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Reconstruction and revitalization in Fukushima a decade after the "triple disaster" struck: Striving for sustainability and a new future vision

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ABSTRACT

While disasters occur relatively frequently almost none are of a scale as serious or complex as the triple disaster that devastated coastal regions of Tohoku, Japan. How can a region recover from a disaster as horrific as that triggered by the earthquake, tsunami and radioactive contamination linked to the explosions and reactor meltdowns at the Fukushima Dai-ichi nuclear power plant? Recovery and reconstruction in cases of large-scale disasters involves multiple activities which extend over long periods of time. This article focuses on one aspect of this – the efforts that are being made to bring about deeper transformative changes that aim to make the region in and around Fukushima both more sustainable and resilient. The region is betting on becoming a leader of global significance in several areas: tsunami disaster management and recovery, nuclear disaster recovery know-how (technological, scientific, and social), renewable energy development, and hydrogen fuels and battery storage technologies. This effort is made difficult, however, by many evacuees' reluctance to return to the region and the complex challenges associated with dealing with the aftermath of the nuclear accident.

1. Introduction

Situated on the Asian ring of fire, Japan is subject to more earthquakes than almost any other country in the world and has been hit by numerous tsunamis which have resulted in fatalities ranging from dozens to thousands of people (e.g. major tsunamis resulting in fatalities in the past 125 years include: Sanriku 1896, Great Kanto Earthquake 1923, Sanriku 1933, Tōnankai 1944, Nankai 1946, Niigata 1964, Sea of Japan 1983, Okushiri 1993, and Tōhoku 2011). The archipelago is also prone to damaging typhoons and volcanic eruptions. This domestic reality has made Japan one of the most disaster prepared nations in the world with strict building codes to shield against building and infrastructural collapse during earthquakes and regular drills in schools and companies to prepare for the worst. Nevertheless, the limits of this preparedness were exposed by the triple disaster of March 2011 when one of the world's largest ever recorded earthquakes (the 4th largest) unleashed one of the world's most damaging series of tsunamis (second in scale in the last several hundred years only to the Indian Ocean Tsunami of 2004), and triggered days later the world's second worst nuclear catastrophe after Chernobyl, at the Fukushima Dai-ichi nuclear facility.

In the ensuing decade clean up and reconstruction efforts continue. What have been the longer-term impacts of the triple disaster for Fukushima prefecture and neighboring regions? How is the region coping? What has changed? Is the region becoming both more resilient and more sustainable?

2. Methodology

This article follows a qualitative case study methodology which is based on what could loosely be called participant observation as well as a mix of interviews, group discussions, and professional meetings. In the period since the 2011 triple disaster, I visited Japan 34 times primarily in my role as an environment and energy policy expert.[1] The visits which spanned an eight-year time frame have provided me with a unique opportunity to observe developments in Fukushima since the triple disaster and collect information during site visits and meetings with a wide range of groups. My visits were not designed as part of a specific research project following a strict research protocol. Nevertheless, combined they provide a wealth of insights and information related to disaster recovery and reconstruction in Fukushima.

Visits to Fukushima and neighboring areas involved three separate tours of the Fukushima evacuation zone as well as multiple visits to other parts of the prefecture. During the visits in the evacuation zone, I observed nuclear decontamination and tsunami clean-up efforts, interviewed

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[1] I have lived in Japan and also speak and read Japanese.

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officials about their recovery efforts, and assessed progress and setbacks. I visited temporary storage sites of radioactively contaminated soil and other wastes and exchanged information about radioactive waste management plans and progress in Japan and Germany.

In other visits, I learned from volunteers about their efforts to measure food radiation and was invited to meetings with inhabitants of impacted communities, including meetings with evacuees living in temporary housing facilities and local farmers. Such meetings took place in Ogunimura, Date-shi, Namie-shi, Iidate-mura, Okuma-machi, Minami Sōma-shi, Sōma-shi, Koriyama, Fukushima, and Sendai. The National Institute for Environmental Strategies arranged a visit for me and other experts to the revitalization project in Shinchi-machi to learn about their efforts to be a new community-based energy town. We also visited memorial sites for the victims of the tsunami and were driven along the newly constructed sea wall meant to protect against future tsunamis. During a visit to the Environment Ministry's Fukushima Office, officials explained to us their efforts to become a repository for information about nuclear accident recovery. I had numerous discussions with representatives of various think tanks (e.g. Institute for Sustainable Energy Strategies, Institute for Institute for Global Environmental Strategies), government agencies (e.g. National Institute for Environmental Studies), academics conducting research about various aspects of the Fukushima disaster (e.g. from Fukushima Univ, Hokkaido Univ., Rikkyo Univ., Tokyo Univ., United Nations University), government officials (members of the Japanese Diet, including former Prime Minister Naoto Kan), local officials and non-governmental organizations and citizens' groups. Gaps in understanding have been supplemented by references to official documentation and other academic research.

The perspectives discussed in this article are influenced by these visits, the field trips to Fukushima and other impacted areas organized by my hosts, the people I was introduced to, the conference participants I interacted with, the cities I was toured through, and the institutions we visited. The article also draws on official and non-governmental organization documents and some media coverage addressing what has been accomplished in terms of recovery, clean up, reconstruction and the development of a new set of visions aimed at creating a new economic future for the region and strengthening Fukushima's resilience against future disasters.

3. Post-disaster reconstruction and strengthening resilience

Disaster recovery is often influenced by individuals and communities' desire to return to some kind of pre-disaster normalcy. There are socio-cultural norms and traditions which can keep communities holding on to what is familiar, even when much of it has been damaged or lost [1]. There are also economic and political interests which often have a strong desire to maintain or in a post-crisis scenario to return to something resembling the previous status quo. Yet, a return to a pre-disaster normalcy is largely ruled out by the special nature of the triple disaster, which has required dealing with multiple types of disaster management and recovery.

Typically, disaster resilience is associated with the restoration of essential basic structures and functions. Increasingly, however, there are calls to connect resilience to more extensive forms of adaptation and transformation [2]. The concept of resilience has moved beyond its original engineering usage to become more interdisciplinary and system oriented [3,4]. Increasing attention is being given in disaster research and practice to the ways in which communities can learn from the causes and consequences of disasters in order to become more resilient against future shocks and more capable of facing uncertainties and risks. Simply returning to past ways would mean that little had been learned and risks had not been reduced.

This aligns with research that treats crises as potential turning points, critical junctures which can break path dependencies and trigger change in behaviors, policies, and broader goals and visions [5,6]. Resilience as transformation involves individuals and communities "owning the need to change" and engaging in radical change (physical, social, psychological, economic) in order to not only recover but to recover better and stronger. Such transformative change can refer to infrastructure, but also to social, political, and economic structures and principles [7]. There may also be efforts to link post-disaster recovery to other major objectives such as the promotion of sustainability in order to achieve a double dividend, reducing risks while enhancing environmental quality and societal resilience [8–11] or the development of new high-tech sectors.

This article examines steps being taken in this direction in Fukushima in the face of a disaster of profound proportions. There have been many bottom-up and top-down efforts aiming at reviving the region and bringing about larger structural and political-economic changes to post-disaster Fukushima. The process has involved national, provincial, city and town-led goal and vision setting as well as substantial experimentation and citizen-led efforts at change (e.g. Ref. [12]) and information sharing.[2] As there is little global experience with the kind of nuclear crisis that occurred in Japan, there is also a strong learn as you go approach to the decontamination work at the reactor site and across impacted regions. In the wake of the triple disaster, the Fukushima Prefectural Government issued a "Vision for a Revitalization in Fukushima Prefecture". This vision has as its first goal building a safe and secure society, free of nuclear energy, and tied to sustainable development (Fukushima Prefecture, n.d.).

4. The impacts of the triple disaster

Fukushima Prefecture is located in the relatively sparsely populated Tohoku region. The total population of Tohoku was about 8.8 million (as of 2017), with about 1.8 million living in Fukushima prefecture. Fukushima and Miyagi are the wealthiest of the region's six provinces. The largest number of tsunami casualities were in Miyagi (9543), Iwate (4675) and Fukushima (1614) with a further 2529 people still missing [13]. Although the death toll was not as high in Fukushima as in Miyagi or Iwate, due to the nuclear accident's impacts on the region, Fukushima has received particularly large amounts of media and political attention. Fukushima Prefecture had over 160,000 evacuees in May 2012. According to Fukushima Prefecture's Revitalization Station, as of December 2018 that number had decreased to 43,000, suggesting a declining but still large challenge in terms of winning people back to the region.[3] The region experienced a big growth in construction as a share of the industrial sector after the 2011 disasters but the region continues to fall behind other regions economically and is experiencing a faster population decline than the national average [14].

5. Going de-nuclear in Fukushima

Considerable attention has been paid over the past decade to the factors that led to the nuclear disaster in Fukushima. The costs of the nuclear disaster have been enormous; estimates of the clean-up and decontamination costs continue to grow [47]. Blame has been placed on the lack of a culture of questioning and scrutiny that resulted from the close relationships that existed among politicians, bureaucrats, academics, banks, the utility companies, and the manufacturers of nuclear facilities and parts

[2] See for example, United Nations University's International Symposium on "Information Sharing and Communication for Recovery in Fukushima: A Human Security Approach," Fukushima, Japan, 1–3 February. 2014 (See https://ias.unu.edu/en/events/archive/book-launch/information-sharing-and-communication-for-recovery-in-fukushima-a-human-security-approach.html#overview) and the Japan Society of Political Economy Fukushima Symposium where the causes of the nuclear accident and its consequences for the region were discussed (https://jspe.gr.jp/ja/fukushima), 16–26 March. 2012. The author attended both of these events.

[3] https://www.pref.fukushima.lg.jp/site/portal-english/en03-08.html. Accessed June 1, 2020.

(often referred to as the nuclear village) and their strong belief that nuclear energy was safe and essential to Japan's economic growth [3,15,51].[4] Fukushima was no exception. The province hosted ten nuclear reactors. These reactors produced electricity not only for use within the province but also for delivery to Tokyo, the country's largest demand center. The nuclear facilities were viewed as critical to the modernization of this agricultural and fishing region. Towns which agreed to host facilities were generously rewarded. The nuclear facilities thus brought not only the jobs tied directly and indirectly to the nuclear facilities, but also monetary and infrastructural compensation [7,15,16,51].

Since the triple disaster, nuclear energy has become more controversial.[5] The big trend both nationally and in Fukushima has been away from nuclear energy. Japan reduced the share of nuclear energy in its electricity mix from 30% in 2011 to 6% in 2020. As of May 2020, only 9 nuclear reactors (accounting for about 6% of electricity generation) were operating in Japan despite the government's aim to increase nuclear production to 20% of electricity production by 2030 [17]. All ten of Fukushima's nuclear reactors are scheduled for decommissioning. This aligns with the aims of the Fukushima Revitalization Policy which calls for the creation of "a society that is safe and secure, and can continue to develop without depending on nuclear power" (Fukushima Prefecture, n.d.).

This is not to say that nuclear energy is being completely abandoned in the surrounding Tohoku region or in Japan, more generally. Nuclear operators in Miyage Prefecture aim to restart at least one of the reactors at the Onagawa nuclear facility. The number 1 reactor at the Onagawa facility was retired in 2018 after Tohoku electric determined it would be too expensive to upgrade the plant to meet new safety requirements established after the 2011 nuclear accident. On 26 February 2020, the Nuclear Regulatory Authority cleared the number 2 reactor for a restart based on its meeting the new safety standards. In the Onagawa facility's case this included the building of an 800-m long seawall that is to be just short of 30 m above sea level. The reactor was scheduled for a restart in 2021 pending local authorities' approval but in May 2020 that date was pushed back by two years to the end of fiscal 2022 (which ends in March 2023) [18]. This is the second damaged nuclear reactor to get a restart approval after meeting new safety standards. The first is the Tokai No. 2 reactor in Ibaraki Prefecture [19]. The future of the number 3 reactor has yet to be determined.

The restart plans have, however, been met with opposition from local citizens' groups as well as groups across the country.[6] To block restarts, citizens' groups have turned to the courts. They are also seeking to win greater compensation for those forced to evacuate from the region because of the nuclear disaster. Fukushima evacuees had a victory in March 2020, when the Sendai High Court ruled in favor of plaintiffs ordering Tokyo Electric Power Company, TEPCO, which ran the Fukushima Dai-ichi facility, to pay ¥730 million in damages, ¥120 million more than had been ordered by a lower court [20]. A week later, however, the Tokyo High Court reduced the damage amount to be paid by TEPCO, ordering the utility to pay an additional ¥1 million in damages to 300 evacuees substantially less than had been determined by the Tokyo District Court in 2018 [21]. Significant in these rulings is that they put to question the adequacy of the Fukushima compensation program given the difficulty of returning to the region even once evacuation orders were lifted [22].

6. Fukushima as a leader in renewable energies

At the time of the nuclear accident, Japan had a paltry share of electricity from new renewables (onshore and offshore wind and photovoltaics) in its electricity mix although it had a substantial share of hydropower because of its mountainous terrain. The situation has changed dramatically with Japan now ranking as one of the countries with the largest installed solar photovoltaic capacity in the world (REN 21). By the end of 2018, Japan had installed more photovoltaic capacity (55.5 GW) than Germany (45 GW), putting it third behind the much larger China and the United States. Total installed renewable capacity in Japan (90 GW, of which 50 GW was hydropower) was still lower than in Germany (120 GW of which only 11 GW was hydropower), largely because Japan had installed little wind capacity (3 GW compared with 59 GW in Germany), but plans are emerging for floating offshore wind farms off the coast of Fukushima (IRENA Renewable Capacity Statistics 2019). The national government has set a goal of achieving 22–24% renewables in the electricity mix by 2030, far less than the German target of 65% by 2030. Although in comparison with many European countries, the Japanese national renewables target is not viewed as particularly ambitious, given the limited attention that was paid to renewables before, it does mark a significant break with the past.

Within this national shift towards more renewables, Fukushima is playing a particularly dramatic role. In 2014, Fukushima Prefecture set a goal to meet 100% of primary energy demand from renewable power (windpower, solar thermal heating, photovoltaics, biomass for power and heating, geothermal energy and hydropower) by 2040. This is an extremely ambitious goal for a region that was previously heavily invested in nuclear energy. As of 2018, Fukushima prefecture was being supplied by almost 1.5 GWh of electricity from solar, wind, geothermal, and biomass (compared with only 400 MWh in 2012).

A transition to renewables in Fukushima has been pushed forward by various individuals and groups [23,24]. Tetsunari Iida founded the Institute for Sustainable Energy Policies (ISEP),[7] bringing concepts about energy democracy he learned in his time in Sweden and his many trips to Denmark and Germany to Japan. Together with film maker Hiroyuki Kawai, he produced a film, "Renewable Japan: The Search for a New Energy Paradigm" (2014). ISEP has supported policy makers in Fukushima to develop renewable energy plans and has been actively engaged in citizen education about renewables. Another critical player is the Japan Renewable Energy Institute, a think tank created in the wake of the Fukushima nuclear accident by billionaire and SoftBank CEO Masayoshi Son, who has also invested heavily in renewable energy technologies.[8]

The National Institute of Advanced Industrial Science and Technology opened the Fukushima Renewable Energy Institute in Koriyama, Fukushima in April 2014 with the aim of promoting R&D into renewable energy. Industrial groups are encouraged to invest in renewable energy development in the three prefectures most heavily impacted by the triple disaster. In April 2016, a testing, evaluation, and R&D center for advanced power electronics products was opened. The facility works on

[4] Similar views were expressed at the International Symposium on the Truth of the Fukushima Nuclear Accident and the Myth of Nuclear Safety, Univ. of Tokyo, 30 August. – 2 September. 2012 attended by the author. https://cnic.jp/english/?p = 2675; https://cnic.jp/english/?p=2648.

[5] In meetings I held with Democratic Party of Japan officials on June 4, 2011 organized by the Institute for Sustainable Energy Policies (ISEP) and the Friedrich Ebert Stiftung, there was great interest in Germany's decision to phase out nuclear energy and in the question of how Japan might reduce its dependency on nuclear energy. The same was the case six years later in a meeting I had with members of the Rikken Minshutō's Energy Committee in the Diet (26 February. 2018).

[6] I was invited to discuss nuclear issues with various citizens' groups, including Tomari Genpatsu no Hairo wo Mezasu-kai (Committee for the Shut Down of the Tomari Nuclear Plant) in Sapporo, 16–25 November. 2012 and to critically discuss nuclear energy issues with participants at the International Seminar on Environmental Radioactivity, Hokkaido Univ., Sapporo, 8–10 Nov. 2013.

[7] Conversations with Tetsunari Iida and Noriyaki Yamashita during visits to the Institute for Sustainable Energy Policies, March 16, 2015. See also Institute for Sustainable Energy Policies, https://www.isep.or.jp/en/. Accessed June 1, 2020.

[8] The author has given a talk at the institute, met with researchers there, and supervised one of its employees, https://www.renewable-ei.org/en/.

renewable energy networks, hydrogen technologies, wind-turbine components, thin-film silicon photovoltaic module technologies, and geothermal heat and optimization technologies. Fukushima now also hosts an annual renewable energy industrial fair. Fukushima has established cooperation agreements on renewable energy with the Frauenhofer Society and with Denmark in 2014 and with North Rhine Westphalia in 2017 [25]. Regions which were heavily impacted by the tsunami but not completely destroyed by it, have invested the most in building up solar power capacity [23].

Numerous mega solar projects have been started. Minami-Soma, which lies about 25 km north of the Fukushima Dai-ichi nuclear facility, was badly hit by the tsunami, losing about 1700 residents, and was also impacted by radiation fallout. Over 10,000 citizens were ordered to evacuate their homes. After decontamination work was completed in the city, restrictions on entry into most areas were lifted in July 2016, meaning that citizens could return to their homes, but as is common in many parts of the stricken region, many families, especially those with children, are not returning. Much of the coastal land that was flooded is no longer fit for agriculture due to the high salt content and other toxic substances left behind by the tsunami. In Minami-soma, some of this land has been turned into massive solar parks. The Minamisoma Mano Migita Ebi Solar Power Plant is the largest in Fukushima, with an output large enough to power 20,000 households. In describing the plant, the Sumitomo Corporation points out that the solar plant is not only providing electricity and energy jobs, it is also a tool for environmental education for children [26].

The Shirakawa Solar Park scheduled to open in Shirakawa City, Fukushima in December 2021 is expected to become one of the country's largest. The Amp solar park in Fukushima City, is already operating at 14.7 MW, enough to power 6000 homes [27]. The Mega solar Nasu Shirakawa is big enough to power about 500 homes [28]. The Okuma Town Furusato Revitalization Mega Solar facility was completed in 2016. These various projects have helped Fukushima advance towards its goal of becoming a renewable energy prefecture although it should also be noted that objections to the landscape damage and nature destruction associated with some of these megasolar projects has led to the formation of a bylaw in Otama Village calling for the harmonization of solar PV facilities and nature conservation (大玉村太陽光発電設備と□然環境保全との調和に関する条例, December 2019).[9]

Japan has invested relatively little in wind energy with the main arguments for this being limited available suitable land onshore and the steep drop in sea depth close to the coast. This is, however, leading to new technology developments in the form of offshore wind projects. The Fukushima Offshore Wind Consortium, funded by the Ministry of Economy, Trade and Industry, and bringing together major firms like Marubeni, Mitsubishi Heavy Industries, Mitsubishi Shipbuilding, Mitsu E&S Shipbuilding Co., Ltd., and Hitachi Ltd. as well as the University of Tokyo is developing Japan's first floating offshore wind farm demonstration project, called Fukushima FORWARD, off the coast of Naraha [29].

7. Creating smart communities

Efforts are being made to promote transitions also at the city level. The National Institute for Environmental Strategies has linked up with Shinchi-machi in Fukushima and is seeking to help the town realize its goal of becoming a "FutureCity". The community was badly impacted by the tsunami, with 20% of the city washed away. It has in the meantime seen the construction of a giant new tsunami protection sea wall, as well as the reconstruction of railway lines and the Shinchi Railway station, and various new housing communities. The city is being digitally integrated to help residents connect with each other and the municipality and to share information related to living conditions as the city works to recover. To encourage energy conservation, residential buildings, businesses, and municipal facilities have been outfitted with energy monitoring devices. A district energy system is being developed and information about renewable energy generation and demand are being shared to improve the efficiency of the energy system. In addition, public transportation and taxi services are connected to digital information systems.

The city is also integrating renewable energy into construction design. NIES [30] runs research projects in the town aimed at understanding how to best develop a model of not only renewable energy integration, but also societal integration through internet-based communication technologies.[10] In addition, an industrial park is being built that is to derive its energy from a thermal power plant supplied by an LNG terminal [31].

Rebuilding Shinchi-Machi as a new energy town. Photo: Miranda Schreurs, 30 August 2018.

Smart Community and Future City concepts have been embraced as a means of bringing new economic potential to the damage struck region. The projects are focused on the development of communities, companies, and think tanks addressing renewable energy and energy storage technologies as well as smart grid systems. The government hopes that these projects will bring international attention to the region. By focusing on next generation technologies the goal is to develop "smart" energy and resource efficient model communities and eventually help to stimulate economic activity in the region and entice people (back) to the region. Examples of the projects being developed include offshore floating wind farms, solar facilities, and smart community development projects.

Fostering public-private partnerships, the national government also has subsidized smart community projects in Mizako and Kitakami in Iwate Prefecture, Zamamoto, Ohira, Ishinomaki and Kesennuma in Miyage Prefecture, and Aizuwakamatsu in Fukushima Prefecture. Beyond the central goal of stimulating the economy in these regions, renewable energy and smart community technologies are increasingly recognized as important global growth sectors [31].

The projects have offered not only direct employment, but also contributed to post-disaster tourism. Some of this tourism is promoted by national and local agencies bringing foreign dignitaries and experts to view the region for its future-oriented energy and high-tech industries as well as to showcase the steps being taken to revitalize the area. There is

[9] Communication with ISEP's Noriaki Yamashita on 12 November 2020.

[10] I had the opportunity to visit Shinchi FutureCity in a tour organized by the National Institute of Environmental Strategies, 5 September. 2018. During this visit we also visited Minami-Soma to observe reconstruction efforts, viewed a temporary storage field and interim storage facility for radioactive waste in Ookuma-town, and visited Sendai.

also an effort by the prefecture to promote what they call "hope tourism" to inform people about the triple disaster but also about the revitalization of the region.[11] Numerous sites impacted by the tsunami have been turned into memorials.

8. Linking the Tokyo Olympics to hydrogen fuel development in Fukushima

Before their delay due to the CoVid 19 pandemic, the Olympics were to be brought to Japan in 2020 with the idea of supporting reconstruction of the region with the first two days of the Olympic relay planned to go through the badly damaged areas of Fukushima, starting with Naraha and Hirono towns and moving on through Iwaki, Kawauchi, Okuma, Futaba, Tomioka, Kasurao, Namie, Minamisoma, Soma, Iitate, Shinchi, and Kawamata before reaching the capital city of Fukushima. There was some questioning about the wisdom of this decision by environmental groups with Greenpeace reporting concentrated radiation levels throughout Fukushima prefecture as well as at J Village, the intended starting point for the torch rally [32]. The decision for this route was clearly intended by the government as a message to the Japanese people as well as to the outside world, that the region is recovering. It has also been used to stimulate further energy development projects in the region.

A next major development in global energy transitions is being pinned on hydrogen fuel development. Japan is investing in the development of green hydrogen in Fukushima Prefecture. It has become an expectation globally that Olympic games be designed to reduce their environmental footprint through the use of renewable energy and recyclable products. This is also the case for the Tokyo Olympic and Paralympic Games, which are based on the sustainability concept, "Be better, together: For the planet and the people". On the environmental front, goals were set for utilization of existing buildings, using 100% renewable electricity, reuse and recycling of 99% of procured goods, and utilizing fuel cell vehicles. The New Energy and Industrial Technology Development Organization (NEDO), Toshiba Energy Systems & Solutions Corporation, Tohoku Electric Power Co., Inc. and Iwatani Corporation opened a renewable energy-powered 10 MW-class hydrogen production unit, the largest-class in the world, in 2018 in Namie-town. Namie-town is just 10 km north of the Fukushima Dai-ichi Nuclear facility. Although not all of the town was equally impacted by the radioactive plume, the western parts of the town were heavily contaminated and given the town's proximity to the nuclear facility, it fell into the exclusion zone that was drawn around the nuclear facility. On 1 April 2017, restrictions regarding entry into some sections of the town were lifted, but the western parts of the town remain off limits. Mayor Baba Tamotsu has worked fervently since the crisis struck to try to keep in contact with his town's people, but few residents appear prepared to return [33].[12] The hydrogen fuel plant is an effort to help revitalize the town and create new employment opportunities there.

9. Radioactively contaminated waste removal, recycling, and incineration

One area of remarkable post-disaster recovery has been in relation to the clean-up of the mountains of debris caused by the tsunami. A year after the disaster, the United Nations Environment Programme, at the invitation of Japan, conducted a study of the post-disaster clean up. The report, which defined the disaster as the most economically damaging in human history (estimated at US$ 210 billion), noted that 400,000 people were displaced. In an effort of enormous proportions, the Japanese Self Defense Forces, communities, industries and civilian groups teamed up to address the destruction the tsunami left in its wake: destroyed houses, roads, railroads, industries, agricultural and fishing equipment, automobiles, ships, as well as of course, human and animal remains. The waste was a mix of materials, sea debris and mud, some of which was recyclable or biodegradable, some of which was hazardous or non-recyclable. In the city of Ishinomaki, among the worst impacted, there was an estimated 6.15 million tons of debris, equivalent to about 100 years' worth of the city's normal solid waste production. Although waste management is typically a municipal level responsibility, in this case, the Ministry of Environment's newly formed Task Force on Disaster Debris Management issued guidelines in May 2011 for dealing with the disaster waste and called for inter-municipal cooperation and cross-jurisdictional involvement between prefectures. In a remarkably efficient manner over the next three years, the waste was separated into categories: combustible waste to be used for cement calcination and power generation; waste wood to be turned into multi-purpose wooden boards or fuel for boilers and power generation; non-combustible waste for disposal in landfill sites; scrap metal for recycling; waste concrete to be used as material inputs for reconstruction in the impacted areas; home appliances and automobiles to be separated and recycled; watercraft to be dismantled and recycled to the extent possible; hazardous waste separated for special treatment; tsunami sediments; and waste at post-fire sites. At the worst hit locations, incineration plants were quickly built. The incineration ash is often used in construction, for example, of roads. It has also been used as a form of fuel. While the UNEP expert team found some areas that could be improved (such as limiting the long-distance transport of waste for incineration), they also found many positive lessons in Japan's post disaster clean-up efforts [35].

A more challenging category of debris that received little attention in the UNEP report was the waste which was generated by the radioactive fallout from the Fukushima nuclear plant facilities. This waste requires special handling. For cities and rural regions of Fukushima impacted by radioactive fallout, much of the tsunami debris needed to be treated as radioactive waste. In addition, radioactively contaminated soil, plants, and leaves needed to be removed creating an additional waste management challenge of enormous scale. Substantial progress was made in the first years after the disaster in decontaminating cities where buildings and roads could be washed clean, with the water used for washing collected and also designated as radioactive. Building by building, areas which were exposed to radioactive fallout were decontaminated to allow people to move back into some of the less heavily contaminated areas.[13] As of March 2018, 418,583 houses, 11,958 public facilities, and 18,841 roads had been decontaminated. The decontamination efforts have helped reduce radiation air dose rates substantially.[14]

The removal of soil and vegetation from impacted regions has, however, created a new problem: monstrously large quantities of waste, with varying degrees of radiation. There is no clear number on just how many sacks containing radioactive soil there are but estimates range in

[11] See for example, Hope Tourism, https://fukushima-guide.jp/experience/hope-tourism/. Accessed June 1, 2020.

[12] I met Baba Tamotsu in July 2012 during a scheduled expert visit to Namie-town as part of the FAIRDO research project on post-nuclear disaster conditions (see Ref. [34]). In February 2014, we were co-panelists addressing post-recovery issues in a symposium held in Fukushima, https://fgc.unu.edu/en/events/symposium/feb2014_int_sym.html. Accessed June 1, 2020.

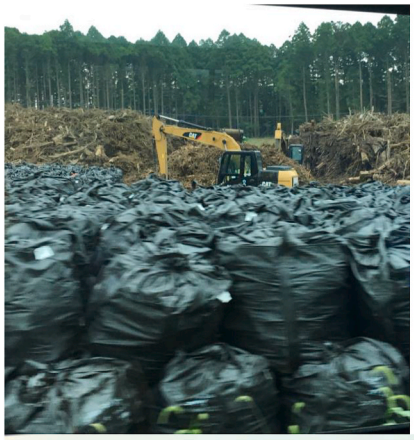
[13] As a participant in the Institute for Global Environmental Strategies' FAIRDO project addressing radioactive decontamination efforts, I had the opportunity to observe these efforts first hand. Workshops were held at Fukushima Univ. to discuss these efforts with field visits to the Kyu-Oguni area, Date City and the Takakura area of Minami Soma. Meetings to discuss the challenges associated with decontamination and the progress which was being made were held with Mr. Uchibori, Vice-Governor of Fukushima and Mayor Baba of Namie town. A tour of the Tsushima and Ukedo areas of Namie town highlighted the earthquake damage to the area. Site visits occurred from 18–25 July 2012. For a protocol of our visits see Ref. [34].

[14] Images of what this decontamination work involves are available at the Fukushima Prefecture site: http://www.pref.fukushima.lg.jp/site/portal-english/en02-03.html. Accessed June 1, 2020.

the many millions. These mounds of contaminated soil are stored in thousands of temporary sites across Fukushima Prefecture [36]. Where this waste is to end up is only now beginning to be addressed. Interim storage sites near the Fukushima Dai-ichi nuclear plant are being constructed. The Ministry of Environment confirmed in October 2019 that some of the bags were swept away during flooding caused by Typhoon no. 19, in Tamura, Fukushima, indicating just how precarious the situation is [37]. An incinerator designed for burning some of the low-level radioactive waste has also been built inside the exclusion zone.

The question of what to do with the huge amounts of radioactive water that has been stored in the thousands of tanks that now fill the grounds of the Fukushima Dai-ichi nuclear facility grounds also needs to be addressed.[15]

Construction work on a facility for containment of radioactive soil. Okuma-Machi, Fukushima. Photo: Miranda Schreurs, 30 August 2018.



Bags of contaminated soil awaiting transport to a storage facility. Photos: Miranda Schreurs, Ōkuma, Japan, 30 August 2018.

The new incineration plant in Ōkuma town inside the evacuation zone.

Photo: Miranda Schreurs, 30 August 2018.

10. Fukushima as a global leader in radioactive decontamination and nuclear decommissioning

Beyond renewable energy and hydrogen fuel, Fukushima Prefecture is becoming a new center for research and expertise related to nuclear decontamination and decommissioning. While certainly an unwanted lesson, the knowledge being gained could be of critical importance should in the future further nuclear accidents occur in Japan or other countries. There is also much useful information that is being obtained as a result of the research on-going in Fukushima, which can aid in radiological decontamination and decommissioning associated with nuclear energy facilities and military facilities around the world. There are many dimensions to the expertise being developed in the region.

The Fukushima Prefectural Center for Environmental Creation, an expansive information, educational, and R&D center was established in Miharu in 2016. It is a cooperation between the Japan Atomic Energy Agency's Fukushima Environmental Safety Center, the NIES Fukushima Branch, and Fukushima Prefecture. In addition to being an information center related to the nuclear disaster and its aftermath and regional reconstruction and revitalization for educating the public, the center deals with radiation measurements, decontamination and contaminated waste disposal, environmental impacts, and creation of an

[15] This was a regular topic of discussion during my visits to the Fukushima evacuation zone.

environmentally resilient post-disaster society.[16] The center has auxiliary facilities involved in radiation monitoring, radiochemical analysis, aquatic environment monitoring, and wildlife monitoring. These facilities are part of the effort to turn Fukushima into a knowledge hub for understanding the short, medium, and long-term impacts of the nuclear disaster as well as recovery efforts.

NIES researchers are engaged in projects focused on post-disaster environmental recovery and renovation and the creation of environmentally more resilient communities. This involves research into the management and treatment of radioactively contaminated waste, measuring and simulating the status of radioactivity in the environment, and assessing radiation doses in humans and impacts on organisms and ecosystems. An important aspect of this work is also reducing the volume of radioactive waste for interim storage and final disposal. NIES aims to further knowledge on disaster preparedness and post-disaster environmental risk management.[17]

Another area has to do with the robotic technologies needed for the decommissioning of the nuclear reactors. The nuclear accident resulted when as a result of the tsunami, electricity to the plant was cut. The back-up cooling system was damaged by the flood waters resulting in nuclear meltdowns inside three reactors. While over the course of the past decade the damaged reactor buildings have been stabilized and work on removing undamaged fuel rods has begun, the technological challenges involved due to the radiation levels are enormous.

The Japan Atomic Energy Association's Naraha Center for Remote Control Technology Development was established to develop robot technologies that can be operated remotely underwater in conditions with extreme radiation levels. The center, which started operations in 2016, has a mock-up test building with a model of a reactor core and a virtual reality room that reproduces images of the inside of the reactors in 3D to help train robot technicians [38]. The robotic and simulation technologies developed here will certainly also have many other potential uses and bring high-level jobs to the region. There are however still no answers for how to decommission the damaged nuclear reactor cores thus years of additional research and development will be required. The dangerously radioactive melted uranium fuel in the severely damaged Unit 3 reactor was only located by a specially manufactured robot in 2017 after several earlier attempts to send robots into the damaged core ended in failure as they could not withstand the radiation. It is estimated that it could take another 30–40 years to decommission the damaged nuclear reactors.

11. Lessons from Fukushima: the Sendai Framework for Disaster Risk Reduction

Fukushima is actively working to share knowledge about disaster preparedness, management, and reconstruction with the international community in other ways as well. Japan has long played a major role in United Nations disaster relief initiatives. The First World Conference on Natural Disasters was hosted by Japan in 1994, leading to the adoption of the Yokohama Strategy for a Safer World: Guidelines for Natural Disaster Prevention, Preparedness and Mitigation, and an accompanying plan of action. After the fateful Indian Ocean Tsunami in 2004, where the death toll of over 220,000 people primarily in east and southeast Asia, could have been reduced had an early warning system been in place in the Indian Ocean, the Hyogo Framework for Action 2005–2015 was agreed upon. The action framework carries the name: Building the Resilience of Nations and Communities to Disasters. It is also at this time, that the idea of building better to strengthen resistance was adopted, in recognition that building practices along coastlines had destroyed protective natural cover, such as mangrove forests, which could have reduced the force of the tsunami waves.

After the 2011 triple disaster, the Sendai Framework for Disaster Risk Reduction (2015–2030) was formulated. It aims to make countries and communities more resilient against disasters through learning from past experiences. Stakeholder consultations began in 2012 and intergovernmental negotiations took place from July 2014 to March 2015 [39]. Under the Sendai Framework, disaster risk reduction is to be realized through building back better during recovery, reconstruction and development [53]. In part because of the Fukushima nuclear accident, the Sendai Framework moved beyond the traditional focus of disaster management, which focused on natural hazards like earthquakes, hurricanes, and fires, to incorporate technological risks into risk preparedness and a broader range of issues, including health [40].

The Sendai Framework calls for development to be risk-sensitive so that it can also be sustainable. With the costs of disasters increasing, and expectations that climate change will lead to more frequent disasters, the international community is stressing the importance of linking disaster preparedness to the Sustainable Development Goals [41]. For Fukushima and the broader Tohoku region, which have been hit by many natural disasters in the past and still have decades of work to deal with the aftermath of the nuclear radiation, focusing on sustainable development will be critical not only for this, but also for future generations.

12. Civil society responses to the triple disaster

Efforts to transform Fukushima into a non-nuclear, sustainable region have been embraced by scholars and civil society groups [45]. Similar to the case after the Kobe earthquake of 1995 which awakened a sense of civic-duty and pressured the government to become more open to civil society participation in governance [42,43], the Tohoku earthquake made visible the willingness of civil society groups not only to work together to overcome tragedy but also to contribute to bringing about sustainability transitions. Early on many citizens' groups provided immediate aid to the region, in the form of donations of food and clothing. With time, they focused more on efforts to bring a sense of normalcy back to the region. For example, the *Fukushima no Kodomotachi o mamorukai Hokkaido* (Hokkaido Association for the Protection of Fukushima's Children) sponsored vacations for young children from impacted communities.[18] Various programs formed to assist elderly evacuees living in temporary housing facilities (see also [52]).[19] Other groups focused their efforts on assisting those with concerns about their health, such as the 3–11 Fund for Children with Thyroid Cancer, or addressing victims' rights, such as the *Shienho Shimin Kaigi* (Citizens' Conference to Promote the Nuclear Victims Support Act) (see also [44]).

There have also been many groups that have added sustainable energy to their repertoire of activities as a result of the Fukushima accident. The Seikatsu Club Consumers' Co-operative, formed in 1965 at the initiative of women concerned about food safety, destruction of the environment and poverty, has since the Fukushima nuclear accident expanded its concerns to include energy issues. In 2011, four Seikatsu club consumers' cooperatives in the metropolitan Tokyo area (Tokyo, Kanagawa, Saitama, and China) jointly launched an energy self-sufficiency campaign and set their eyes on building a Seikatsu Club Wind Power Plant, which was realized in 2012 and given the name

[16] As a member of the International Advisory Board for the National Institute of Environmental Strategies, I was toured through the facility and had the opportunity to discuss the work being conducted there on 1 September 2017. We also visited a radioactive waste temporary storage facility in the Nakasato district, Miharu.

[17] I have had numerous opportunities to discuss with NIES researchers about the work they are doing related to Fukushima's radiation challenges and to review their scientific writings.

[18] Discussion with group members during a 2019 visit to Hokkaido.

[19] The author had the opportunity to discuss with many individuals and groups who volunteered in the region directly or indirectly (e.g. collecting money for the region).

Dream Power (Yumekazu). The project linked these four cooperatives with the agricultural region of Nikaho City in Akita Prefecture and led to greater agricultural purchasing from the region where their wind turbine was erected.[20] They have begun collective purchasing of electricity with a high percentage of renewable electricity [48].

Non-governmental organizations (e.g. Greenpeace, Peaceboat, Friends of the Earth Japan, Citizens' Nuclear Information Center, Green Action) have organized many conferences, workshops, and events protesting nuclear energy and calling for a greater focus on sustainability and green energy.[21] These workshops and events are both educational and political in nature. Church groups, such as the Anglican Communion in Japan (Nippon Sei Ko Kai) have organized events in the region to discuss the radioactive contamination and its health and environmental effects, to introduce experiences with non-nuclear, low carbon energy transitions from abroad, and to discuss with local groups steps that could be taken to shift society away from nuclear dependence.[22] The United Christ of Church has through a program called Tohoku HELP, assisted with measuring radiation in food products, providing disaster victim support to non-Japanese among other projects.[23]

13. The challenges which still lie ahead

Substantial progress has been made in revitalizing Fukushima and the broader Tohoku region so that a decade after the disaster, it is possible to say there are many signs that many of the areas badly damaged by the earthquake and tsunami are rebuilding. It will however, still take many years to realize if Fukushima can succeed in reinventing itself as a center of robotics, fulfill its goal of achieving 100% renewable energy by 2040, and situate itself as a global leader in radioactive waste management and nuclear decommissioning.

There are many remaining societal challenges facing the region. Despite indications that the region is slowly recovering, many evacuees are still either unable or unwilling to return [49]. Those who have returned tend to be older. The change in population demographics in the impacted areas of Fukushima, in particular, are dramatic and raise questions about what will happen to these towns when the older generation dies out. Thus, although the government has invested in new industries and technologies as well as new schools and medical facilities, it will still take many years to win back confidence and trust in the government's messages that the region is safe. Attracting a next generation of young people to the area will require further efforts.

There are still many justice issues to be addressed associated with those who were forced to evacuate, those who have suffered mental stress as a result of the triple disaster, and those who are experiencing medical issues. What the long-term impacts of decontamination work will be on the health of workers are also open questions.

There has been relatively little discussion of inter-generational equity issues. It will largely be next generations that will be left with the burden of completing the highly dangerous and complex decommissioning work at the Fukushima Dai-ichi nuclear facility. And even once this is completed, there is also the still big and open question of how Japan plans to manage the high-level radioactive waste from the site as well as from all of its other nuclear facilities. While a process to identify a site location for a high-level radioactive waste depository is on-going, even once a location has been found, the process of building the facility and transporting high-level radioactive waste there will still take many decades.

Promoting resilience in the region will certainly require further efforts in transitioning the economy in more sustainable directions while investing more strongly in the rebuilding of damaged communities. For the most heavily contaminated regions, it may take many more decades before a new normalcy is achieved. While civil society groups from around the country stepped in to help the region in the aftermath of the triple disaster, how long these support networks will continue to invest in the region remains to be seen.

To what extent the efforts to rebuild and reinvent the region will succeed will certainly depend on how well the government and relevant industrial stakeholders manage to develop acceptance of the new image they are working to create for Fukushima, one that goes beyond the nuclear disaster, and focuses instead on the region as being safe, sustainable, resilient, and future-oriented. It will also depend on the extent to which locals feel they have been given a voice in the process. For far too long, not enough has been done to invest in the more rural regions of the country and to spread wealth and investment beyond Japan's urban centers. Fukushima and the broader Tohoku region have much to offer in terms of natural beauty and natural resources. The biggest tragedy would be to fail to seize the opportunity created by a disaster of horrendous proportions to set the region on a new more resilient and sustainable trajectory. Important steps have been taken in this direction. Yet, beyond new infrastructure and industries, people must feel safe, and for this, the trust in political and economic institutions that was broken by the failures of the nuclear safety regime and in the approaches taken to dealing with triple disaster victims still need to be repaired.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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[21] Invited speaker at the Citizens' Nuclear Information Center's Global Conference for a Nuclear Free World, Yokohama (http://npfree.jp/global-conference1/english/) 14-15 January. 2012 and participant in their tour through tsunami-struck Minami Soma, bordering the evacuation zone, 16–18 January. 2012; 16–26 March. 2012; invited speaker at the Nuclear Free Now Global Conference for a Nuclear Power Free World 2 organized by Peace Boat, ISEP, Green Action, Citizen's Nuclear Information Center, FoE Japan, and Greenpeace Japan 15–16 December. 2012 (http://npfree.jp/english.html); speech and discussions at workshop organized by Genshiryoku Shimin Iinkai (Citizens' Commission on Nuclear Energy), Tokyo, 14–15 December. 2013; meeting with anti-nuclear activists and visit to Sakurajima, Kagoshima, 16–19 May 2014; at the invitation of Yoshinori Ikezumi, I was invited to lecture and meet with concerned citizens in Nagoya and Nisshin City and to participate with them in a field visit to the Fukushima evacuation zone (Ookuma Town and Naraha), 22–28 February. 2018; I was invited to meet with members of the Sendai Christ Church and together with Kay Ikezumi to visit the tsunami ravaged Arahama elementary school museum, tour the Miyagi memorial park, view the damage and recovery efforts in Natori, and to discuss energy transitions with members of the Catholic Church in Hakodate, Motomachi, Hokkaido as well as the Sapporo Christian Church, Sapporo, Hokkaido.

[22] The author was invited to give a key note about energy transitions in a forum organized by the Anglican Communion from 27–31 May 2019 and to exchange experiences with the church members (https://www.anglicannews.org/news/2018/12/nippon-sei-ko-kai-launch-campaign-to-free-the-world-of-nuclear-power.aspx).

[23] Based on author's discussions with Rev. Dr. Naoya Kawakami and others from the Sendai Christian Alliance Disaster Relief Network Töhoku HELP who the author met in Japan in 2019.

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