Japan: building a lower-carbon power society

The role of gas and renewables to achieve energy security, economic efficiency, environmental sustainability and safety

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Executive Summary

Japan is the third-largest economy in the world with an estimated 2020 GDP of $4.8 trillion (538.7 trillion yen). The recent COVID-19 crisis decreased GDP by 5.7% in 2020, but GDP is expected to recover back to 2019 levels in real terms by 2021.

Japan is heavily dependent on fossil fuels for its energy, with coal and natural gas being the largest sources of power generation, and their importance increased after the 2011 Fukushima tsunami and nuclear accident. In 2019, coal and natural gas together accounted for two-thirds of Japan's electricity generation.

Japan's energy policy is guided by the principles of energy security, economic efficiency, environmental sustainability and safety (the "3E + S"). The expected 6th Strategic Energy Plan, scheduled for adoption in the fall of 2021, aims to achieve a more diversified energy mix by 2030, with larger shares for renewable energy (36–38% of electricity supply), the restart of nuclear power (20–22%), and hydrogen/ammonia (1%). It also aims to enhance the efficiency of fossil fuel use and to increase energy conservation efforts.

In order to realize the above, GE believes there are several major hurdles that must be overcome: (1) to introduce renewable energy to the maximum extent possible, (2) while taking into account geopolitical risk factors unique to Japan, (3) and accelerating R&D and the introduction of low-carbon technologies, and (4) to realize both stable electricity supply and economic efficiency.

This white paper will provide a summary of the initiatives that can help Japan move forward on the goal of being a carbon neutral society by 2050. In addition, this paper provides details on how the country's power needs could be addressed with the combination of renewables and gas power plants while moving forward with lower CO_2 emissions goals. Gas-fired power plants are available regardless of the time of day or weather conditions, providing dependable capacity as long as needed, whether for minutes, hours, days or weeks at a time. Approaches to further decarbonize gas-fired power plants include the use of hydrogen as a fuel for gas turbines to reduce CO_2 emissions, and Carbon Capture, Utilization, and Storage (CCUS) technologies available today that can be rapidly deployed to have a near-term impact on the country's path to decarbonization.*

Also discussed in this whitepaper is a region-specific alliance between GE and a Japanese industrial partner to develop an Ammonia Roadmap that could pave a way for reduced CO_2 emissions while operating the gas turbines in the region.

Based on our extensive analysis and experience across the breadth of the global power industry, GE believes that the accelerated and strategic deployment of renewables and gas power can change the near-term trajectory for climate change.

GE has the capability and experience running gas turbines on increasing levels of hydrogen and partnering with the right players for CCUS projects.

Creating the right energy mix won't be easy—but with the right strategy and the right technology, Japan can chart a unique path to a greener economy with sustainable, reliable, and affordable power.

**Decarbonization in this paper is intended to mean the reduction of carbon emissions on a kilogram per megawatt hour basis.*

Overview

Japan depends heavily on fossil fuels for power generation (see Figure 1) but with the country's 3E + S and decarbonization (CN) policy, it plans to invest heavily in renewables in the coming decades.

According to IEA, power demand in Japan is expected to remain relatively stable, thanks to energy conservation measures that are expected to offset the effects of economic growth and the electrification of the economy. The government projects power demand to reach 980 TWh in 2030, 2% above the 2018 consumption level.

The country must take a pragmatic approach to meeting its commitments on the recently announced policy while ensuring that power needs are met by complementing renewables with reliable, affordable and dispatchable gas power.

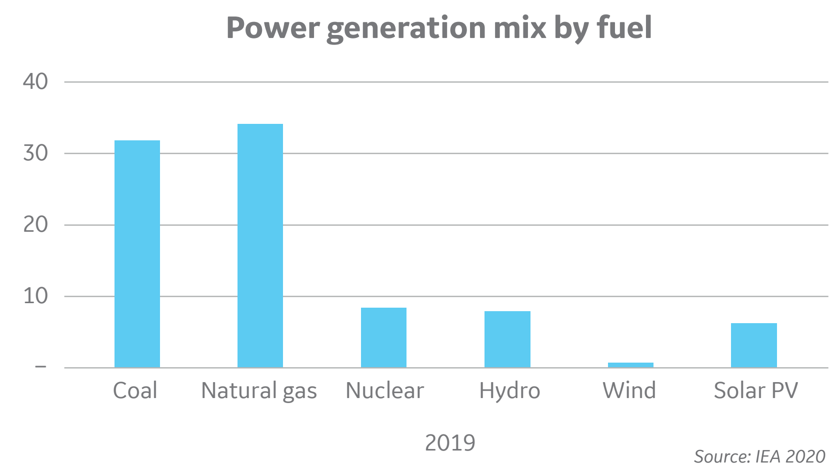

FIGURE 1

CO_2 emissions and the path forward for their reduction

In October 2020, the Prime Minister of Japan pledged that by 2050 Japan will aim to reduce greenhouse gas emissions to net-zero and to realize a carbon-neutral, decarbonized society.

According to the International Energy Agency's (IEA) Japan Energy Policy 2021, the power sector is the largest CO_2 emitter, representing 49% of total emissions from fuel combustion in 2018. Energy-related emissions have decreased in all sub-sectors since 2000, but this was offset by increasing emissions from power generation, which grew by 24%. CO_2 emissions reached a historic peak in 2013, as fossil fuels filled the gap caused by the temporary shutdown of all nuclear power plants after the Fukushima accident.

The shift from nuclear to natural gas, coal and oil for power generation caused energy-related emissions to peak at 1,234 Mt CO_2 in 2013. Emissions have since decreased (by 14%) between 2013 and 2018 due to the gradual expansion of renewable power generation, energy efficiency improvements and the restart of some nuclear power plants.

Achieving the aim of carbon-neutrality by 2050 will require Japan to substantially accelerate the deployment of lower-carbon technologies, address regulatory and institutional barriers, and further enhance competition in its energy markets. It will also be important to develop different decarbonization scenarios, to prepare for all eventualities.

To introduce renewables in a large scale, GE believes that necessary measures should be taken to mitigate the variable supply that's inherent with renewable energy. In other words, there should be a mechanism to promote investment in thermal power generation in the interim that secures capacity value and supports the introduction of renewable energy.

Gas-fired power plants are highly reliable, and capable of being available regardless of the time of day or weather conditions, providing dependable capacity as long as needed, whether for minutes, hours, days or weeks at a time. Because electricity supply and demand must always be in balance, variable renewables require dispatchable backup power such as natural gas power plants or batteries to ensure system reliability.

The Dependable Capacity metric shown in the table below has been developed by GE to illustrate the ability of a technology to reliably produce electricity during summer or winter daytime and nighttime peaks considering nameplate capacity, degradation due to ambient temperature effects, and the coincidence of a renewable generation source to peak demand. The values shown below in Figure 2 are global averages.

Average Dependable Capacity

Gas	84%
Coal	78%
Nuclear	92%
Hydro	63%
Wind	14% Onshore, 27% Offshore
Solar	20–40%

FIGURE 2

Natural gas-fired combined cycle power plants are the lowest emitting fossil fuel power plants, whether measured based on CO_2, SO_x, NO_x, particulate matter, or mercury. Going forward however, there will be a need to reduce CO_2 emissions further. There is a concern that deploying new gas generation capacity will "lock in" CO_2 emissions for the lifetime of the power plant or create stranded assets. Gas turbines currently in operation or yet to be deployed have a pathway to enabling decarbonization and avoiding lock in of CO_2 through utilization of hydrogen as a fuel or through carbon capture technologies, see Figure 3.

HYDROGEN AS A FUEL

Hydrogen is expected to play a central role in Japan's transition to cleaner energy. Japan was among the first countries to launch a national hydrogen strategy, which aims to make hydrogen cost-competitive with natural gas.

The basic configuration of a gas turbine capable of burning natural gas would remain unchanged for burning hydrogen. Specific areas that need to be addressed within the gas turbine, its accessory systems, and the plant include: 1) fuel delivery piping and components, 2) gas turbine combustion system and controls, 3) gas turbine enclosure, and 4) the heat recovery steam generator (HRSG) and selective catalytic reduction (SCR) system for NO_x removal.

All GE gas turbines have the ability to burn hydrogen fuel to some degree. The specific amount that can be burned in any particular gas turbine model depends on several factors, but most importantly on the combustion system.

Due to technical considerations this limit today without modifications is 5% hydrogen by volume and if all GE gas turbines in Japan burned 5% hydrogen it would result in a reduction of ~1 million tons of CO_2 emitted per year. If the GE gas turbine fleet is upgraded to its full current capability, including upgrades to accessory systems, this would result in a reduction of ~8 million tons of CO_2 emitted per year. In the long-term, if all the GE gas turbines are upgraded to expected capability based on planned development programs, this would result in a reduction of ~27 million tons of CO_2 emitted per year. See Figure 4.

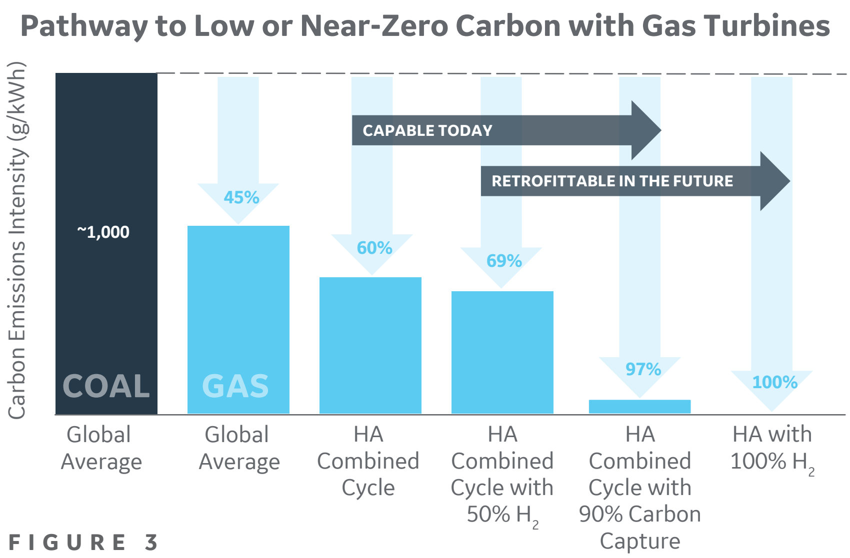

FIGURE 3

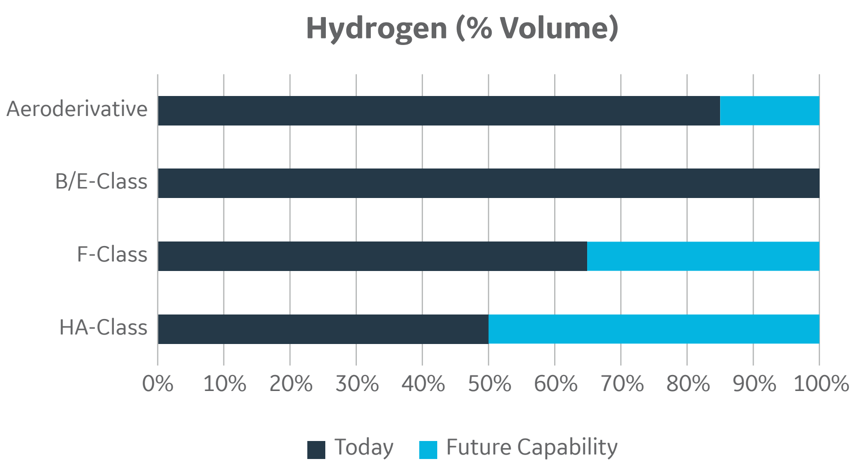

FIGURE 4

GE has more experience with operating gas turbines on hydrogen and associated low-Btu fuels than any other gas turbine original equipment manufacturer. The GE gas turbine fleet burning these fuels exceeds 100 units and it has accumulated more than 8 million hours of operation. This experience can be leveraged to upgrade the existing GT fleet enabling longer term operation with lower CO_2 emissions. Figure 5 is a snapshot of some of the key milestones in GE's hydrogen experience.

GE is continuing to develop increased hydrogen capability for its gas turbines through in-house R&D and testing as well as participating in US Department of Energy hydrogen fuel programs.

Timeline of GE Experience with H_2 and Associated Fuels

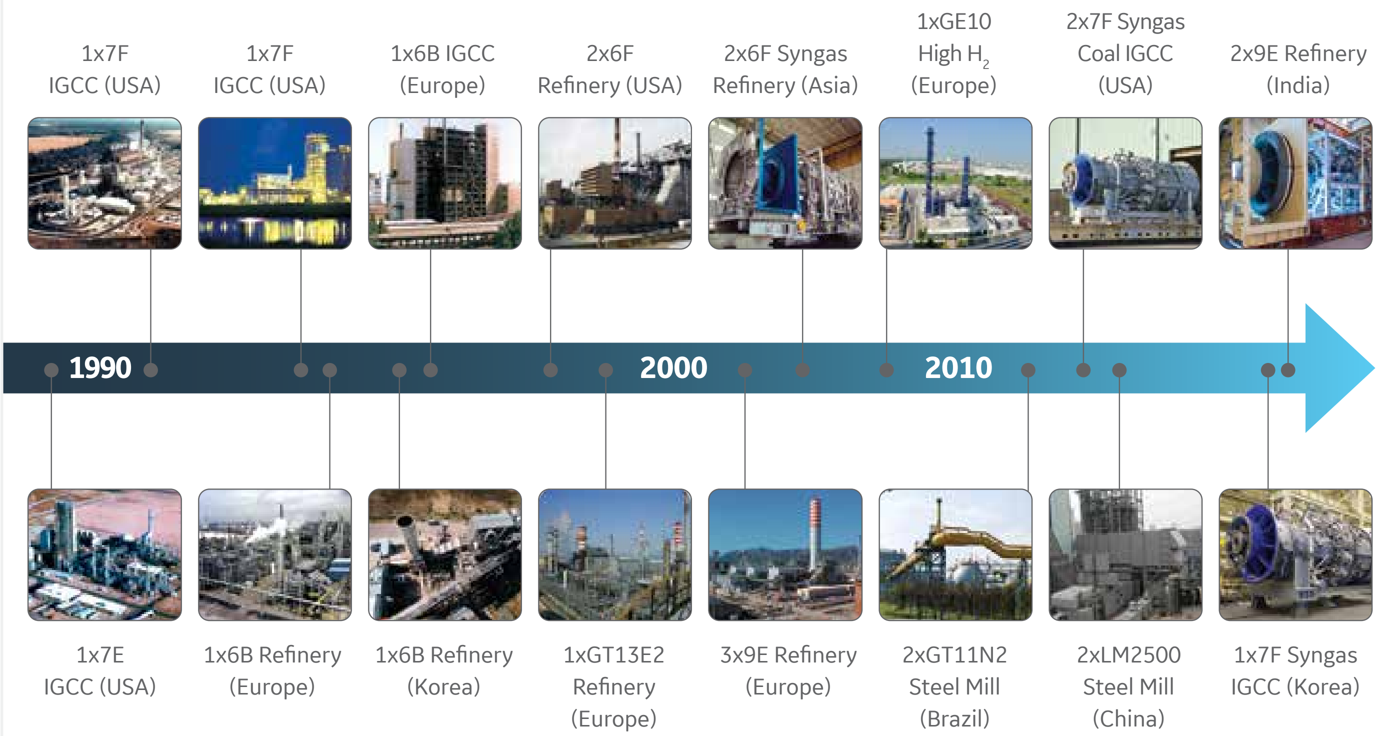

FIGURE 5

CARBON CAPTURE UTILIZATION AND STORAGE

In its simplest sense CCUS is the process of removing CO_2 from the waste gas of industrial or power generation processes. It has four central components: (i) capture, (ii) compression, (iii) transport, and (iv) storage or use.

GE believes that the accelerated and strategic deployment of CCUS and gas power can change the trajectory for climate change.

Due to Japan's heavy reliance on fossil fuels, the use of carbon-free fuels such as hydrogen and ammonia, as well as CCUS, will be key focus areas in Japan's decarbonization journey. Japan requires new gas-fired power plants to be constructed "capture ready," so that CCUS can be more easily deployed at a later date, thereby reducing the risk that new plants become stranded assets.

In addition to the benefit of applying CCUS to existing assets, it can also be deployed as a modular solution, solving for incremental amounts of carbon reduction with each additional module. This translates to greater optionality for plant owners, allowing either a phased approach by deploying carbon capture systems over years and spreading out the capital expenses over a longer period, or an immediate approach by building out the carbon capture system to full capacity.

An added benefit of a retrofit strategy is that it helps de-risk plants against future carbon regulations that impact the decision to build a gas-fired power plant today and reduces the possibility of the plant becoming a stranded asset in the future.

To date, however, CCUS deployment has been limited due to limited available space, prohibitive costs and a lack of incentives and business models. Meanwhile, Japan is among the few advanced economies to anticipate new coal generation capacity, which, if unabated by CCUS, would place additional pressure on meeting its 2030 and 2050 climate goals.

For an existing power plant to build CCUS facilities, an additional land allotment nearly the same size as the plant's footprint itself would be required. According to GE's estimates, not many existing power plants in Japan would be able to secure enough land to install CCUS facilities. Even if CCUS installation at existing power plants were to proceed, securing land is a significant roadblock in Japan. There is also the issue of where to store the collected CO_2, and early development of CO_2 utilization is desirable.

AMMONIA ROADMAP

To address the decarbonization challenges specific to the region, GE is working with a local Japanese partner for collaborative development of a gas turbine business roadmap (Ammonia Roadmap). The Ammonia Roadmap will support the use of ammonia as a carbon-free fuel to lower carbon emissions in both existing and new gas turbines. Both companies will conduct advanced research on the marketplace for ammonia as well as feasibility studies for ammonia as feedstock for gas turbine power plant installations in Japan and other regions.

Ammonia is utilized today as a fertilizer, chemical raw material and more recently, as a fuel. Japan lacks the resources to produce blue and/or green hydrogen, therefore hydrogen will have to be imported from outside the country as is the case with LNG. When used as a carrier for hydrogen, ammonia has the potential to enable efficient, lower-cost transport and storage of a carbon-free fuel which can be used directly in power generation. Since ammonia contains no carbon, it does not emit carbon dioxide when burned and may therefore enhance the power sector's efforts in reducing carbon emissions. Burning ammonia as a fuel will typically increase NO_x emissions, and additional NO_x removal equipment may be required.

"GE is continuing to advance our gas power technologies towards near zero-carbon power generation and part of this evolution may involve the use of ammonia as a fuel in order to reduce CO_2 emissions," said Ramesh Singaram, President and CEO for GE Gas Power in Asia. "We look forward to the collaboration with the local partner. Together, we'll define an ammonia gas turbine business roadmap supporting both companies' goal of reducing carbon emissions from gas turbines power installations."

GE as a company is uniquely positioned to play a key role through its scale, breadth, and technological depth. We have been a key player in the power industry since its inception and have a suite of complementary technologies including gas-fired power with hydrogen and CCUS capability, onshore and offshore wind, hydro, small modular reactors, battery storage, hybrids and grid solutions needed for the energy transformation.

Recommendations

To ensure a stable supply of electric power for Japan and to achieve effective and rapid reductions in CO_2 emissions in the power generation sector, GE makes the following recommendations:

- Regarding the Sixth Basic Energy Plan and its triennial review, develop a clear policy and timetable to ensure investments going forward can be implemented with proper foresight and feasibility in mind, achieved through dialogue with industry.
- Provide incentives for the steady fade-out of coal-fired power generation and encourage a shift to more efficient gas turbine power generation, which has a smaller environmental impact, as a near-term measure to rapidly reduce CO_2 emissions.
- Introduce small and medium-sized gas turbines within business sites to ensure the stability of power generation at power facilities to help increase the number of renewable energy power facilities. To this end, GE believes it will be necessary to make exceptions for gas turbine-based combined cycle plants with power generation efficiency of 49% or less, which are currently regulated under the Energy Conservation Law, provided they use hydrogen or ammonia co-fired turbines.
- As for Electricity Sector Reform, we recommend a pragmatic regulatory framework with rapid implementation of features such as a capacity market, a balancing market, and a non-fossil fuel value market.
- Increase funding in Research and Development and incentive mechanisms to accelerate cost effective CCUS, hydrogen, and other potential low or zero-carbon technologies for dependable capacity to complement renewables with funds provided by the government's Green Innovation Fund and others.

- In addition to incentives and investments for installation of equipment and machinery, provide incentives for land acquisition around existing power plants (tax exemptions and subsidies for land acquisition) to promote the utilization of CCUS.
- Steady implementation of a new grid code to enable maximum adoption of renewable energy and a strengthening of inter-regional lines to ensure stability of electricity supply.
- With a basis in the US-Japan Climate Partnership, support the steady realization of the Paris Agreement in Japan and elsewhere, and support joint research and the introduction of cleaner energy technologies in the industry.

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