from both nuclear and renewable energy sources.

Conclusions

The catastrophic events of March 2011 led to hundreds of changes to Japan's energy system in its entirety. Many of these changes include increased nuclear safety regulations and new standards that utility providers and NPP operators must adhere to. Whether these changes are effective enough to mitigate a similar nuclear disaster in the future is yet to be determined. Japan is home to a volatile natural environment, so it can be assumed that significant earthquakes and other natural disasters will continue to impact the island nation well into the future, just as disasters have been plaguing Japan since time immemorial. Furthermore, the severely disruptive nature of the most expensive natural disaster in human history jeopardized Japan's attainment of energy security. The necessary decision to drastically increase fossil fuel imports negatively impacted both the economy and the environment, but it enabled Japan to meet post-Fukushima energy demands while the nation grappled with combating ideas and a growing anti-nuclear sentiment.

In the post-disaster policy process, Japan has again incorporated nuclear into its energy mix since modern renewable energy is unpredictable; if the sun is not shining or the wind is not blowing, cities and towns could go dark if supplementary power systems and back-up generators are insufficient. Renewable energy is also highly susceptible to damage in high winds, earthquakes, storm surges, and other natural disasters. Whether the energy needed to power Japan is generated from nuclear or from renewables, the nation is particularly prone to the aforementioned naturally occurring phenomena, which threatens Japan's long-term ability to obtain energy security with today's technology. Changes implemented since the disaster have been largely progressive, including a swifter move to renewables than the government had originally planned, but until the volatile island nation experiences another natural disaster, Japan's ability to safely procure all forms of energy will not be tested. Japan must never forget this major incident, and it should establish resiliency through innovation rather than resorting to past schemes that are tried, tested and failed.

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