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Japan's Nuclear Reactor Fleet: The Geopolitical and Climate Implications of Accelerated Decommissioning

By Dr. Phyllis Genther Yoshida

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Cover: An illuminated Tokyo Tower is seen between skyscrapers in Tokyo, Japan, March 10, 2016. Source: REUTERS/Issei Kato

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Executive Summary

In the decades since Japan became the first country to join US President Dwight D. Eisenhower's "Atoms for Peace" initiative, nuclear energy has become a critical component of Japan's energy security strategy. Nuclear energy has enabled Japan to mitigate its dependence on energy imports, especially oil and gas from the Middle East. In the beginning of the 21st century, as global climate concerns grew, Japan recognized its nuclear reactor fleet as a key asset in the fight against climate change. However, following the March 2011 Fukushima Daiichi nuclear accident, Japan took its reactors offline and began the process of decommissioning part of its reactor fleet, which has led to Japan increasing its energy imports and a greater dependence on imported and domestic fossil fuels. Additionally, a weakened domestic nuclear reactor fleet has had significant implications for Japan's civil nuclear export program.

In comparison to the fifty-four nuclear reactors that had been in operation prior to March 2011, Japan—as of November 2020—only has nine nuclear reactors in operation. The nine reactors online now accounted for about 7.5 percent of Japan's electricity production in 2019, compared to the full reactor fleet that had provided 30 percent of Japan's electricity. In the years since 2011, Japan has had to make up the shortfall in power while also working to meet increasingly ambitious climate goals.

As Japan has had to import more oil and gas from the Middle East in order to compensate for having less nuclear in its energy mix over the last decade, it has found itself back in the situation that it had been trying to avoid when, after the oil crises of the 1970s, it sought to build up its nuclear reactor fleet as a quasi-domestic source of energy. Japan has had to navigate geopolitical challenges that include the diplomatic and economic boycott of Qatar by Saudi Arabia, the United Arab Emirates (UAE), Bahrain and Egypt. Japan has also had to find new sources of oil following the United States' refusal in April 2019 to reissue waivers to allies to import oil from Iran.

Japan's weakened domestic reactor fleet has had ramifications far beyond its domestic energy mix. The premature decommissioning of Japan's nuclear reactor fleet and a lack of new nuclear builds have damaged Japan's ability to export nuclear energy technologies internationally. At a time when Russian and Chinese state-owned nuclear enterprises are working to dominate the international civil nuclear market, the private sector nuclear energy industries in the United States, Japan, and other allies must be as strong as possible in order to compete against the nationalized civil nuclear industries in Russia and China.

Finally, Japan has recently set a target of net-zero greenhouse gas (GHG) emissions by 2050. However, the slow restart of closed nuclear reactors and the planned decommissioning of more nuclear power plants will pose challenges to Japan's ambitious climate goals. Although greenhouse gas (GHG) emissions fell from 2013 to 2019—largely due to strong energy efficiency measures, an increase in renewable energy use, the return of some nuclear power, and the enhanced efficiency of fossil-fuel power plants—Japan is still not on target to meet its pledged 26 percent reduction below 2013 levels by 2030, let alone net zero by 2050.

In order to mitigate the challenges detailed herein, this report provides the following recommendations:

- **Japan must use its existing nuclear fleet in the near and long term to 2050:** Japan's existing nuclear power is important to reducing GHG

emissions and meeting Japan's 2030 climate pledge and 2050 net-zero goal. Additionally, Japan's use of its nuclear fleet will mitigate its dependence on energy imports and make Japan more energy secure.

- **Japan must remain involved in global civil nuclear trade:** Japan's civil nuclear export program is critical to help ensure the maintenance of the present international order based on strong, legally binding nonproliferation and safety standards.

- **Japan needs to develop a role for advanced nuclear technologies, including SMRs, which it should deploy as early as feasible:** These reactors would help Japan regain its influential position in global civil nuclear exports. Importantly, advanced nuclear technologies would also assist in the deployment of renewables and the decentralization of the grid, and they would provide a source of low-carbon energy that could replace coal in the energy mix.

- **Japan should rebuild its nuclear energy workforce and public trust in nuclear power:** Japan must rebuild its nuclear energy workforce and reverse the precipitous decline in the number of nuclear science students through extensive public education efforts that stress safety and the contribution of advanced reactors to the uptake of renewable energy and the mitigation of climate change.

- **Japan should regain its leadership position in the climate battle:** Nuclear power should complement and work with growing renewable energy to enable a retreat from fossil fuels, especially coal.

Introduction

Prior to 2011, nuclear power was a significant source of energy in Japan, accounting for 30 percent of the country's electricity generation. As a clean and quasi-domestic source of power, nuclear energy helped Japan lessen its dependence on energy imports and curb its carbon emissions. However, following the March 2011 Fukushima Daiichi nuclear accident, Japan began to decommission part of its nuclear reactor fleet. Taking nuclear reactors offline has had consequences for Japan that have included increased dependence on imported fossil fuels—even as Japan's climate goals have become more ambitious—and diminished capabilities in Japan's civil nuclear export program.[1] Japan's energy security, its role in the international nuclear market, and its ability to meet emissions targets have implications for Japan, the United States, and for rest of the world.

Given the loss of much of its nuclear power, Japan has had to replace most of its nuclear energy with imported liquified natural gas (LNG), oil, and coal. There is no guarantee that the supply of these fossil fuels will not be disrupted. Japan, due to its current dependence on foreign energy imports, is particularly susceptible to global market disruptions. It has had to walk a fine line between its close relationship with the United States and its desire to continue to import oil from Iran, even as the United States has ramped up secondary sanctions on countries and companies doing business with the Islamic Republic. In response to these sanctions, Japan has had to seek waivers and, at other times, has switched to importing more expensive oil from the UAE.[2]

As Japan's domestic reactor fleet has faltered, Japan has been limited in its ability to serve as a regional counterweight to China's civil nuclear export program. Japan is a critical ally of the United States, as it supports US safety and nonproliferation standards globally through its nuclear energy export program and its leadership in international nuclear organizations. The United States and its allies—specifically, Japan, the Republic of Korea (ROK), Canada, France, and the United Kingdom—must maintain primacy in civil nuclear exports in order to set safety and nonproliferation standards for the next generation of nuclear energy technologies. This is increasingly important as more new-to-nuclear countries than ever before are expressing an interest in purchasing nuclear energy technologies, with Russia and China each eager to claim the mantle of global nuclear export leadership. However, with a weakened domestic reactor fleet, Japan's ability to partner with allies on civil nuclear exports will suffer.

Japan increased the ambition of its climate goals in October 2020 with an announcement by Japanese Prime Minister Yoshihide Suga that Japan would pursue a target of net-zero greenhouse gas emissions by 2050, up from the goal—announced in May 2016—of an 80 percent reduction by 2050 over 2013 levels. However, the slow restart of closed nuclear reactors—and the planned decommissioning of more nuclear power plants—will make it difficult for Japan to achieve its decarbonization goals. The current uptake of renewable energy is growing but still slow, and Japan is still overly dependent on fossil fuels, especially coal. In the global fight against climate change, it is necessary for all countries to meet their emissions goals, and Japan is no exception.

As the United States also moves to decommission part of its nuclear reactor fleet—but without replacing its aging reactors with new ones—Japan can serve as a cautionary tale. Nuclear power provides the United States with a domestic source of reliable low-carbon energy and, without a robust reactor fleet, the United States will have to meet its energy demand through greater reliance on fossil fuels, unless and until renewable energy and energy storage are much more widely available.

Civil nuclear energy serves as a cornerstone of the US-Japan energy partnership, and it is in the best interests of both countries that Japan's nuclear energy sector remain strong.

[1] Nikkei staff writers, "Japan to reduce greenhouse-gas emissions to net zero by 2050," Nikkei Asia, October 21, 2020, https://asia.nikkei.com/Spotlight/Environment/Japan-to-reduce-greenhouse-gas-emissions-to-net-zero-by-2050.

[2] Yuka Obayashi and Bozorgmehr Sharafedin, "Japanese refiners load first Iran oil cargo since U.S. sanctions," Reuters, January 21, 2019, https://www.reuters.com/article/us-iran-oil-japan/japanese-refiners-load-first-iran-oil-cargo-since-u-s-sanctions-idUSKCN1PF0EH; Takeo Kumagai, Gawoon Philip Vahn, and Andrew Toh, "UAE becomes Japan's largest crude supplier in May as Iran oil imports halt," S&P Global Platts, June 28, 2019, https://www.spglobal.com/platts/en/market-insights/latest-news/oil/062819-uae-becomes-japans-largest-crude-supplier-in-may-as-iran-oil-imports-halt.

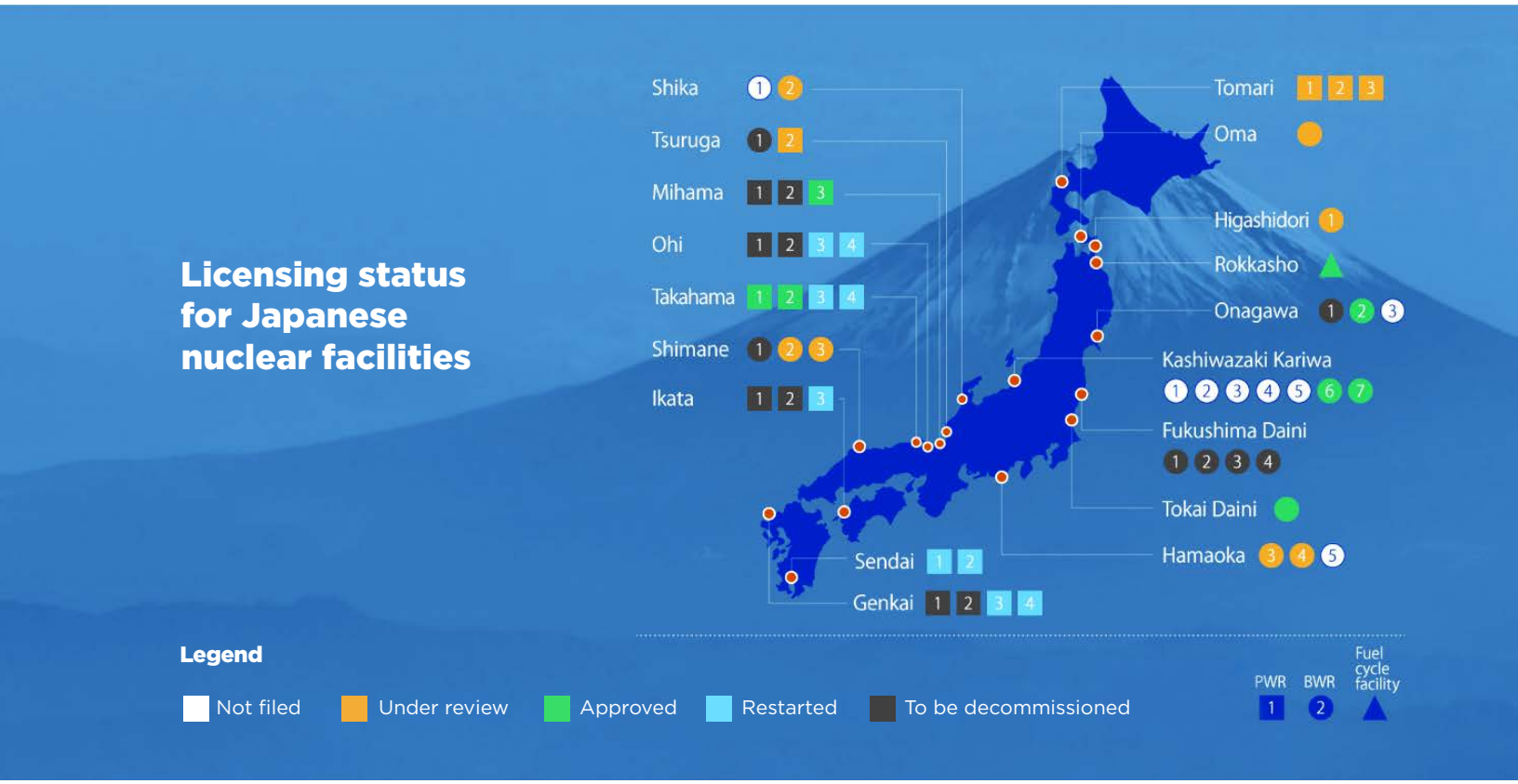
The Current Status of Japan's Domestic Reactor Fleet

Following the Fukushima Daiichi nuclear accident, Japan's nuclear reactors were shut down until they could be inspected and reauthorized by the country's newly established and independent Nuclear Regulation Authority (NRA) under new safety and stress regulations.[3] As a result of the initial shut down, Japan experienced a 30 percent shortfall in electricity, which it filled with imports of coal, oil, and natural gas, as well as notable efforts to increase energy efficiency. Japan has slowly restarted a small percentage of the nuclear reactors that had been in operation prior to 2011, but it cannot reach pre-2011 levels due to the decommissioning of many of its nuclear reactors. Many reactors could ultimately be decommissioned, especially if some that are approved but not yet restarted fail to reopen, and if reactors that have not yet applied to restart remain dormant. Without nuclear energy, Japan's domestic energy security and its civil nuclear export program will face grave challenges, and it will struggle to meet its ambitious climate goals.

As of November 2020, nine nuclear reactors at five power stations had reopened, with a capacity to generate 9,130 megawatts electric (MWe). These reactors accounted for only about 6 percent of electricity

[3] For details of the current administrative structure and regulatory framework of Japan's nuclear industry see: Nuclear Energy Agency and OECD. 2017. *Nuclear Legislation in OECD and NEA Countries: Regulatory and Institutional Framework for Nuclear Activities: Japan*. https://www.oecd-nea.org/law/legislation/japan.pdf.

Japanese Prime Minister Yoshihide Suga gives his first policy speech in parliament announcing Japan's net-zero by 2050 commitment, on October 26, 2020.
Source: REUTERS/Kim Kyung-Hoon



Source: Japan Nuclear Safety Institute, http://www.genanshin.jp/english/index.html

production in 2018 and about 7.5 percent in 2019, as opposed to nearly 30 percent prior to the accident from fifty-four nuclear reactors that had been in operation in early 2011. There are sixty reactors under consideration now; of those, nine have reopened (as previously mentioned); eleven are applying to reopen; seven are approved for initial permission; nine have not filed applications; and twenty-four will be decommissioned.[4]

It is likely, however, that many of Japan's nuclear reactors will not restart due to a number of reasons that include continuing social acceptability issues, rising costs for new regulatory safety standards, projected lower returns on investment the longer reactors are shut down, and the NRA's resistance to extending the operating life of the domestic reactor fleet. Prior to the Japanese government's announcement of its net-zero by 2050 goal, Japan's Central Research Institute of Electric Power Industry (CRIEPI) had found that, even with maximum penetration of renewables [about 806 terawatt-hours (TWh)], approximately 220 TWh from nuclear power [about 29 gigawatts (GW) capacity] would be required to meet the earlier goal of 80 percent reduction of CO_2 by 2050.[5] This study estimates that, assuming sixty-year operating lives, 29 GW of nuclear capacity requires twenty existing units, including those that have not yet applied to restart, and 7 GW from new unbuilt plants in the planning stage. It is very likely that even more nuclear energy will be required to meet the net-zero goal announced by Suga. These unit estimates do not reflect the possible substitution of advanced nuclear reactors for conventional large-scale nuclear reactors.

The Japanese government and large utilities face skyrocketing costs to restart additional reactors. Kyodo News reported that it will cost around ¥849.2 billion ($7.9 billion) to decommission fifteen commercial reactors at nine nuclear power plants—their owners decided it would be too expensive to implement

[4] Agency for Natural Resources and Energy, Current Situation of Nuclear Power Plants in Japan, 11 November 2020.

[5] Sumio Hamagata, et al, *Quantitative Analysis for Economy, Energy, and Electricity Supply and Demand to Realize Substantial CO2 Reduction by 2050*, CRIEPI, April 2019.

the new required safety measures for these reactors.[6] In addition, the Japan Atomic Energy Agency (JAEA) estimates the costs of decommissioning seventy-nine of its nuclear facilities will reach at least ¥1,900 billion ($17 billion); this includes the decommissioning of the failed Monju prototype fast-breeder reactor, research reactors, and test buildings. The Japanese government estimates Fukushima's decommissioning cost ¥8 trillion ($73 billion) with an estimated total cost of ¥22 trillion, "adding compensation, decontamination of surrounding areas and medium-term storage facilities."[7]

In November 2019, Japan's NRA decided it would not allow plants to operate if they have failed to complete upgrades. According to the Institute of Energy Economics, Japan (IEEJ), the average time between the acceptance of draft safety reports and a nuclear power plant generating power for the nine reactors now operating was one year and five months, and it is expected to be longer for the next group of reactors seeking approval.[8] The Japan Atomic Industrial Forum estimates that safety investment costs will be approximately ¥3,025.2 billion ($27.9 billion) for the twenty-seven reactors that have finalized safety review applications. Other estimates are as high as ¥5,400 billion for fifteen reactors.

6 Kyodo News, "Costs for managing Japan's nuclear plants to total 13 trillion yen," January 15, 2020, https://english.kyodonews.net/news/2020/01/8722fafaff9b-costs-for-managing-japans-nuclear-plants-to-total-13-trillion-yen.html.

7 Mari Yamaguchi, "Japan revises Fukushima cleanup plan, delays key steps," *Star Tribune*, December 27, 2019, https://www.startribune.com/japan-revises-fukushima-cleanup-plan-delays-key-steps/566503882/.

8 Murakami, *Outlook*.

Japan's Energy Policy Since 1945: Seeking Energy Security

In the post-World War II era, Japan at first continued to pursue a domestic coal-first, imported oil-second energy policy. But with Japan's rapid expansion in the late 1950s and 1960s, its energy demand increased and it needed a secure supply of inexpensive energy to fuel its rapid economic expansion. By the 1960s, the price of imported coal fell below that of domestically produced coal due to advances in mining and lower shipping costs. Domestic reserves also were dwindling rapidly and Japan needed a new source of energy. It began to import significant quantities of inexpensive oil from the Middle East. As a result, Japan relaxed restrictions on oil use and built ports to facilitate imports. By 1973, coal had fallen to 16.9 percent of Japan's energy mix and oil had risen to 75.5 percent. This energy mix assumed that Japan's alliance with the United States would preserve its access to global energy markets and that oil would remain relatively inexpensive.

Japan's interest in nuclear energy intensified with the 1973 oil crisis, when Japan's strategy for its energy mix—based on a stable and inexpensive oil supply—suddenly became unviable. Triggered by the Yom Kippur War in October 1973, the Organization of the Petroleum Exporting Countries (OPEC) prohibited oil exports to the United States and its allies. The global price of oil quadrupled between October 1973 and January 1974. Japan was the second-largest consumer of petroleum at the time and the biggest importer. Economic growth in Japan slowed, resulting in an economic recession and inflation. To cope with the change, Japan revised its neutral Middle East policy and adopted pro-Arab rhetoric to be more independent of the United States. Japan's Ministry of Foreign Affairs released the Nikaido Statement in November 1973 supporting United Nations Security Council Resolution 242, which called for Israeli withdrawal from lands occupied in the 1967 war and respect for the territorial integrity and security of nations in the region, and Palestinian self-determination. Japan also signed economic and technical cooperation agreements with Arab states. Domestically, it adopted measures to reduce dependence on oil, and to restructure its economy towards technology and knowledge-based industries less dependent on oil and raw material imports.

The 1973 oil crisis also pushed Japan to pursue independent relationships with OPEC oil producers, instead of following the United States' lead.[9] To ensure reliable energy access, Japan began greater cooperation with oil-producing countries in their economic development through public and private sector technical and financial assistance. This policy later expanded to include other types of energy and natural resources, and encompassed policies to promote free trade and transportation route safety.

While Japan sought to shore up its trade relationships with energy exporters in the Middle East, it also worked to bolster its nuclear reactor fleet. Nuclear energy could contribute to Japan's energy security due to the small amount of imported fuel needed and the future possibility of creating fast breeder nuclear reactors to reuse rather than import as much fuel.[10] Japan, therefore, considered nuclear power as a quasi-domestic source of energy and counted it as such in its self-sufficiency and energy independence ratios. After 1973, Japan greatly accelerated nuclear plant construction, and—as nuclear energy became the backbone of Japan's energy system, its energy security, and later its climate policy—Japan also became a new global competitor in civil nuclear exports and assistance to other countries, and in international nuclear governance [e.g., through support to the International Atomic Energy Agency (IAEA)].

The Rise of Nuclear Energy

Japan had started exploring nuclear power in the 1950s with the idea of both acquiring and then domestically developing nuclear technologies for the full fuel cycle. Japan's political leaders and scientists agreed on the potential of nuclear energy to help Japan become more energy independent.

[9] Martha A. Caldwell, "The Dilemmas of Japan's Oil Dependency," *Politics of Japan's Energy Strategy: Resources-Diplomacy-Security* (1981), edited by Ronald A. Morse, 65-84, Research Papers and Policy Studies #3, Institute of East Asian Studies, University of California at Berkeley.

[10] Japan invested heavily in fast-breeder reactors such as its Joyo and Monju experimental reactors. The Monju reactor was abandoned at the end of 2016 due to enormous cost ($10,593 million from 1971-2017) and technological problems, including a string of accidents that contributed to the Japanese public's concerns about nuclear energy and lack of transparency in policy making. See Noriko Behling et al., *Japan's Quest for Nuclear Energy and the Price it has Paid* (Elsevier: Amsterdam, 2020), 62-63.

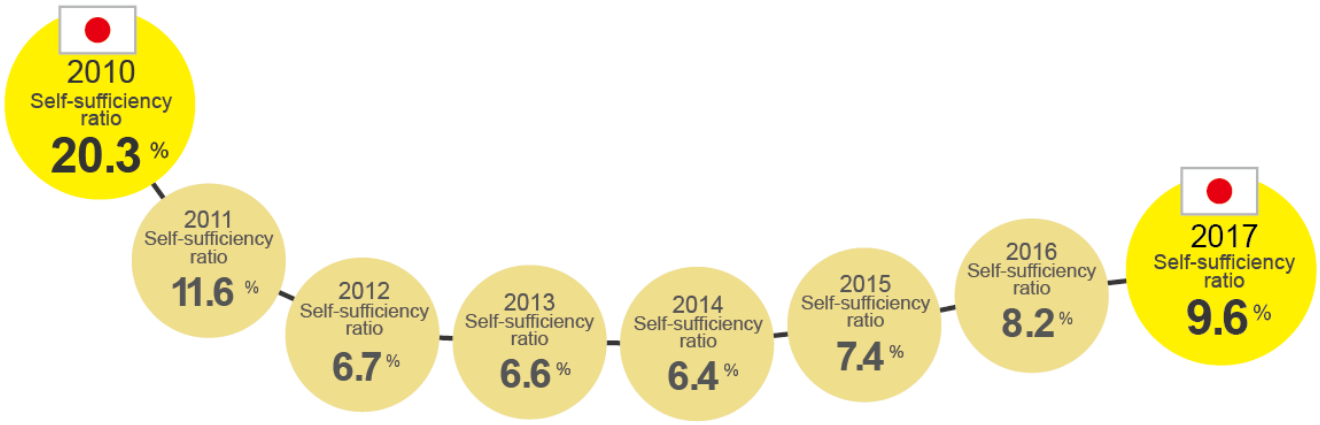
Japan was the first country to join US President Eisenhower's "Atoms for Peace" initiative by passing the Atomic Energy Basic Law in 1955.[11] In the 1960s, Japan looked at various reactor designs before settling on large boiling and pressurized water reactors as best suited for it, and the country's first commercial nuclear reactor—the Tokai Nuclear Power Plant—started generating power in July 1966.

Nuclear energy made enormous contributions to Japan's energy security and energy availability, enabling the island nation to lower its dependence on imported fossil fuels in its power market from 76 percent in 1973 to 61 percent in 2010, while increasing total power supplied by about 245 percent. However, dependence on imported fossil fuels surged to 88 percent in 2012, the year after the loss of nuclear power following the Fukushima Daiichi nuclear accident. Electric power rates, as a result, surged 25 percent for residential and 38 percent for industry in Japanese Fiscal Year (JFY) 2014 compared with JFY 2010 before dropping back primarily due to declines in world LNG and oil prices. Japan's overall self-sufficiency—or energy independence ratio—in 2010 stood at 20.3 percent but fell dramatically after the Fukushima Daiichi nuclear accident.[12] In JFY 2019, due to the loss of nuclear power from permanently shuttered reactors and the unclear future of others, Japan's primary energy self-sufficiency ratio was 11.8 percent—lower than any other Organisation for Economic Cooperation and Development (OECD) country except Luxembourg—creating a risk to Japan's energy security.[13] With a diminished role for nuclear power in its energy mix, Japan has had to increase its reliance on fossil fuel imports and the network of geopolitical alliances that allow for dependable trade in energy resources.

Japan's government and industry invested about $130 billion over the past fifty years to build the current reactor fleet.[14] Five reactors were in operation in 1973. By 1974, there were eighteen reactors under construction. At the same time as Japan was expanding its reactor fleet, public opposition to nuclear energy was also increasing. Opposition tended to be local and situated around individual nuclear projects. It was mitigated to some extent by subsidies to local and prefectural entities seeking to host reactors. Japan passed the Three Power Source Laws (Dengen Sampo) in 1974, which allowed for the collection of taxes from the electric utilities that were deposited into an account within the government's Energy Measures Special Account (EMSA).[15]

The funds were used to subsidize various initiatives, many of which were directed to local and prefectural

Figure 1: Japan's Total Self-Sufficiency Energy Ratio



Source: METI/ANRE, https://www.enecho.meti.go.jp/en/category/special/article/energyissue2019_01.html

[11] The Japanese and the US governments have maintained a close relationship in nuclear energy since the 1950s, signing several cooperative agreements, including the landmark 1968 "US-Japan Agreement for Cooperation Between the Government of Japan and the Government of the United States on Peaceful Uses of Nuclear Energy Agreement" that was revised in 1988 and extended for thirty years, and was automatically extended in July 2018.

[12] Includes power, industry, and transportation.

[13] Statista, "Self-sufficiency rate of primary energy in Japan from fiscal year 2009 to 2018," March 2020, https://www.statista.com/statistics/1116602/japan-primary-energy-self-sufficiency-rate/.

[14] Behling et al., *Japan's Quest*, 279.

[15] The Three Power Source Laws are: 1) the Regional Maintenance Surrounding Power Source Facilities Act, 2) the Power Source Development Acceleration Tax Law, and 3) the Power Source Development Acceleration Special Account Law.

governments willing to host nuclear power plants.[16] Prefectural and local governments also had the right to tax nuclear reactor owners. Other subsidies supported research and development by both public institutions and private companies.

Various subsidy measures were added and expanded until the Ministry of Economy, Trade and Industry (METI) revised the subsidy system in 2003. While it is unclear how much the subsidies accelerated construction, thirty reactors were constructed between 1974 and 1991. In early 1992, construction slowed when Japan's bubble of vastly overinflated stock and real estate prices burst, and the economy stagnated. Only five additional reactors were built after 1991, while fourteen planned reactors were cancelled. By 2010, Japan had fifty-four reactors that generated 287.8 TWh, 28.6 percent of Japan's total power production, with three new reactors in the planning stage.

The Current Situation

Japan announced its *Third Strategic Energy Plan* in 2010, which continued efforts to enhance energy security by seeking an energy mix that was both less dependent on imports and more environmentally sustainable. It sought to raise the energy independence or self-sufficiency ratio for electricity from 38 percent (including nuclear) primarily through a proposed expansion of nuclear power from 30 to 50 percent of total electricity consumption by 2020 and to 70 percent in 2030.[17] The expansion of nuclear power would also help meet Japan's CO_2 emission target. This increase in nuclear energy would necessitate building an additional fourteen nuclear reactors. It also sought to maximize the use of renewable energy but without specifics on how that was to be achieved.

With the Great Eastern Japan Earthquake and Tsunami in 2011, the *Third Strategic Energy Plan* was essentially

An LNG tanker is tugged towards a thermal power station in Futtsu, east of Tokyo, Japan, on November 13, 2017.
Source: REUTERS/Issei Kato - RC1F61927820

[16] Behling et al., *Japan's Quest*.

[17] The self-sufficiency ratio of 38 percent is for the electricity sector alone.

abandoned before it could be implemented. It was replaced by the *Fourth Strategic Energy Plan* in 2014 along with the *Long-Term Energy Demand and Supply Scenario to 2050* in 2015 and the *Long-Term Environmental Strategy for Technological Innovation Toward 2050* in 2016. These government plans called for a flexible, resilient, and diversified energy strategy to meet energy security goals and emissions targets. They posited reducing dependency on nuclear power to the greatest extent possible, introducing renewable energy, and improving energy efficiency, including the efficiency of thermal power generation.

Japan's energy policy has long stressed economic growth and energy security. These long-standing "Es" were joined by a third "E"—environmental quality—in Japan's pre-Fukushima 2003 *Basic Energy Plan* and an "S" for safety after the Fukushima Daiichi nuclear accident. However, with a diminished role for nuclear power in Japan's energy mix, meeting energy demand while keeping climate commitments will be an uphill battle.

Japan's thirty-two years of trade surpluses turned into deficits from 2011 to 2016 due to the need to import fossil fuels, recovering only with the global decline in energy prices. Moreover, there is no guarantee that the supply of these fossil fuels will not be disrupted in the future, whether due to man-made disruptions like market shocks or extreme weather events.

The Risks of Overdependence on Energy Imports

In terms of potential security and sea lane disruptions, Japan remains heavily dependent on the Middle East for approximately 80 percent of its oil. In 2019, Japan's largest suppliers were Saudi Arabia (34.1 percent), the UAE (32.6 percent), and Qatar (9.2 percent). Japan must, therefore, continue to pursue a delicate diplomatic balance with the nations in the region, which has become increasingly challenging since 2017, when Saudi Arabia, the UAE, Bahrain, and Egypt began their diplomatic and economic boycott of Qatar.[18] Japan has also had to find ways to make up the shortfall in oil imports from Iran, since the Trump administration's refusal in April 2019 to reissue waivers to allies who wished to import Iranian oil without suffering secondary sanctions from the United States.[19] For its oil and LNG imports from the Middle East, Japan is dependent on the Strait of Hormuz and on the Strait of Malacca. In 2018, China, India, Japan, the ROK, and Singapore accounted for 65 percent of all crude oil that was transported through the Strait of Hormuz, while Japan and the ROK imported the largest quantities of LNG through the Strait of Malacca in 2017.[20]

Japan's other fossil fuel imports are less dependent on geopolitically volatile regions but still must arrive by sea, creating the potential for political and accidental supply disruptions. Japan's LNG imports are more diversified than oil, as it imports most of its LNG from Australia (34.6 percent), Southeast Asia (28.6 percent, nearly half from Malaysia at 13.6 percent), and the Middle East (21.6 percent, predominantly from Qatar at 12 percent). Especially after many of its long-term contracts with traditional suppliers expire around 2021-2022, Japan could further diversify its LNG by sourcing more from North America, which only supplied 5 percent of Japan's LNG in 2019. Coal comes overwhelmingly from Australia (71.5 percent), followed by Indonesia (11.8 percent), and Russia (10.8 percent).

[18] Al Jazeera, "Qatar blockade: Five things to know about the Gulf crisis," June 5, 2020, https://www.aljazeera.com/news/2020/6/5/qatar-blockade-five-things-to-know-about-the-gulf-crisis.

[19] Ginger T. Faulk, Mark D. Herlach, and Beverly J. Rudy, "Iran sanctions update - US announces it will not re-issue sanctions waivers for Iran oil imports to any country," Lexology, April 25, 2019, https://www.lexology.com/library/detail.aspx?g=d2cc06df-1ae6-4d1d-b1ed-24b32c901be6.

[20] Today in Energy, "The Strait of Hormuz is the world's most important oil transit chokepoint," US Energy Information Administration, June 20, 2019, https://www.eia.gov/todayinenergy/detail.php?id=39932; Today in Energy, "The Strait of Malacca, a key oil trade chokepoint, links the Indian and Pacific Oceans," US Energy Information Administration, August 11, 2017, https://www.eia.gov/todayinenergy/detail.php?id=32452.

Japan's Civil Nuclear Export Program

Nuclear energy is closely intertwined with geopolitics since civil nuclear exports place the vendor and purchasing countries into a century-long diplomatic relationship. Nuclear energy remains closely tied to national security issues due to the nonproliferation risks of the technology and the materials, as well as waste and safety issues. The United States—in concert with its allies—was able to dominate the global market for nuclear reactors after World War II until the 1990s. Between 1969 and 1990, US-based vendors supplied 41 percent of the nuclear reactors on the global market, but only 8 percent between 1991 and 2017.[21] US leadership in commercial nuclear technology provided it the credibility and leverage to shape the international institutions and instruments that govern how nuclear energy technology is used and exported, and the United States was able to place strong, legally binding nonproliferation and safety conditions on the international market. These conditions were fundamental to fulfilling Eisenhower's call for peaceful power from atomic energy.[22]

However, the United States is no longer the preeminent builder and exporter of nuclear power plants; Russia has assumed the leading position and China is emerging as a major force. With the shrinking of US global leadership in nuclear energy, its civil nuclear partnerships with other countries, including Japan, have become essential to upholding high safety and nonproliferation standards and mitigating the spread of enrichment capabilities that drive the proliferation threat.[23] Premature decommissioning of nuclear reactor fleets in both countries—and a lack of new nuclear power plant builds—have damaged human capital in the United States and Japan and have also made it more difficult for both countries to maintain strong civil nuclear export programs.

Japan's nuclear industry grew by importing and indigenizing US nuclear technology. As Japan's domestic nuclear industry grew—and as its companies partnered with US nuclear companies—Japan played an increasingly critical role in international efforts to uphold US nuclear norms. Japan plays an active role in international nonproliferation, safety, and export control institutions and instruments, such as the IAEA, the Nuclear Suppliers Group, and the OECD's Nuclear Energy Agency. Japan is the third-largest contributor to the IAEA's regular budget and provides significant extra-budgetary funding for activities such as human resource development.

With emerging markets for nuclear energy technologies, especially advanced reactors and SMRs, it is increasingly important for the United States and its allies to leverage their resources against efforts by Russia and China to sell their nuclear technologies to new-to-nuclear countries. According to the think tank Third Way, the total world market for nuclear power conservatively could triple to 7,500 TWh per year.[24] Interest is highest from non-OECD nations, most of which are still building the necessary regulatory frameworks and other infrastructure needed to host nuclear power plants.

The emergence of competition for export markets in the last decade between traditional private sector exporters tied to the United States and its allies and state-owned companies of Russia and China has given urgency to the discussion of the global governance of nuclear energy. Russia currently has $133 billion in foreign orders, giving it the largest share of global nuclear reactor exports.[25] Russia accounts for two-thirds of nuclear reactor plants that are either planned or under construction, with thirty-six new builds in twelve countries. China has nearly a dozen proposed projects and is constructing four reactors abroad. These projects are assisted by generous government-backed financing packages provided by the Russian and Chinese state-owned enterprises, Rosatom and the China National Nuclear Corporation (CNNC), respectively. While not all

[21] Travis Carless, "The US Shouldn't Abandon the Nuclear Energy Market," *Issues in Science and Technology*, XXXVI (2) (Winter 2020), https://issues.org/the-us-shouldnt-abandon-the-nuclear-energy-market/.

[22] US President Dwight D. Eisenhower, "Atoms for Peace," speech to the United Nations General Assembly, September 8, 1953, https://www.iaea.org/about/history/atoms-for-peace-speech.

[23] Daniel B. Poneman, *Double Jeopardy: Combating Nuclear Terror and Climate Change* (Cambridge, MA: MIT Press, 2019), 140.

[24] Jackie Kempfer et al., "Mapping the Global Market for Advanced Nuclear," Memo, Third Way, September 22, 2020, https://www.thirdway.org/memo/mapping-the-global-market-for-advanced-nuclear.

[25] Partnership for Global Security, "Clawing Back Nuclear Markets Requires More than Rhetoric," June 26, 2020, https://partnershipforglobalsecurity.org/clawing-back-nuclear-markets-requires-more-than-rhetoric/.

Shikoku Electric Power's Ikata nuclear plant is pictured near the water in Ikata, Japan, October 2, 2018.
Source: REUTERS/Mari Saito

of these projects will see completion, the projects that are completed will constitute strategic energy partnerships between Russia and China and the purchasing countries, allowing Russia and China international influence that could last decades.[26]

Nuclear exports lead not only to the construction of the reactor itself and the provision of related services but also decades-long relationships between the exporting country and the recipient countries. The potential geopolitical implications of such long-term relationships add to the seriousness of the discussion. It is clear that exports of nuclear reactors result in the building of hundreds of personal and professional research and commercial relationships among individuals, companies, and institutions over the lifetime of the reactor.[27] The US-Japan nuclear energy partnership has played a key role in shaping the relationship between the two countries, and a similar phenomenon has taken place between the UAE and the ROK, which have established new ties based on the Barakah nuclear power plant project.

Among US civil nuclear allies, the ROK leads the Barakah nuclear power project in the UAE, which has resulted in expanded cooperation between the two countries and cooperation in infrastructure development, and which will involve decades of human resource development, maintenance, and operational services support.

The United States and Japan have no foreign orders. Although Japanese nuclear companies have demonstrated overseas ambitions—especially through Toshiba's purchase of Westinghouse and involvement in US projects, as well as Toshiba and Hitachi's efforts to be involved with nuclear projects in the United Kingdom—these ambitions have faced challenges. Westinghouse declared bankruptcy and was sold following construction problems with Vogtle and V.C. Summer in the United States, and Hitachi announced its suspension and withdrawal from the Horizon project in the UK in September 2020.

[26] Robert F. Ichord, Jr., *US Nuclear Power Leadership and the Chinese and Russian Challenge*, Atlantic Council, March 2018, https://www.atlanticcouncil.org/wp-content/uploads/2018/03/US_Nuclear-Power_Leadership_web.pdf.

[27] Poneman, *Double Jeopardy*, 140.

As the next phase of global nuclear energy deployment becomes characterized by a transition to advanced reactors, the United States and Japan, with like-minded partners, have an opportunity to maintain and expand their influence. This phase could come within the next decade or so, and "achieving control or significant influence in that market will require careful and comprehensive preparation now."[28]

The development and deployment of advanced reactors, especially SMRs, could be a game changer for low-carbon energy in the critical 2030-2050 period. Japan started its Nuclear Energy x Innovation Promotion (NEXIP) initiative in 2019, which includes work on SMRs and seeks to pursue the possibilities of various technologies in response to diversifying social issues, including improvement of safety, coexistence with renewable energy, and multipurpose uses such as the production of hydrogen.[29] NEXIP initially received $6 million in first-year funding for JFY 2019 for feasibility studies, and it seeks to accelerate the development of innovative nuclear technologies.[30] NEXIP has four components: 1) industry cost-shared research and development funding for new reactor concepts and accompanying technologies (e.g., safety, digital technologies); 2) access to JAEA experimental facilities, reactors, simulation tools, and databases; 3) human resource development in academia and industry; and 4) international cooperation; for example, the US versatile test reactor (VTR).

As commercial companies—with Japanese suppliers and partners—start demonstrations in the United States, Canada, and elsewhere, opportunities for collaboration can expand beyond government-to-government joint research. For example, GE Hitachi Nuclear Energy is working with the US Department of Energy on its VTR and with TerraPower on a sodium fast reactor with molten salt energy storage. Mitsubishi Electric Company (MELCO) is working with Holtec International, a US company, on SMRs. Enhanced US-Japan collaboration as well as collaboration with Canada, the ROK, and others can help retain and expand that option.

For Japan to continue to have a strong voice in international nuclear energy trade and governance, it needs to have credibility, which is strongest when a country has its own domestic nuclear industry and is involved in global exports. This credibility will continue even if Japan does not build any new large-scale nuclear reactors in the short term. However, this credibility is at risk as existing reactors are decommissioned or if their lifetimes are not extended without being supplemented then replaced by new nuclear reactors, whether by conventional light water reactors or advanced nuclear technologies.

Japan must also invest in the research, development, and demonstration of the latest advanced technologies. Japan spent 3.265 percent of its gross domestic product (GDP) on all research and development in 2018, the fifth-highest in the world.[31] In 2019, it had the second-highest spending among International Energy Agency (IEA) nations on energy research, design and development (RD&D), at $3 billion, of which about $1 billion was for nuclear energy research. In comparison, the United States spent $8 billion on energy research, with approximately $1 billion on nuclear.[32]

Social acceptance also remains an important issue that must continually be addressed. Demonstrable progress in public education and societal acceptance of safe, transparent, and advanced nuclear energy solutions is essential to support Japan's continued ability to engage globally. Much of Japan's ability to play a role in the expansion of nuclear energy globally—and to export the principles of safety, security, and nonproliferation—will depend on whether Japan is able to maintain a robust domestic reactor fleet.

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[28] Partnership for Global Security, "Clawing Back."

[29] Japan's Ministry of Economy, Trade and Industry, *Japan's Nuclear Energy Policy*, September 2019, www.jaif.or.jp/IAEA2019/data/METI_Japans_Nuclear_Energy_Policy.pdf.

[30] The following agencies are involved in NEXIP: METI, the Ministry of Education, Culture, Sports, and Science and Technology (MEXT), and the Japan Atomic Energy Agency (JAEA). NEXIP is in addition to continued government research and development on such areas as fast reactor development, safety of light water reactors, waste disposal, and basic science (e.g., fusion, advanced materials), and research and development by companies. For example, see JAEA, *JAEA R&D Review 2019-2020*, https://rdreview.jaea.go.jp/review_en/2019/pdf/e2019_all.pdf.

[31] World Bank, IBRD/IDA, *Research and development expenditure (% of GDP)*, https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS, 2020. Countries with a higher rate are Israel (4.95%), South Korea (4.81%), Switzerland (3.37%), and Sweden (3.34%).

[32] IEA (International Energy Agency). 2020. *Energy Technology RD&D Budgets 2020*. (Paris: IEA). https://www.iea.org/reports/energy-technology-rdd-budgets-2020.

Moving Away from Nuclear Power Will Affect Japan's Climate Ambitions

As an island nation, Japan has been severely affected by extreme temperatures and by destruction from typhoons exacerbated by climate change. In 2019, the Faxai and Hagibis typhoons alone cost Japan $20 billion.[33] For this reason, Japan has an urgent need to address climate change and bolster its mitigation efforts through low-carbon energy sources.

Nuclear energy has been the backbone of Japan's low-carbon strategy to mitigate climate change. Dating back to the adoption of the Kyoto Protocol in 1997, Japan has played a major role in global climate change leadership. In March 2002, the Japanese government announced that nuclear power would contribute to Japan's efforts to meet its GHG emission reduction goals. Renewable energy production is growing, but without long-duration storage renewables can only provide energy intermittently. It also is unclear if Japan has sufficient renewable resources to replace fossil fuels and nuclear in its energy mix.[34]

The increased reliance on imported fossil fuels after the Fukushima Daiichi nuclear accident made it more difficult for Japan to meet its low-carbon goals, weakening its credentials in the global fight against climate change, and resulting in trade deficits. Emissions grew by about 8 percent from 2010 to 2013. From 2013 to 2019, GHG emissions fell about 13 percent to just below the 2010 level, due primarily to strong energy efficiency measures, an increase in renewable energy use, the return of some nuclear power, and the enhanced efficiency of fossil-fuel power plants. However, even with the emissions decline, Japan is still not on target to meet its pledged 26 percent reduction below 2013 levels by 2030, let alone net zero by 2050.

Domestically, the comparative low price of coal to the high price of LNG in the first years after the Fukushima Daiichi nuclear accident was attractive. However, the increase in coal usage in particular triggered blowback from many global climate change experts over Japan's plans to build many new coal plants and its financing of coal plants overseas.[35] In 2020, Japan responded to the criticism about coal use. Japanese Environment Minister Shinjiro Koizumi announced in July 2020 that Japan would scale back and tighten the rules for its overseas financing of coal plants.[36] Exemptions will remain for high-efficiency technology and plants under construction. Japan will also take the purchasing country's overall decarbonization policies into acount. METI Minister Hiroshi Kajiyama announced on July 9 that of Japan's one hundred and forty domestic plants, approximately one hundred aging, inefficient coal plants would be decommissioned or mothballed by 2030. The number of planned new coal plants has been scaled back with approximately a dozen higher-efficiency, lower-emission (HELE) coal plants still planned. As a result, approximately 77 percent of Japan's coal-fired power would be produced by HELE coal plants by 2030.[37]

Coal use domestically in Japan, however, will remain a contentious issue without significant advances in technology, as well as cost decreases, for carbon capture, utilization and storage (CCUS). High dependence on fossil fuels for power without a technological breakthrough in CCUS will prevent Japan from reaching its decarbonization goals. Oil, while no longer a factor in power production, remained about 40 percent of total primary energy supply in 2018 due to its role in transportation and industry. Oil consumption can be mitigated by advances in electric vehicles, including fuel cell and battery vehicles, and in hydrogen use as an energy carrier, in industry, and for storage.

[33] Yukiko Nukina, "Extreme Weather Events Affect Japan," Climate Scorecard, February 12, 2020, www.climatescorecard.org/2020/02/extreme-weather-events-affect-japan/.

[34] Sumio Hamagata et al., *Quantitative Analysis for Economy, Energy, and Electricity Supply and Demand to Realize Substantial CO2 Reduction by 2050*, CRIEPI, April 2019.

[35] Hiroko Tabuchi, "Japan Races to Build New Coal-Burning Power Plants, Despite the Climate Risks," *New York Times*, February 3, 2020, www.nytimes.com/2020/02/03/climate/japan-coal-fukushima.html.

[36] Daisuke Abe and Kazunari Hanawa, "Japan to halt state support for overseas coal-fired power plants," *Nikkei Asia*, July 9, 2020, https://asia.nikkei.com/Business/Energy/Japan-to-halt-state-support-for-overseas-coal-fired-power-plants.

[37] Jane Nakano, "Japan's Coal Policy Updates—A Glass Half Full or Half Empty?" Center for Strategic and International Studies, August 3, 2020, https://www.csis.org/analysis/japans-coal-policy-updates-glass-half-full-or-half-empty.

Japan's Environment Minister Shinjiro Koizumi talks with Brazil's Environment Minister Ricardo Salles at the United Nations Climate Change Conference (COP25) in Madrid, Spain, December 15, 2019. Source: REUTERS/Nacho Doce

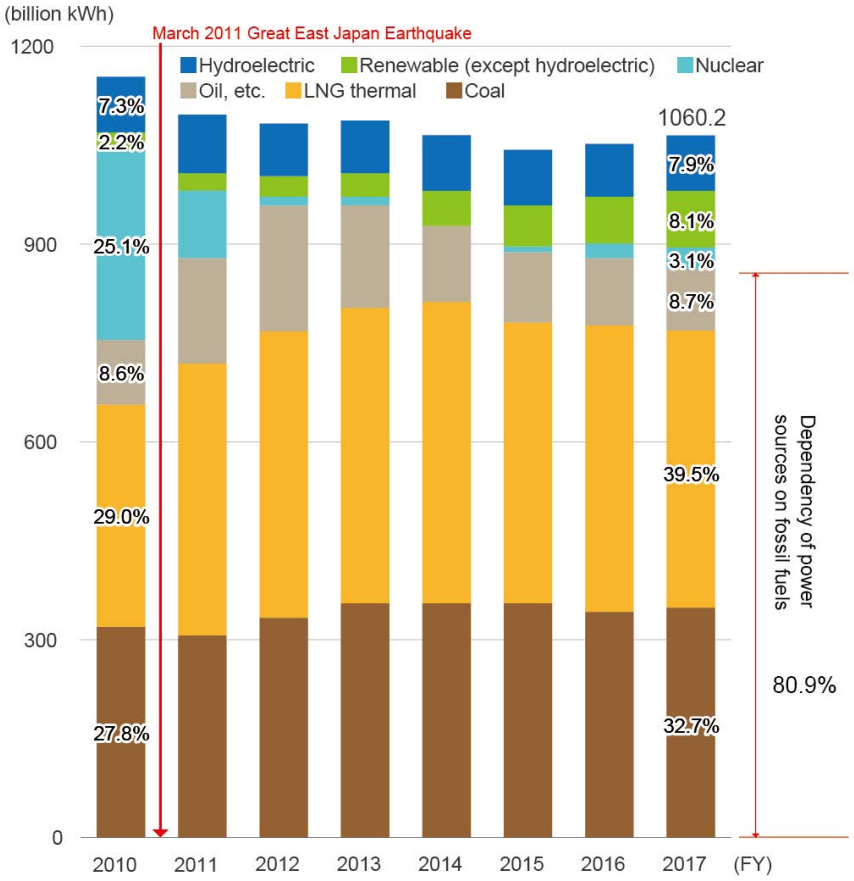
However, meeting power demand without nuclear will be extremely challenging.

Like the *Fourth Strategic Energy Plan*, Japan's *Fifth Strategic Energy Plan*—adopted in 2018—is based on the principles of energy security, improvement of economic efficiency and growth, and environmental suitability and safety (i.e., the 3E + S energy policy).[38] It includes the need for low-carbon energy supplies by promoting renewable energy and restarting nuclear power plants, improving electrification rates, shifting to lower-carbon fossil fuel use, creating a hydrogen society, and improving energy efficiency. The proposed 2030 electricity mix is 56 percent from fossil fuels, 22-24 percent from renewables, and 20-22 percent from nuclear energy. The 2050 outlook is much less specific; it envisions energy transitions that lead to decarbonization and a lower reliance on nuclear energy than planned for 2030, with nuclear growing compared to its current low percentage (7.5 percent of power in 2019) but remaining less than the share of nuclear energy that had been projected in the *Third Strategic Energy Plan* prior to the Fukushima Daiichi nuclear accident. It is unlikely, however, that these goals are achievable given the slow restart of closed nuclear reactors, possible acceleration of decommissioning of many of the remaining plants, and a still slow uptake of renewable energy. The IEA, in its *2019 World Energy Outlook* scenario for Japan from 2018-2020, finds that, even in its sustainable development case, nuclear would rise in 2040 to 24 percent of the energy mix, which would still require fossil fuel consumption at 46 percent even with a continued decline in primary energy demand.[39]

[38] Japan's Ministry of Economy and International Trade, *Strategic Energy Plan*, July 2018, https://www.enecho.meti.go.jp/en/category/others/basic_plan/5th/pdf/strategic_energy_plan.pdf.

[39] IEA (International Energy Agency), *World Energy Outlook 2019*, November 2019, https://www.iea.org/reports/world-energy-outlook-2019.

Figure 2: Japan's Power Source Mix 2010-2017



Source: METI/ANRE, https://www.enecho.meti.go.jp/en/category/special/article/energyissue2019_01.html

How Nuclear Energy Can Facilitate the Adoption of Renewables and Hydrogen

The Great Eastern Japan Earthquake and Tsunami brought increased attention to renewables as a domestic low-carbon alternative to nuclear energy and the spike in fossil fuel imports that occurred to replace nuclear. The Japanese government has urgently and actively promoted renewable energy since the Fukushima Daiichi nuclear accident, including by deregulating oil and gas markets to provide a better business climate for renewable energy growth. Renewable energy is now on track to surpass the goal of providing 24 percent of Japan's electricity needs by 2030 and could reach 35 percent of Japan's electricity generation by then. Paired with nuclear energy to provide baseload power and mitigate intermittency, renewables can contribute to Japan's energy security and its 2050 net-zero goal.

Hydrogen is also a path to electrifying road transportation and kickstarting the decarbonization of hard-to-abate sectors such as iron and steel and shipping.[40] Domestic nuclear energy could be used to create carbon-free hydrogen through high-temperature electrolysis and thermochemical water splitting. According to the US Department of Energy, "nuclear power plants can produce hydrogen in a variety of methods that would greatly reduce air emissions while taking advantage of the constant thermal energy and electricity it reliably provides."[41] Steam produced can be used in steam methane reforming or, if electrolyzed, split directly into hydrogen and oxygen. Additional research and pilot projects to help decarbonize industry and transportation by reducing the cost for carbon-free hydrogen, currently two to four times that produced from natural gas, are underway in Japan as well as the United States and Europe. Using nuclear energy to produce hydrogen could assist in the decarbonization of

[40] Alan Ahn and Bryan Cheong, "A Pathway to Kickstarting the Clean Energy Transition: Hydrogen Production through Nuclear," April 30, 2020, Global America Business Institute.

[41] Office of Nuclear Energy, "Could Hydrogen Save Nuclear?" June 24, 2020, US Department of Energy, https://www.energy.gov/ne/articles/could-hydrogen-help-save-nuclear.

hard-to-abate sectors. Continued work and international cooperation are needed on higher-temperature nuclear reactors as well as the materials needed for them as part of a comprehensive decarbonization strategy and to spur the development of clean hydrogen.

Japan can be an influential player in climate change if it moves away from fossil fuels, especially coal, and toward a low-carbon economy. Japan's current plans for 2030 and 2050 do not do so sufficiently, especially if cost-effective CCUS is not developed. If Japan's nuclear energy capacity goes offline, renewable energy will not be able to fully replace it. This would mean continued heavy dependence on imports of coal and natural gas, and diminished credibility in global climate change leadership.

Conclusion

Japan is at a crossroads. It must choose whether to revive its domestic reactor fleet and civil nuclear industry, which would likely require significant investment and political capital. However, this investment made now would pay dividends for Japan's energy security, its ability to meet ambitious climate goals, and for international civil nuclear exports and nuclear governance. Nuclear energy could play a unique role in helping Japan meet its domestic energy demand while mitigating climate change. Japan's choices are domestically and internationally significant as Japan—alongside the United States—will help determine the future of global nuclear energy and climate leadership. To be successful, Japan will need to reconsider the importance of a robust domestic reactor fleet, even as it is in the process of decommissioning part of that fleet. This report makes the following policy recommendations:

- **Japan must use its existing nuclear fleet in the near and long term to 2050:** Japan's existing nuclear power is important to reducing GHG emissions and meeting Japan's 2030 climate pledge and 2050 net-zero goal. Reactor life extensions, if done scientifically, rigorously, and without unreasonable costs, should be seriously considered if they can be done safely. While still far below what was envisioned prior to the Fukushima Daiichi nuclear accident, their operation provides needed legitimacy for Japan's civil nuclear export program and makes an essential contribution to Japan's domestic sources of energy and the reduction of global GHG emissions. Japanese regulators should consider, based on scientific research in the United States and elsewhere, whether some nuclear reactors' lives could be extended safely with appropriate protocols beyond sixty years and institute policies and regulations to encourage life extension.

- **Japan must remain involved in global civil nuclear trade:** This is critical to help ensure the maintenance of the present international order based on strong, legally binding nonproliferation and safety standards. Japan needs to work with like-minded countries—including the United States, the ROK, Canada, and the countries of Western Europe—to develop advanced nuclear technologies through research, demonstration, and deployment. Importantly, Japan needs to maintain a presence in the domestic and global commercial market in the short and long term.

- **Japan needs to develop a role for advanced nuclear technologies, including SMRs, which it should deploy as early as feasible:** These reactors would help achieve Japan's vision of a decarbonized society and regain its influential position in global civil nuclear exports. Importantly, advanced nuclear technologies also would assist in the deployment of renewables and the decentralization of the grid, and they would provide a source of low-carbon energy that could replace coal in the energy mix. Advanced nuclear technologies could provide flexible generation to complement renewable energy and replace thermal generation; nuclear technologies can also facilitate hydrogen production along with supporting energy integration technologies.

- **Japan should rebuild its nuclear energy workforce and public trust in nuclear power:** Japan must rebuild its nuclear energy workforce and reverse the precipitous decline in the number of nuclear science students through extensive public education efforts that stress safety and the contribution of advanced reactors to the uptake of renewable energy and the mitigation of climate change.

- **Japan should regain its leadership position in the climate battle:** It can do this by accelerating the adoption of advanced nuclear power and expanding its renewable energy production, especially wind and geothermal, in the short term and marine energy in the longer term. Nuclear power should complement and work with growing renewable energy to enable a retreat from fossil fuels, especially coal.

In the short and medium term, Japan's current fleet of large-scale reactors is of tantamount importance for both energy independence and climate goals. Japan should apply its expertise in technology and innovation to help deploy the next generation of nuclear reactors and participate fully in the global energy transition.

Japan's energy transition is underway. Success will mean creating a new energy system that is socially acceptable, adequately addresses energy security, and supports its ambitious net-zero clean energy goals. Nuclear energy, especially in conjunction with renewables or other clean energy sources like hydrogen, can play an essential role in helping Japan reach a high level of energy independence and security, partner on civil nuclear exports with the United States and other allies, and achieve its decarbonization and climate goals.

About the Author

Dr. Phyllis Genther Yoshida was formerly the senior fellow for energy and technology at the Sasakawa Peace Foundation USA. Prior to joining Sasakawa USA, she served as deputy assistant secretary for Asia, Europe, and the Americas at the US Department of Energy (DOE), coordinating bilateral and multilateral relationships. She served as the lead shepherd of Asia-Pacific Economic Cooperation's Energy Working Group and on the Board of the Indo-US Science and Technology Forum. She also served as DOE's director of the FreedomCAR and Fuel Partnership, a government-industry cooperative research partnership. In 2017, she established Pimmit Run Consulting LLC, which provides energy and technology analysis and services to the private and public sectors.

Dr. Yoshida has written extensively on Japanese and international science, technology, and energy issues. She also has held policy and research positions over her career at the US House of Representatives, the Japan Economic Institute, George Mason University, and the US Department of Commerce. As director of the Department of Commerce's Asia-Pacific Technology Program, she received the Commerce Department's Gold Medal for expanding US access to foreign science and technology and Silver Medal for work creating the International Intelligent Manufacturing Systems Partnership.

She received her bachelor of arts from Carleton College, and master of arts and PhD from the George Washington University. She was the first recipient of Japan's GARIOA/Fulbright Fellowship, under which she studied in 1983-1984 at the University of Tokyo and conducted research on Japan's automobile industry.

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