The Role of Nuclear Power in Advancing Japan's Economic & Climate Goals

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The Value of Certainty in an Uncertain Time

The world around Japan is changing. Globalization and economic development are altering political relationships and patterns of trade. Heat is still accumulating in the ocean and atmosphere, strengthening rains, raising higher waves, and fueling scorching summer weather. Simultaneously, a historic technological shift is taking place, as humankind begins to reinvent the basic energy technologies that power modern civilization.

Given large economic opportunities presented by these technological changes and a shared obligation to reduce climate impacts, many countries face growing pressure to move towards clean energy. However, the Japanese starting position for the shift to new forms of energy is somewhat disadvantageous.

Japan currently utilizes relatively little clean or domestically produced energy while relying heavily upon imported fossil fuels, resulting in high energy costs. And as the current global energy shortage illustrates, a tight energy supply can shrink domestic stockpiles, intensify competition for energy shipments, and cause substantial spikes in fuel and electricity prices. Such difficulties only add to existing economic challenges since many key economic sectors from shipbuilding to steel and aluminum manufacturing are particularly sensitive to the costs of energy inputs. In short, Japan possesses relatively little room for error in future energy system planning.

Fortunately, Japan can greatly improve its energy circumstances by leveraging the maximum possible potential from the 22.2 gigawatts of clean nuclear power still awaiting restart nationwide. In the near term, the large capacity of standby nuclear generation available can simultaneously advance Japan's climate goals while providing greater energy security and economic certainty.

Looking further ahead to 2030 and beyond, Japan can take advantage of next-generation nuclear technology to promote new growth sectors for the Japanese economy with opportunities abroad. Advanced reactors could powerfully support Japan's technological ambitions in clean manufacturing, green hydrogen, green ammonia, and carbon capture and utilization. Early efforts to develop these approaches will all benefit from reliable, abundant nuclear heat and electricity. Japanese leadership in all these areas could then secure strong positions in future international markets, including the market for smaller, safer advanced nuclear reactors. Meanwhile at home, new nuclear facilities can facilitate clean energy installation by reducing new transmission needs, supporting additional deployment of renewables, and opening the possibility of re-using some thermal power plant infrastructure. Additional nuclear capacity can thus improve the speed and efficiency with which Japan transitions to clean energy.

Consequently, nuclear energy's role in Japan's clean energy transition is larger than near-term risk reduction alone. Next-generation nuclear technologies can streamline progress towards a low-carbon economy while also creating new opportunities for Japanese technology leadership and economic growth. Realization of these possibilities will depend on the efforts of Japanese policymakers, researchers, and industry leaders today.

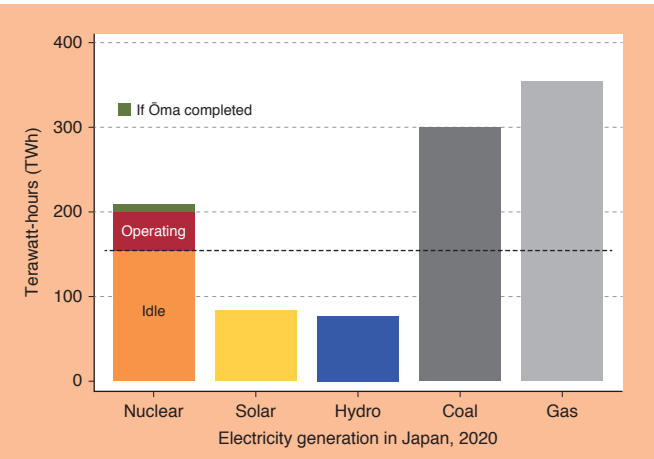
Managing Current Economic Risks

In this decade, diligent efforts to restart the maximum number of nuclear reactors can alleviate constraints on the domestic electricity supply and produce substantial economic benefits. It is important to recognize just how large of a resource Japan's 22.2 gigawatts of idle nuclear capacity represent. Assuming an 80% availability factor, the 23 reactors currently on standby could produce 155 terawatt-hours of electricity each year. That would equate to over half of the electricity that Japan's coal plants produced in 2020, or 44% of Japan's 2020 electricity generation from natural gas (see BP's "Statistical Review of World Energy 2021"). Restarting these reactors would generate about as much new clean electricity annually as every single solar panel and hydroelectric dam in the country combined. Completing the Ōma nuclear power plant in Aomori Prefecture would add a further 9.7 terawatt-hours annually *(Chart)*.

Accelerating nuclear restarts over the next several years thus produces benefits at a national scale. Compared to other advanced nations, heavy industry and manufacturing remain of relatively high importance to the Japanese economy. For some of Japan's key industries like the steel, aluminum, semiconductor, and shipbuilding sectors, electricity represents a key input and an important cost factor. Energy costs for industrial customers in Japan are already high by international standards even under normal circumstances (see International Energy Agency's "Japan 2021 – Analysis" https://www.iea.org/reports/japan-2021). Volatile energy prices and energy shortages pose additional risks to manufacturers that are already confronting challenges ranging from supply chain disruptions to the

CHART

Power generation potential from restarting idle nuclear plants



Source: Breakthrough Institute

ongoing Covid-19 pandemic.

In an era where the global economy is evolving and becoming increasingly multipolar, with new and strengthening competition from overseas, Japanese industries must take measures wherever possible to maintain their market position. Within this context, reactivation of idle nuclear power generation can help ensure a more stable and consistently priced supply of electricity, thereby improving the ability of manufacturers to remain competitive.

The current volatility of energy markets also increases financial challenges for Japanese households in ways that can produce economy-wide effects. Increases in the cost of fuel and electricity for citizens can produce numerous negative impacts, from public health risks during extremely hot or cold weather to reductions in household spending. Severe energy shortages may also affect the reliability of the electricity system, with major impacts upon public well-being particularly for older people.

Japan's energy situation is also unlikely to improve in the near term. Oil and gas production will remain depressed relative to global demand in the near term, with regular supply shortages and price spikes in upcoming winters as countries compete to fill energy reserves.

The reactivation of idle nuclear capacity can help manage these economic and social risks. Nuclear restarts do not solve Japan's energy security issues completely, as the country's proportion of fossil fuel energy use would remain high even if existing nuclear capacity was fully operational. However, Japan's energy situation is so precarious that even the marginal improvement from leveraging these reactors will be important.

In the past, Japanese policymakers have often alleviated shortages with energy efficiency measures and public campaigns to reduce energy demand. But with Japanese businesses and households already having exerted great efforts to improve energy efficiency over recent decades, policies to further reduce energy demand confront diminishing returns. Future energy efficiency gains may now depend upon advances in technology that will take years to become adopted on a wide scale.

A stable national energy supply therefore depends on additional domestic energy production. Restarting reactors and deploying new clean energy generation will gradually reduce energy-related vulnerabilities, and such efforts can take place alongside continued initiatives for increasing energy efficiency.

Streamlining the Path Towards a Carbon Neutral Society

In addition to minimizing energy-related economic and social concerns, clean nuclear energy can also facilitate Japan's joint pursuit of climate action and economic growth. The global transition to clean energy will create major technological and economic shifts, and domestic nuclear power can help prevent Japan from falling behind, particularly when new advanced nuclear concepts themselves represent an exciting emerging technology area. Nuclear energy can help streamline Japan's path to a low-carbon economy in two ways.

First, nuclear restarts and new nuclear projects in Japan will help accelerate the deployment of renewables by optimizing challenges related to variable electricity generation and transmission infrastructure upgrades.

Due to the intermittent nature of solar and wind resources, the increasing deployment of renewable energy in Japan will introduce greater daily and seasonal variability in electricity generation. Particularly in conjunction with unpredictability in fossil energy markets, an electricity mix composed of renewables, coal, and gas could experience problematic generation shortfalls or price fluctuations due to compounding events. Clean firm generation such as nuclear, hydroelectricity, or geothermal power will moderate these risks and ensure more stable supply and pricing. This in turn encourages faster addition of renewable generation and faster retirement of less efficient coal capacity.

Besides variable electricity generation, Japan's transmission infrastructure poses an additional challenge. The country's electricity grid is currently configured around a traditional model with large, central sources of power generation. As older, less efficient fossil fuel capacity retires over time, electricity infrastructure will need to evolve to support more geographically distributed generation. This represents an important opportunity for Japan to upgrade its national power grid but will also pose challenges as planners strive to connect solar and wind farms in rural or offshore areas to urban centers of demand.

Failing to restart a large fraction of Japan's existing nuclear fleet will only increase the scale of this infrastructure problem. If even more of the burden of the clean energy transition falls upon renewables, the deployment of renewables, transmission lines, and energy storage capacity will have to greatly accelerate. To maintain a stable electricity supply without a base of clean firm power

generation, Japan would need to "overbuild" excess solar, offshore wind, and energy storage capacity, further exacerbating infrastructure-related difficulties.

While the affordability of solar and onshore wind farms at the level of a single solar panel or wind turbine is well-recognized, this does not account for grid-level system costs associated with installing renewable generation (see the OECD Nuclear Energy Agency's "The Full Costs of Electricity Provision", 2018). Given the current Japanese electricity network's lack of interconnectedness, frequency differences, unsuitability for distributed power production, and poor regional coordination, the grid-level costs of upgrading the transmission system could become substantial. Particularly in conjunction with today's unpredictable energy markets, such expenditures could put serious financial pressure on power companies and raise the cost of electricity for commercial and residential consumers. A more distributed electricity grid system may also experience greater vulnerability to disruptions due to natural disasters and extreme weather.

Such issues can be minimized by restarting the largest possible fraction of idle nuclear power plants nationwide. These facilities are already integrated into Japan's existing grid network, which is designed around central power stations. Noting the ongoing global trend in which other nuclear operators around the world are taking steps to extend the lifetimes of their nuclear plants by an additional 20 to 40 years, Japanese planners could leverage existing nuclear capacity for decades to come, greatly facilitating the shift to cleaner electricity.

Interesting efforts are also underway in the United States to study the possibility of retrofitting retiring coal plants with small modular nuclear reactors. Such a technique could allow for the re-use of existing transmission and steam cycle infrastructure, reducing nuclear construction costs while also taking advantage of existing grid equipment. By leveraging existing and new nuclear generation together, Japan can further reduce the need to overbuild renewables and associated transmission infrastructure.

Finally, from a national climate policy perspective, maximum utilization of clean electricity from nuclear will also optimize the rate at which Japan can increase its overall proportion of clean power by installing renewables. In the near term, this improves Japan's ability to meet its declared climate targets, strengthening Japan's position in international climate negotiations while also maximizing indirect domestic economic benefits from reduced air pollution. At the same time, such a full mobilization of clean energy sources in Japan will decrease the economy's overall carbon intensity, reducing some of the risks that Japanese manufacturing exports could face in coming years from international carbon tariffs.

Synergies with an All-Fuels, All-Technologies Decarbonization Approach

Second, considering Japan's strong interest in developing clean fuels, nuclear power offers a high potential to synergize with national efforts to develop green hydrogen, green ammonia, and low-carbon fuels produced from captured carbon. Techniques for carbon capture and for producing hydrogen, ammonia, and low-carbon fuels using electricity all have one common characteristic: they are highly electricity-intensive processes. Particularly during early stages of development, high or volatile electricity costs could inhibit investment and deployment of low-carbon hydrogen and low-carbon fuels, while also reducing their cost-competitiveness. With such concerns in mind, existing and new nuclear generation capacity can create a more favorable environment for the maturation of these key clean technologies, improving Japan's ability to compete for leadership in these emerging global growth sectors.

While Japan could always import clean hydrogen or ammonia from overseas, Japanese industry will require a strong domestic base of production to maximize innovation across the entire supply chain. In other words, Japan is unlikely to emerge as a key player in clean hydrogen, ammonia, or synthetic fuels if it participates in these markets predominantly as an end user. Gaining experience as a producer will also be crucial.

If domestic production is a critical priority, then nuclear energy presents many advantages. A green hydrogen economy with large-scale domestic production will be most feasible if the electricity supply is not only clean but also reliable, abundant, and affordable. For many of these technologies, low-carbon fuel production is most economical when operators can achieve a high utilization rate with key equipment like hydrogen electrolyzers. Nuclear power can reduce the likelihood of shortages or price spikes that could force production halts or drive up the price of the manufactured product beyond the point of market viability.

Furthermore, for downstream export industries such as steel that will depend heavily upon hydrogen-based heat, the consistency of clean nuclear electricity can ensure consistently lower carbon intensity, better protecting the product from international carbon tariffs.

If Japanese industries and policymakers are serious about building a hydrogen economy with large-scale hydrogen utilization across the power, industrial, and transportation sectors, the electricity requirements will be substantial. Energy demand in a low-carbon economy will only increase further if carbon capture and utilization technologies are deployed widely. Japan would need to transition from a country with very little reserve capacity in power generation to a country with high electricity abundance. Particularly given how power sector and industrial hydrogen users will be geographically concentrated, the density and scalability of nuclear energy offer considerable advantages (see the OECD Nuclear Energy Agency's "Advanced Nuclear Reactor Systems and Future Energy Market Needs", 2021).

In addition, unlike wind and solar energy, nuclear generation can co-generate heat, which can directly support hydrogen electrolysis, hydrogen steam electrolysis, ammonia and methanol synthesis, and various petrochemical processes.

Securing Future Economic Opportunities in Nuclear Energy

To fully explore the potential of such synergies, it will be important for Japan to invest further in advanced nuclear research. For instance, some advanced reactor concepts such as high-temperature, gas-cooled reactors could generate higher-quality, higher-temperature heat with a wider array of useful industrial applications. Next-generation reactor designs also exhibit vastly improved safety characteristics, an important advantage given Japan's complicated nuclear politics. Nuclear research efforts themselves can become a strategic area of Japanese clean technology leadership. Historically, the domestic nuclear research sector has produced important innovations and placed Japan as a key nuclear technology provider. Yet nuclear R&D efforts have faltered in recent years, and Japan should energetically work to reclaim leadership in this sector. As has been the case in the past, nuclear energy research can drive future advancements in related areas such as materials science, medical devices, and heavy forging.

Existing and new collaborative research efforts with international partners like the US that are also pursuing next-generation nuclear innovation also open opportunities for Japan to guide the global development of an exciting clean technology sector. Relatedly, many nuclear power developers globally are seeking to formalize supply chains, a need that could align well with the strengths of Japanese industry in manufacturing reactor components ("Modular Manufacture and Construction of Small Nuclear Power Generation Systems" by Clara Anne Lloyd, University of Cambridge, 2020). Prioritizing next-generation nuclear power as a growth sector can promote other international opportunities as well. From India to Southeast Asia, many countries face challenges like Japan's as they plan their own transitions away from coal-fired power. Japan has historically played an important role in exporting power generation designs internationally, and should the country successfully demonstrate advanced nuclear reactors, the international market may develop a similar appetite for newer Japanese technologies.

Participating in the nuclear export market would also help Japan diversify its international clean technology offerings. While Japanese industries could also, for example, provide products and guidance to help overseas customers refit existing coal plants for carbon capture or for co-firing with clean hydrogen and ammonia, it is worth considering the possibility that such technologies will encounter opposition by international stakeholders and activists. Japan's past efforts to export highly efficient supercritical coal technologies in the face of considerable criticism from interest groups abroad highlight the reality of such risks.

Nuclear power projects, whether standalone or intended to help retrofit existing fossil fuel infrastructure, can address concerns related to carbon emissions, air pollution, and upstream fossil fuel extraction. Just as Japanese partnerships have historically played a major role in developing much of the modern energy infrastructure in Asian markets, Japan could aim to become a key nuclear technology provider across the region tomorrow.

Ultimately, nuclear energy in Japan is not only powerfully capable of supporting the development of growth sectors like clean hydrogen, ammonia, and low-carbon fuels, but also represents an important new growth sector itself.

Charting a Path Forward

With Japan's Reiwa Era only recently begun, it is obvious that the age of nuclear energy is also just beginning. With Russia and China in the lead followed by the US, Canada, the United Kingdom, France, and South Korea, a new generation of nuclear designs are securing orders and even entering service for the first time.

Despite past accidents and decades of activist opposition, the global future of nuclear power is not only bright but virtually assured, regardless of whether Japan participates. Excluding nuclear energy from Japan's chosen climate strategies will only aggravate the energy-related risks that the Japanese economy faces today and tomorrow. Therefore, Japan should aim to become a leader in nuclear energy, rather than fall behind in a sector with high and growing worldwide potential.

To accomplish this, Japanese policymakers and industry should also nurture nuclear energy as a growth sector alongside technologies like hydrogen, ammonia, and carbon recycling. Government policies can increase support for nuclear research and incentivize private-sector investment in nuclear projects, while continuing to enact regulatory reforms that build greater public trust in nuclear power generation. In anticipation of advanced nuclear designs, such regulatory reforms should incorporate evidence and science-based principles that acknowledge the greatly improved safety characteristics of next-generation reactor concepts. In the near term, the Japanese government should also increase the funding and staffing capacity of the Nuclear Regulation Authority and optimize review of existing reactors to accelerate the reactivation of units that meet the standards for restart.

Given the considerable challenges of the Japanese energy situation today and the complex path to a low-carbon economy, clean nuclear power has the potential to reduce economic risks and guide the country towards a more prosperous and climate-friendly future. As shifting energy markets, a warming climate, and geopolitical changes continue to alter the world, decisive action to promote full utilization of clean nuclear energy can help set Japan upon a more favorable course for many years to come. JS

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