Energy Technology in an Era of Great Power Competition:

Challenges and Opportunities in U.S.-Japan and U.S.–South Korea Cooperation

By Paul J. Saunders

ENERGY INNOVATION REFORM PROJECT

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Cover design and layout by Gabriella Turrisi
Editing and proofreading by Anne Himmelfarb
Cover photograph by Anton Balazh and NASA/Shutterstock.com

Energy Innovation Reform Project is a non-partisan non-profit organization dedicated to promoting policies that advance innovation in energy technologies and practices to improve the affordability, reliability, safety, and security of American energy supplies and our energy economy. EIRP was founded in Washington, DC in 2013. Its work combines policy reports, scholarly research, and economic modeling with creative efforts to bridge partisan differences over energy policy.

Contents

Acronyms

BCF	billion cubic feet
BCM	billion cubic meters
CCS	carbon capture and storage
CCUS	carbon capture, utilization, and storage
DOE	Department of Energy
EDGE	Enhancing Growth and Development through Energy
G7	Group of Seven
GDP	gross domestic product
IEA	International Energy Agency
IEC	International Energy Commitments
JUSEP	Japan-U.S. Strategic Energy Partnership
KEPCO	Korea Electric Power Co.
LNG	liquified natural gas
MTOE	metric tons of oil equivalent
NREL	National Renewable Energy Laboratory
PPP	purchasing power parity
R&D	research and development
RD&D	research, development, and demonstration

Executive Summary

The United States and other nations are grappling simultaneously with intensifying U.S.-China geopolitical rivalry and an energy transition driven by new technologies, changing markets, and evolving policies to combat climate change. Innovation in energy technologies is central to this competition. American allies like Japan and South Korea share many—though likely not all—U.S. interests in managing the global energy transition, addressing climate change, and competing effectively with China. They can be valuable partners in these and other areas.

In recent years, the U.S.-Japan and U.S.–South Korea energy technology relationships seem to have lagged behind the parallel energy trade relationships, which have expanded rapidly. While Japan and South Korea have each emphasized developing clean energy technologies, the Trump administration sought to slash domestic investment in energy research and development and focused its attention on boosting U.S. energy exports. As a result, the administration slowed clean energy cooperation that the Bush and Obama administrations had each sought to accelerate. Many expect the incoming Biden administration to be more committed to clean energy innovation and more open to pursuing it together with U.S. allies, making this an appropriate time to assess the strategic challenges and opportunities in these relationships.

There is a strong foundation for U.S. energy technology cooperation with Japan and South Korea. Longstanding alliances establish the close relationships and mutual trust necessary for deep collaboration. The three nations all prioritize scientific research and development. All likewise respect intellectual property rights, which is essential to close cooperation in technology research and development and have innovation-driven economies. Finally, the United States enjoys well-developed frameworks for government-to-government cooperation with Japan and South Korea, and significant existing energy R&D relationships.

Notwithstanding the strong basis for energy technology cooperation between the United States and both Japan and South Korea, there are significant challenges to deepening collaboration. These include differing perspectives on cooperation with China, often varying R&D priorities, difficulty in building markets and financing projects, economic competition among the three allies, and Japan–South Korea tensions. Practical joint projects are among the best means to work through these challenges.

The United States has opportunities to work closely with Japan and South Korea across a broad range of clean energy technologies:

- **Advanced nuclear energy technologies** could be quite important in providing reliable and clean energy and in contributing to global nonproliferation efforts. While Japan and South Korea have each turned away from nuclear energy, emerging designs for small, modular reactors and micro-reactors could address many safety, waste, and proliferation concerns.

- Though they have also lost favor to some extent—notably in South Korea—**carbon capture, utilization and storage technologies** will likely be essential in reducing global greenhouse gas emissions, especially in China, India and other nations where coal remains a key source of electric power.
- Japan and South Korea have each put **hydrogen** at the center of their plans for future clean power systems; the United States has a strong hydrogen research and development program too. Since large-scale hydrogen power remains 10-15 years in the future, joint work can avoid some of the competitive pressures inherent in working with existing commercial technologies.
- **Batteries** and the **critical minerals** needed to make them (and other high-tech systems) are drawing increasing attention both as an energy technology and as a potential vulnerability. Developing more powerful, efficient and compact batteries could be a promising area for cooperation, as could broader efforts to protect supply chains.
- Japan and South Korea have committed to increase their reliance on **solar** and **wind power** despite limited solar and wind resources—and land constraints—in the two countries, which could push each toward offshore wind. Still, joint solar research and development might offer opportunities to engage other governments, particularly India.
- Beyond energy technologies, the United States could also benefit from working with Japan and South Korea in a variety of cross-cutting technological and functional areas, including **smart cities, grid security, artificial intelligence, and data science,** as well as **global development projects** and **research integrity.** With South Korea, **intellectual property** discussions might facilitate deeper collaboration.

U.S. international leadership rests heavily on America's ability to continue developing innovative technologies—especially energy technologies, which quite literally power everything else in the U.S. economy. China is poised to become a formidable competitor in this respect, with an economy that is comparable in scale to the U.S. economy and a large, dynamic, and increasingly well-educated population. To ensure continued technological and economic leadership in the 21st century, the United States must not only accelerate its own innovation, but also align its efforts with allied nations. Japan and South Korea are capable and willing partners.

1. Introduction

As the global energy economy begins to recover from the COVID-19 pandemic, the United States and other nations are grappling simultaneously with intensifying geopolitical rivalry and an energy transition driven by new technologies, changing markets, and evolving policies to combat climate change. These circumstances highlight the role of energy innovation as a contributor to economic growth, trade, and prosperity; as a means of reducing greenhouse gas emissions; and as an arena of high-stakes international competition. They likewise dramatize the tensions among U.S. national interests and between cooperative and competitive approaches to achieving America's international goals.

Americans increasingly see China as their nation's principal global competitor. And it is a competitor across multiple dimensions, including in global politics and trade, regional security, and in advanced technologies—including 5G communications, quantum computing, artificial intelligence and autonomous weapons, and energy systems.

In the energy sector, while most of China's renewable energy products are of medium or medium-high rather than high technical complexity,[1] China is the world's largest producer of solar panels, wind turbines, batteries, and electric vehicles.[2] It is also the second largest exporter of nuclear power plants, behind Russia but ahead of the United States,[3] and in 2019 was building or planning over 300 coal power plants outside the country.[4] In a world in which most nations are seeking to slash greenhouse gas emissions, China's nuclear and renewables industries put the United States at a competitive economic disadvantage even as Chinese construction—and financing—of coal power plants extends Beijing's political influence. China's leading role in the global nuclear market may also undercut U.S. efforts to establish strong non-proliferation standards.

Fortunately, the United States is not alone in contending with the twin challenges of China and the global energy transition. Many U.S. allies have similar interests and perspectives and would welcome greater collaboration with the United States in addressing them. Indeed, research suggests that Japan's and especially South Korea's reliance on high-tech goods exports may make the two countries vulnerable to China's Made in China 2025 policy, which represents its attempt to become a global leader in high-tech manufacturing.[5] Japan and South Korea also face difficult dilemmas in their domestic energy policies and are applying advanced research and development (R&D) capabilities to address them. And each is already working closely with the United States to preserve and strengthen regional security.

As America's natural gas exports grew prior to the COVID-19 pandemic, both Japan and South Korea became important markets for U.S. liquified natural gas (LNG), which has contributed to energy security in each country. Nevertheless, despite similar shared interests, the U.S.-Japan and U.S.–South Korea energy technology relationships seem in some respects to have lagged behind energy trade relationships—largely due to the Trump administration's limited interest in clean energy technologies. Deeper energy technology cooperation with these two important partners could advance important U.S. strategic and economic interests while simultaneously strengthening key alliance relationships.

This report seeks to assess the U.S.-Japan and U.S.–South Korea energy technology relationships and to identify opportunities for deeper collaboration. It draws upon open source research, including government documents, academic and think tank reports, and press accounts, as well as approximately two dozen off-the-record interviews with U.S., Japanese, and South Korean officials and experts. As the first study in a broader program focused on energy technology cooperation and competition, the report offers a broad evaluation of challenges and opportunities for the United States in pursuing further cooperation with Japan and South Korea rather than detailed recommendations.

2. Background

The United States, Japan, and South Korea each have large and technologically sophisticated economies; they ranked 1st, 3rd, and 12th in size among the world's economies in 2019, with a gross domestic product (GDP) of $21.3 trillion, $5.08 trillion, and $1.64 trillion, respectively.[6] In a 2018 assessment of the knowledge intensity of the world's economies, Japan ranked 1st, South Korea 4th, and the United States 13th.[7] Notably, South Korea had the largest number of patent applications reported to the World Intellectual Property Organization (WIPO) per unit of GDP in 2018, followed by China and Japan.[8] The United States had the second highest number of reported patent applications that year, with about 600,000—compared to over 1.5 million originating in China.[9]

Foreign trade plays varied roles in the three nation's economies, with trade comprising 77% of South Korea's GDP, 37% of Japan's, and 26% of America's in 2019.[10] Unsurprisingly, U.S.-Japan and U.S.–South Korea trade ties are close; Japan was America's fourth largest goods trade partner in 2019,[11] while South Korea was the sixth largest.[12] Despite their sometimes tense political relationship, Japan and South Korea are also close trade partners; South Korea is the third largest market for Japanese goods,[13] while Japan is the fifth largest market for South Korea's.[14] China and the United States are each country's top goods trade partners; in both cases, China is the larger partner.[15]

The United States, Japan, and South Korea are likewise important investors in one another's economies. On a historical cost basis, cumulative U.S. direct investment in Japan and Korea in 2019 totaled $131 billion and $39 billion respectively, compared to $116 billion in China.[16] Also on a historical cost basis, cumulative Japanese and Korean direct investment in the United States had reached $619 billion and $61 billion respectively in 2019; China's had reached approximately $37 billion.[17] Japan is the leading national source of foreign direct investment in the United States by this measure.[18]

Credit: Igor Grochev/Shutterstock.com

Trade comprises 77% of South Korea's gross domestic product. The Port of Busan is one of the busiest in the world.

About 22% of cumulative U.S. direct investment in Japan has gone into manufacturing, as has roughly 28% of U.S. cumulative direct investment in Korea.[19] Some 46% of U.S. direct investment in Japan has been in finance and insurance, excluding banks; for U.S. direct investment in South Korea the figure is 23%.[20] Conversely, 44% of Japan's cumulative direct investment in the United States and almost 13% of South Korea's has been in manufacturing.[21] Japan and

South Korea have also invested significantly in U.S. wholesale trade; it has been the destination for 18% of Japan's cumulative direct investment and a striking 76% of Korea's.[22] This latter figure reflects the fact that the U.S.–South Korea economic relationship remains somewhat less developed than the more diverse and integrated U.S.-Japan relationship.

The U.S. energy economy is fundamentally different from the Japanese and South Korean in that America is not only a leading energy consumer, but also a major energy producer. In 2017, the United States was the second largest consumer of primary energy as well as the second largest producer; China ranked first in both categories.[23] Though Japan and South Korea ranked fifth and ninth among energy consumers that year, each has limited domestic fossil fuel resources.[24] At 2,823 million metric tons of oil equivalent (MTOE), total U.S. energy production is roughly 50 times that of Japan (56 million MTOE) and nearly 69 times that of South Korea (41 million MTOE).[25] The combination of high energy consumption with low production forces Japan and South Korea to meet a substantial share of their energy needs through imports; in 2015, Japan imported 93% of its primary energy supply and South Korea imported 81%.[26] High dependence on imported energy significantly shapes Japan's and South Korea's energy policies.

3. U.S., Japanese, and South Korean Policy Priorities

While Japan's and South Korea's international energy policy priorities have been broadly similar, U.S. priorities have overlapped with those of these two East Asian allies in some areas while diverging in others. During the Trump administration, the greatest convergence surrounded the complementarity interests that drove expanded U.S. LNG exports to Japan and South Korea, while the greatest divergence surrounded clean energy technologies and their role in combatting climate change. The divergence in attention to clean energy technology was a departure not only from the Obama administration's policies, but also from the approach taken by the George W. Bush administration, which invited both governments to join its Asia-Pacific Partnership on Clean Development and Climate in 2006.[27]

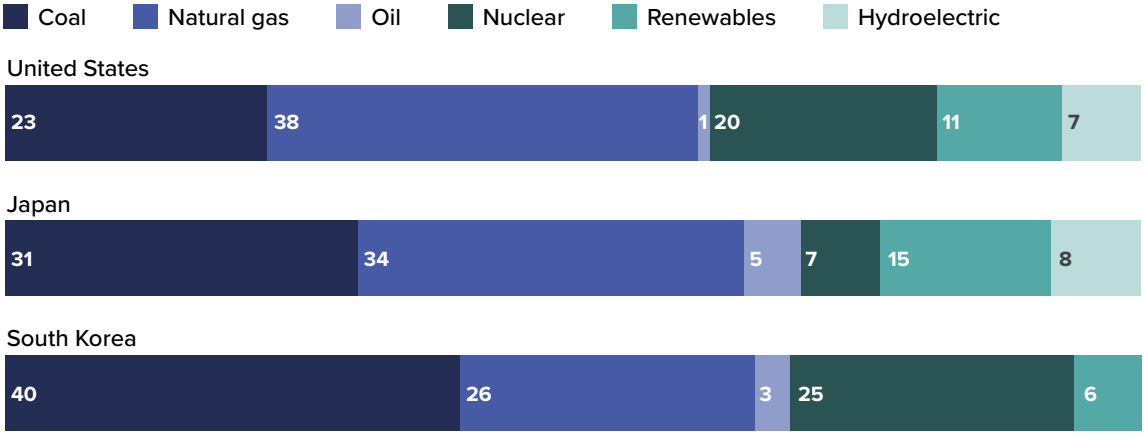
Credit: Drop of Light/Shutterstock.com

U.S. natural gas exports to Japan quadrupled between 2017 and 2019; natural gas now provides over one-third of Japan's electricity. This is a natural gas-fired power plant in Yokohama.

U.S. priorities—Recent and future

The United States generated 23% of its electricity with coal in 2019; this was roughly half the 44% share that coal held 10 years earlier. Also in 2019, America produced 38% of its electricity using natural gas, 20% from nuclear plants, almost 11% from solar, wind, and other renewables, and 7% from hydroelectric dams. Less than 1% of the country's electricity supply came from oil and other sources.[28] Figure 1 compares U.S., Japanese, and South Korean electricity generation by source.

Figure 1. U.S., Japanese and South Korean electricity generation by source *(%)*



Source: U.S. Energy Information Administration

The Trump administration's strategy documents and international energy policy statements concentrated heavily on establishing U.S. "energy dominance," which the administration defined as "America's central position in the global energy system as a leading producer, consumer, and innovator."[29] In practice, however, the Trump administration focused on expanding U.S. oil and natural gas production and boosting exports; U.S. officials, including former secretary of energy Rick Perry, often framed this as contributing to allies' energy security with LNG "molecules of freedom."[30] U.S. oil exports increased from 6.38 million barrels per day in 2017 to 8.57 million barrels per day in 2019 (the last complete year for which data are available), prior to 2020 production and export declines during the COVID-19 pandemic.[31] During the same two-year period, natural gas exports increased from 3,154 billion cubic feet (bcf, or 89 billion cubic meters, bcm) to 4,656 bcf (132 bcm) per year.[32]

President Donald Trump has appeared to make increasing U.S. energy exports a personal priority in America's international energy policy—part of a larger effort to increase U.S. exports of all kinds. Indeed, in view of his complaints about the U.S.-Japan trade deficit, Tokyo reportedly considered increasing natural gas imports from the United States early in 2017.[33] Later that year, before a June 2017 meeting with Korea's President Moon Jae-in, Mr. Trump said, "The leaders of South Korea are coming to the White House today, and we've got a lot of discussion to do. But we will also be talking to them about buying energy from the United States of America."[34]

The aim to increase U.S. energy commodity exports aligned well with Japan's and South Korea's needs. U.S. natural gas exports to Japan increased by a factor of four between 2017 and 2019, from 53 bcf to 201 bcf; South Korea's gas imports from the United States merely doubled, from 130 bcf to 270 bcf.[35] By 2019, Japan and South Korea were America's top-two customers for LNG exports.[36] The U.S. secured Tokyo's further commitment to align a targeted $10 billion in public and private investment in LNG projects with an administration initiative to grow energy markets in the region.[37] In other words, Japan would not only buy additional U.S. LNG, but would also help to finance projects that could facilitate U.S. LNG exports to third countries.

Though its National Security Strategy established innovation as a component of energy dominance, the Trump administration gave little visible attention to advancing energy technology. Domestically, the White House repeatedly sought to cut spending on federal research across many agencies, including the Department of Energy (DOE);[38] this included a 74% budget reduction for DOE's Office of Energy Efficiency and Renewable Energy.[39] Such work is a necessary foundation for cooperative

R&D programs. The principal exception to this diminished emphasis on innovation has been in nuclear energy technology; in April 2020, DOE released the report *Restoring America's Competitive Nuclear Energy Advantage*, which detailed a security-oriented strategy to compete with Russia and China in nuclear reactor exports that included a call to develop and demonstrate advanced reactors.[40]

In its broad policy dialogues with Japan and South Korea, the administration did not emphasize energy innovation,[41] perhaps in part because Tokyo and Seoul had focused their research on low-carbon technologies to combat climate change. President Trump disputed the science of climate change and, in 2019, announced that the United States would withdraw from the Paris Agreement, a global agreement that established a framework for coordinated voluntary national efforts to reduce greenhouse gas emissions.[42] President-Elect Joe Biden has promised to re-enter the Paris Agreement and has announced his intent to appoint former secretary of state John Kerry as a climate envoy at the National Security Council.[43]

As a candidate, Biden said little about his specific priorities for U.S.-Japan or U.S.–South Korea energy engagement; some attentive Japanese officials worried that the Democrats' Unity Task Force—a group created to bridge the policy gap between Biden's supporters and progressives, especially those backing Senator Bernie Sanders—did not mention Japan.[44] Though Biden's campaign pledged that his administration would "strengthen our alliances with Japan, South Korea, Australia and other Asian democracies,"[45] neither President-Elect Biden nor others provided details about plans to work with these nations. That said, when Mr. Biden served as vice president, the Obama administration made clean energy technology a priority in U.S.-Japan relations.[46]

Credit: Christos S/Shutterstock.com

President-Elect Joe Biden has very different energy and climate priorities from those of this predecessor, President Donald Trump, which could significantly affect U.S.-Japan and U.S.-South Korea cooperation in these areas. This is their first 2020 election debate, in Cleveland, Ohio.

During a campaign town hall event, Mr. Biden indicated his openness to banning fossil fuel exports, "depending on what it is they are exporting for—what they're replacing."[47] Still, the incoming Biden administration seems unlikely to block profitable U.S. LNG exports to Japan and South Korea; in addition to costing American jobs, such a decision would not stop either nation from buying LNG elsewhere. But Biden administration officials may well give less (and less visible) priority to this aspect of U.S.-Japan and U.S.–South Korea relations than their predecessors.

In another contrast with the Trump administration, the Biden campaign stressed a commitment to "pursue a historic investment in clean energy innovation" and to using innovation "from our national labs and universities" to drive job creation, including in clean energy.[48] The campaign likewise promised that a President Biden would "drive dramatic cost reductions in critical clean energy technologies, including battery storage, negative emissions technologies, the next generation of building materials, renewable hydrogen, and advanced nuclear . . . , ensuring that those new technologies are made in America."[49] In parallel, Biden's team has called for renewed partnership with governments participating in the Obama administration's Mission Innovation initiative[50] to quadruple their initial financial commitments to clean energy research and development.[51]

While the Biden administration's approach to energy cooperation with Japan and South Korea will emerge only in the months and years ahead, Mr. Biden's stated goals could facilitate deeper technology collaboration with Japan and South Korea.

Japanese priorities

In 2019, Japan relied upon fossil fuels for over two-thirds of its electricity generation, including coal (31%), natural gas (34%), and oil (5%). The remainder of Japan's electricity is from zero-carbon sources, including nuclear (7%), hydroelectric (8%), and other renewables (15%).[52] Existing mandates call for increasing the share of renewable energy to 22–24% in 2030,[53] with 44% of electricity from nonfossil (principally renewable and nuclear) sources by that time.[54]

Credit: Go_Legacy/Shutterstock.com

Japan's existing energy plans call for increasing the share of renewables in electricity generation to 22-24% by 2030. This photo of a solar facility and wind turbines in the Hyogo Prefecture illustrates the country's complex geography..

Japan's government revised its national energy goals twice in the last decade, in 2014 and 2018. The Fourth Strategic Energy Plan, released in 2014, adjusted the country's energy priorities to reflect the sharp reductions in Japan's use of nuclear energy following the March 2011 accident at the Fukushima Daiichi Nuclear Power Station. Between 2010 and 2012, Japan's nuclear electricity generation fell by over 94%; despite slow recovery in nuclear generation beginning in 2015, nuclear power had attained only 22% of its 2010 levels by 2019.[55] As the share of nuclear power in Japan's electricity mix collapsed, fossil fuels—especially natural gas—soared to fill demand previously met by nuclear.[56]

The Fourth Strategic Energy Plan acknowledged the dilemmas that this created for Japan in its longer-term efforts to limit dependence on energy imports, promote economic growth, and make and carry out plans to reduce greenhouse gas emissions.[57] Key objectives included greater efforts to deploy renewable power, improve the efficiency of fossil fuel systems, and pursue new technologies like fuel cells.[58]

In 2018, Japan's government approved the Fifth Strategic Energy Plan, which aligned its strategy with the 2016 Paris Agreement. The Fifth Strategic Energy Plan further stressed expansion of renewable energy and the contribution that renewable power could make to Japan's attempts (ongoing since World War II) to secure energy independence.[59] More ambitiously, it declared that "Japan, a country with advanced energy technologies, must play a leading role in the development of decarbonized energy"[60] and noted that because of Japan's limited domestic energy resources, "it is a country for which obtaining the initiative in energy technologies is more necessary than anything else."[61]

The Fifth Strategic Energy Plan did not so much define new priorities for Japan as call for—and justify—intensified work toward existing aims, including in energy innovation. The plan expressed support for the Obama administration's Mission Innovation initiative and declared Japan's intent to promote development of clean energy technology, including hydrogen technology,[62] renewable energy, and even (as a long-term possibility) wireless transmission of solar power from space-based collectors.[63] Some of the plan's language was forceful, such as its commitments to "maximum solutions through innovation" and "revolutionary energy technologies."[64]

Internationally, Japan's Fifth Strategic Energy Plan prioritizes closer cooperation with the United States, Russia, and China as "countries that have a major influence on the energy supply-demand structure."[65] With respect to the United States, Japan's goals included not only the growth in bilateral energy trade, but also cooperation in developing LNG demand across Asia. Possibly in deference to the Trump administration's focus on fossil fuels and nuclear energy, Japan's technology priorities in dealing with the United States were limited to these two areas.[66] In contrast, Japan's priorities in relations with China and Russia included "low carbon energy infrastructure" and "renewable energy," respectively—aims absent from its assessment of cooperation with Washington.[67] Finally, the plan refers to the similarity in Japan's and South Korea's energy circumstances and outlines a number of areas for potential cooperation, including regional LNG markets, nuclear safety, energy conservation, and "global warming countermeasures."[68]

South Korean priorities

Though both Japan and South Korea generated about 70% of their electricity using fossil fuels in 2019, South Korea's generation depended even more heavily on coal, which provided 40% of the country's electricity supply. Natural gas and oil produced 26% and 3% of South Korea's electricity, respectively; nuclear power contributed 25%. South Korea received just 6% of its electricity from renewables.[69] South Korea's government seeks a 30–35% share of renewable energy in overall electricity generation by 2040, and aims to reach 20% by 2030—slightly less than Japan's goal in that year.[70]

While facing many of the same energy challenges as Japan, South Korea's current left-leaning government has perhaps stressed its "green" aims to a greater extent than Japan's more conservative recent governments. Indeed, President Moon Jae-in borrowed the name—and some of the substance—of U.S. proposals for a "Green New Deal" to outline his own plan, which he described as "responding preemptively to the climate crisis" as well as offering a way to "improve the quality of our lives" by reducing pollution, to "enhance industrial competitiveness," and to "help create a significant number of jobs through the growth of green industries."[71]

Credit: Daengpanya Atakorn/Shutterstock.com

Seoul's skyline by night. South Korean President Moon Jae-in has stressed energy efficiency as a pillar of the country's energy and climate policy.

South Korea's formal plans reflect this rhetorical approach. The 2019 Third Energy Master Plan, "A New Energy Paradigm for the Future," emphasizes climate change more heavily than Japan's energy plan (which refers only to a "sense of crisis" connected to decarbonization, not a "climate crisis"[72]) and seeks a "transition toward clean and safe energy."[73] Seoul's plan describes energy efficiency as "the most environmentally-friendly and economical energy source" and aims for an 18.6% reduction in business-as-usual energy consumption by 2040.[74]

Importantly, and unlike both Japan and the United States, South Korea's plan declares a decisive turn away from nuclear energy. It states explicitly that "nuclear power will be gradually phased out" by forgoing operating license extensions for existing nuclear power plants and declining to build new reactors.[75] Japan's plan on the other hand—notwithstanding frequent references to the Fukushima accident and the importance of "reflecting on and responding to the pain felt by the people affected"—remains committed to (but politically realistic about) nuclear energy as a component of its decarbonization strategy. Tokyo's plan admits that "nuclear power has only partially gained the trust of society" but maintains that "the development of nuclear power is a task for the future."[76]

In practice, the fuel mix in South Korea's electricity system has changed only modestly over the last decade. Indeed, while coal's share of the country's electricity generation has declined slightly, the absolute quantity of coal-fired power has increased.[77] As in Japan—though to a much lesser extent absent the collapse in nuclear generation after the Fukushima disaster—the share of natural gas has grown more than any other source of electricity in South Korea.[78]

In the realm of energy technology, South Korea has perhaps concentrated its formal plans most heavily in two areas: technologies to manage demand (essential in reaching its efficiency goal) and hydrogen, which the plan describes as "a future growth engine and environmentally-friendly energy source . . . that will contribute much to boosting South Korea's energy independence."[79] In the former area, South Korea's government sees "Fourth Industrial Revolution technologies" as a valuable tool in managing demand;[80] President Moon has called for a Digital New Deal in parallel with his Green New Deal.[81] In the latter case, South Korea plans to take "the lead in spearheading the global hydrogen economy by utilizing its world-class hydrogen technologies." Nuclear technology development is confined to "nuclear decommissioning and spent fuel management."[82]

At the international level, South Korea's Third Energy Master Plan focuses on stronger regional cooperation as a means to "overcome its geographical limitations and secure a stable energy supply."[83] This includes a proposal for a Northeast Asia Super Grid, which the plan suggests would connect the electricity systems of South Korea with North Korea, China, Japan, Mongolia and Russia[84]—a project in which President Moon urged America to participate in a 2018 speech in the United States.[85] In conjunction with Japan's ongoing energy engagement with Beijing and Moscow, this proposal illustrates the gap between the U.S. and its two allies' perspectives on working with America's geopolitical rivals, China and Russia.

4. Foundations

Generally speaking, the United States has robust foundations for energy-related cooperation with Japan and South Korea, though the U.S.-Japan relationship is perhaps more well-established and deeper. To begin with, the U.S.-Japan and U.S.–South Korea alliances establish the close relationships necessary for R&D cooperation. Moreover, the three nations each have innovation economies that prioritize scientific research and development, and all have respect for intellectual property rights, which is essential to close cooperation in technology R&D: South Korea's intellectual property protections are above the global median, while the United States and Japan share an especially strong commitment to intellectual property. Finally, the United States enjoys largely well-developed frameworks for government-to-government cooperation with Japan and South Korea and strong existing energy R&D relationships.

Alliances

The United States and Japan signed their foundational security treaty and a related status of forces agreement governing U.S. military bases in Japan in 1960;[86] the Mutual Defense Treaty Between the United States and the Republic of Korea dates from the Korean War armistice, in October 1953.[87] U.S. alliances with Japan and South Korea contribute indirectly but powerfully to cooperation in many areas, including in energy technology R&D. First, alliances formalize a sense of shared purpose that helps to align both goals and efforts to pursue them. Second, and no less important, they establish mutual trust, which is especially significant as some energy technologies—especially nuclear technology—are extremely sensitive. Such trust is critical in sharing scientific research. Finally, the U.S.-Japan and U.S.–South Korea alliances have facilitated close political and economic relationships that ease R&D cooperation and help to expand it beyond governments and universities to the private sector, which provides significant additional human, technical, and financial resources.

Innovation economies

The United States, Japan, and South Korea each have innovation-driven economies and invest heavily in scientific research and development. A 2019 assessment of science and technology research spending by the Group of Seven (G7) countries and China, Russia, and South Korea, ranked the United States, Japan, and South Korea first, third, and fifth respectively.[88] South Korea and Japan had the highest levels of research spending as a share of GDP among these 10 nations.[89] Table 1 presents comparative statistics on research spending in absolute terms and as a share of each country's economy.[90]

More narrowly, the U.S., Japan, and South Korea are also leaders in energy research, development, and demonstration (RD&D) spending. RD&D includes not only science and technology research, but also efforts to develop specific products and to demonstrate their feasibility. Among members of the International Energy Agency (IEA), which excludes China and Russia, the eight remaining nations listed in table 1 have the largest energy RD&D budgets.[91] Table 2 presents these figures along with China's reported 2019 energy RD&D budget. The IEA states that the European Union's combined energy RD&D budget is $2.319 billion, about three-quarters of Japan's RD&D budget.[92] China's 2019 energy RD&D

budget of $7.9 billion is less than 2% higher than the U.S. figure.[93] Looking ahead, South Korea's Third Energy Master Plan calls for a 24% increase in the country's clean energy R&D investment between 2019 and 2021.[94]

While the U.S. spends considerably more on both overall research and energy RD&D than Japan and especially South Korea, the latter two devote substantial resources in each area and—as demonstrated by their high ratios of research spending to GDP—also assign great priority to science and technology research relative to other nations. This spending, and the commitment it reflects, helps to make the two countries desirable partners for the United States.

Table 1. Research Spending in G7 Countries Plus China, Russia, and South Korea

	Spending *(USD billions)*	Share of GDP *(%)*
United States	511.1	2.7
China	451.2	2.1
Japan	191.3	3.5
Germany	118.2	3.0
South Korea	79.4	4.2
France	62.2	2.3
United Kingdom	47.2	1.7
Russia	39.9	1.1
Italy	29.9	1.3
Canada	26.2	1.5

Source: Nippon Communications Foundation (Nippon.com), based on data from Japan's Ministry of Internal Affairs and Communications.

Table 2. Energy Research, Development and Demonstration Budgets

	Energy RD&D Budget, 2019 or latest *(USD billions, PPP)*
China	7.9
United States	7.8
Japan	3.1
France	1.7
Germany	1.6
United Kingdom	1.3
Canada	1.1
South Korea	0.8
Italy	0.7

Source: International Energy Agency.
Note: PPP = purchasing power parity.

Intellectual property protections

The United States and Japan each have a deep commitment to protecting intellectual property rights, something that contributes considerably to their research and development cooperation. The conservative-leaning Property Rights Alliance, which ranks countries on their protection of property rights, placed Japan 5th, the United States 13th, and South Korea 31st in 2020.[95] Basing similar rankings on national surveys of domestic intellectual property protections in 2014 and 2015, the World Economic Forum arrived at broadly similar results, with Japan 6th, the United States 15th, and South Korea 52nd.[96] The disparity between the U.S. and South Korean ranks might explain some of the variance between the extremely close U.S.-Japan R&D relationship and the less close U.S.–South Korea relationship; disputes surrounding a Korea Electric Power Co. (KEPCO) consortium, which the United States argues is using Westinghouse technology in nuclear reactors that the consortium built in the United Arab Emirates, have complicated U.S.–South Korea ties.[97]

Frameworks for cooperation

The United States has well-developed frameworks for energy-related cooperation with both Japan and South Korea. In each case, this includes two foundational treaties—a science and technology agreement and an agreement on peaceful uses of nuclear energy (known as 123 agreements, based on the requirement for such an agreement in Section 123 of the Atomic Energy Act of 1954, which

governs international cooperation).[98] These two treaties create a necessary platform for government-to-government R&D collaboration and, in the case of the 123 agreements, a basis for commercial partnerships as well. The United States has active 123 agreements with 48 countries and Taiwan, as well as with the International Atomic Energy Agency and Euratom.[99] The United States concluded its most recent science and technology and 123 agreements with Japan in 1988 and 1987, respectively, and with South Korea in 1999 and 2015.

The United States has also established a variety of high-level energy-related bilateral dialogues with Japan and South Korea. In Japan's case, the most visible may be the U.S.-Japan Bilateral Commission on Civil Nuclear Cooperation, established in 2012, and the Japan-U.S. Strategic Energy Partnership (JUSEP), launched in 2017. The United States and South Korea have similar structures: the High-Level Bilateral Commission (which covers civil nuclear issues), created in 2016, and the U.S.–Republic of Korea Energy Security Dialogue, begun in 2017. Although the incoming Biden administration may redesign JUSEP and the U.S.-ROK Energy Security Dialogue to suit its priorities, such engagement seems quite likely to continue.

Existing R&D relationships

Japan and South Korea have been among the top U.S. energy research and development partners. The Department of Energy's International Energy Commitments (IEC) Documents Database—an online list of DOE's past and current agreements with foreign governments and international organizations—provides quantitative evidence of this; Japan has the largest number of database entries and South Korea has the third largest. Table 3 lists DOE's top-10 country partners based on IEC database entries.[100]

The IEC database is not a comprehensive measure of DOE's partnership with foreign governments or international organizations; it is a public list of unclassified commitments of various types and may not be complete.[101] Only some commitments are still ongoing, as most have expired. Moreover, individual IEC database entries are not equal—some of the commitments in the database are broad framework agreements that provide a foundation for cooperative work, while others are implementing agreements, memorandums of understanding, or statements of intent.[102] Likewise, some are also more substantively or strategically important than others.

Though many commitments in the IEC database have no visible follow-up activity, some prompt extensive cooperation over time. In Japan's case, 42 entries—nearly one-quarter of all DOE's bilateral commitments involving the country—are Action Sheets (highly specific agreements to pursue concrete joint tasks) derivative to a 1990 agreement between DOE and Japan's Atomic Energy Research Institute to pursue cooperative research and development surrounding accounting for, controlling, protecting, and verifying nuclear materials.[103] These entries reflect close and sustained interaction in nuclear energy and nuclear safety in the immediate aftermath of the U.S.-Japan 123 agreement, which entered force in 1988. The first U.S.-Japan commitment in the IEC database is a 1969 agreement between the U.S. Atomic Energy Commission and Japan's Power Reactor and Nuclear Fuel Development Corporation to explore development of liquid metal cooled fast breeder reactors.[104]

Table 3. DOE's Top-10 Country Partners in the International Energy Commitments Database

	IEC Database Entries
Japan	160
China	111
South Korea	60
France	55
Russia	49
Canada	44
Germany	41
United Kingdom	39
Italy	34
Israel	32

Source: Department of Energy International Energy Commitments Database.

Note: The totals for the European Union member states listed here (and for the United Kingdom, which withdrew formally from the EU on January 31, 2020) exclude seven entries for the European Union and 23 entries for Euratom, which regulates the EU's civil nuclear industry, conducts research and development, and oversees nuclear safety and waste, among other functions. Russia's total excludes eight entries for the Union of Soviet Socialist Republics.

5. Challenges

Despite the robust foundations for energy-related cooperation between the United States and both Japan and South Korea, several challenges to deeper cooperation are apparent. These include differing perspectives on cooperation with China, often varying R&D priorities, financing, economic competition among the three allies, and Japan–South Korea tensions.

Differing perspectives on working with China

Looking ahead, differing perspectives on China seem likely to complicate U.S.-Japan and U.S.–South Korea relations in many areas, including cooperative energy research and development. A *Washington Post* columnist has argued that the incoming Biden administration seems to be "rebranding but not reinventing" the Trump administration's more competitive China policy.[105] Notwithstanding some similar concerns about China's conduct, Japan and South Korea have continued to pursue more cooperative relationships, in part due to their deep economic integration with China. Some have expressed concern that new U.S. limits on foreign investment in critical infrastructure, technologies, and sensitive data—intended to address American concerns about China—might also undercut technology collaboration with Japan.[106]

The U.S. intelligence community has explicitly warned that "China's intelligence services will exploit the openness of American society, especially academia and the scientific community, using a variety of means."[107] This in turn has led to new scrutiny of universities, businesses, and even individual researchers with ties to Chinese partners, owners, or funders.

In one highly visible case, 54 scientists either resigned or were fired after an investigation by the National Institutes of Health found that they had not disclosed financial links to foreign governments. Among the larger pool of 189 researchers investigated, 93% had failed to disclose support from China.[108] Following warnings from the intelligence community, U.S. universities have given much greater attention to Chinese involvement in research work; for example, Stanford University has established a Foreign Influence Policies and Practices Advisory Committee that develops recommendations for the university to address security and foreign influence.[109]

In the author's interviews with Japanese and South Korean academics and researchers, few expressed similar anxiety about Chinese research funding or Chinese researchers and students in their countries. Some noted that Japanese and South Korean universities depend heavily on Chinese students' tuition payments. Still, Japan and South Korea appear to have begun some domestic discussion over relations with China; Tokyo is considering new rules on foreign involvement in research[110] and South Korean government subsidies to Chinese solar cell suppliers have generated controversy in Seoul.[111]

Varying energy R&D priorities

One of the most significant variables allowing for—or constraining—deeper U.S. energy R&D cooperation with Japan and South Korea is the degree to which the countries' R&D priorities are

aligned. This is especially true for government-to-government collaboration, where R&D funding is heavily concentrated and centrally allocated within a few leading agencies; most obviously, the Trump administration's disinterest in clean energy technology slowed cooperation with Japan and South Korea on these issues. One South Korean interviewee reported that during the Trump administration, 90% of U.S.–South Korean cooperation on clean energy was "bottom up," with mid-level career officials pushing the work forward in the absence of "strategic commitment" at senior levels. Unlike government agencies, U.S. universities and companies are able to select their priorities—and their partners—independently, in a manner that aligns with their goals.

Japan's and South Korea's attitudes toward nuclear energy are also a constraint. DOE's past technology collaboration with both Japan and South Korea was focused heavily on cooperation in nuclear energy, despite some limits (especially vis-à-vis South Korea) resulting from U.S. security and nonproliferation concerns. Yet it is unclear whether nuclear technology can continue to serve as the core of these two important relationships, given that South Korea's policy has turned away from nuclear power and Japan's has set it aside for the foreseeable future—though neither of these positions is likely to be final and unchanging. In the United States, the outgoing Trump administration, the incoming Biden administration, and bipartisan majorities in the U.S. Congress have come to agree on the importance of pursuing advanced nuclear technologies.

According to an interviewee at a Japanese multinational company, 7 of every 10 dollars in U.S.-Japan energy collaboration went to the nuclear sector prior to Japan's 2011 Fukushima disaster. This individual questioned whether nuclear energy could play the same role in the future, especially in the wake of the 2017 Westinghouse bankruptcy and Toshiba's 2018 sale of the company's assets. In this environment, pursuing closer collaborative relationships will require all sides to reexamine their clean energy priorities and nuclear energy's role within them. If the United States further expands its efforts to develop advanced nuclear reactors, and Japan and South Korea focus narrowly on decommissioning and spent fuel management, this challenge could become pressing.

Financing

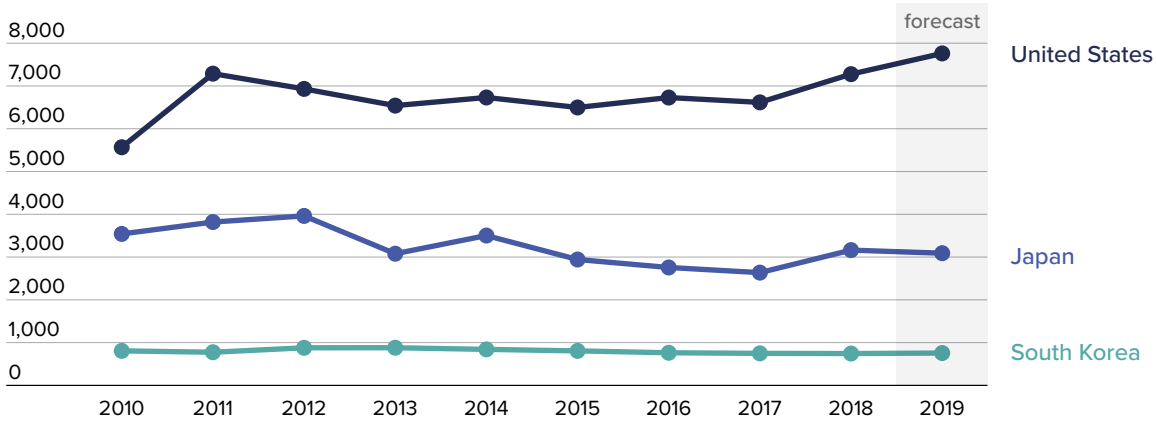
While the United States, Japan, and South Korea are leaders in energy R&D spending, their public budgets for this work have varied substantially. Figure 2 presents U.S., Japanese, and South Korean energy RD&D spending from 2010 to 2019, as compiled by the International Energy Agency and presented in 2019 U.S. dollars, on a purchasing power parity (PPP) basis.[112] Perhaps most notable is that while U.S. energy RD&D spending increased significantly—by almost 40%—Japan's and South Korea's decreased by about 13% and 6%, respectively. This trend is concerning, since adequate financing is essential for energy innovation and for cooperative work; public funding supports both government-conducted research and government-funded research at universities and, to a lesser extent, in the private sector.

Another financing challenge will be in securing markets and buyers for expensive new energy technologies during a period of deepening geopolitical competition. Because high-growth markets are usually most attractive commercially, and because it is the world's largest greenhouse gas emitter, China was a priority market for demonstrating and selling advanced energy technologies in the past. As geopolitical competition has intensified, new U.S. policies have constrained American firms; in 2019, TerraPower scrapped plans to build an experimental nuclear reactor in China.[113]

Though impacts of the COVID-19 pandemic on energy R&D spending remain to be seen, there are some fears that the pandemic could slow investment in energy technology development. In May 2020, the IEA informally surveyed companies active in energy technology; the firms considered broad cuts and delays in electrification and digitalization "likely," and rated their expected impacts as "moderate" to "considerable." Companies also considered uncertainty about public R&D budgets and grants for

carbon capture, utilization, and storage (CCUS) to be "very likely" and to have "significant" impacts (the highest level).[114] That said, President-Elect Joe Biden's economic recovery plans explicitly cite clean energy investment as a catalyst for renewed domestic growth.[115] What remains to be seen is the extent to which such investments prioritize R&D, which tends to drive innovation and growth over time, or deployment, which would likely do less to advance technology but more to provide near-term economic stimulus.

Figure 2. U.S., Japanese and South Korean total RD&D spending in millions of US dollars
(USD, 2019 prices and PPP, total budget)



Source: International Energy Agency

Internationally, the United States has increasingly sought to develop competitive alternatives to China's state-subsidized development projects, at times in cooperation with Japan. In 2018, for example, America combined the former Overseas Private Investment Corporation (OPIC) with the U.S. Agency for International Development's financing system to establish the U.S. International Development Finance Corporation (DFC).[116] During the same year, the U.S. State Department launched the Asia EDGE (Enhancing Growth and Development through Energy) initiative "to grow sustainable and secure energy markets throughout the Indo-Pacific."[117]

Competition

While Japan and South Korea are close and important U.S. allies in the Indo-Pacific region, both countries also compete economically with the United States (and with one another). The incoming administration's "Build Back Better" economic plan states that "Biden will mobilize American manufacturing and innovation to ensure that the future is made in America," and it stresses Biden's focus on creating jobs and building a "clean energy future."[118] Although U.S. economic anxiety today centers around China rather than Japan or South Korea, some U.S. high-tech products might actually compete more directly with Japanese or South Korean goods in global markets. One Japanese interviewee implicitly acknowledged this tension by stating that U.S.-Japan energy R&D cooperation is easier in areas of longer-term basic research and becomes more challenging as the work progresses toward commercially viable technologies. A South Korean interviewee likewise noted that Japan and South Korea are commercial competitors.

In some respects, competition might be a greater obstacle to U.S. energy R&D cooperation with South Korea than with Japan. As one interviewee at a Japanese multinational company put it, Japanese companies are "giving up on the idea of national champions" because Japanese firms can attain the

scale needed to compete effectively with China only through mergers with U.S. or other Western companies. In 2020, for example, Japan's Hitachi acquired an 80% share in the power grid division of Swiss-Swedish firm ABB to create one of the world's largest grid companies.[119]

Conversely, a South Korean researcher argued that U.S.–South Korea collaboration on advanced batteries would be a good fit because America was better at innovating and South Korea had a stronger high-tech manufacturing base—a framework for cooperation that appears to be at odds with the aim of Biden's "Build Back Better" plan to restore U.S. manufacturing jobs. Some researchers have expressed concern that rising "technonationalism" could damage the "innovation and economic ecosystem" in U.S.-Japan relations;[120] such worries seem to apply equally to America's ties with other allies, including South Korea. Still, South Korean interviewees generally expressed satisfaction with the quality of interaction between U.S. and South Korean firms; one saw U.S. tariffs on Chinese goods as an opportunity for South Korea.

Japan–South Korea relations

Thus far, the United States has overwhelmingly pursued its energy technology cooperation with Japan and South Korea either bilaterally with each government or within larger multilateral groups, such as the Carbon Sequestration Leadership Forum, the International Partnership for Hydrogen and Fuel Cells in the Economy, and ITER (International Thermonuclear Experimental Reactor). Should Washington attempt to catalyze trilateral energy R&D efforts, the complex relationship between Tokyo and Seoul—still haunted by imperial Japan's brutal occupation of the Korean Peninsula during World War II—might be an obstacle, much as it has been in other areas.

Recent events have in fact escalated this long-running dispute: In 2018, South Korea's Supreme Court ordered a Japanese company to pay compensation for its use of forced labor.[121] In response, Japan has imposed export restrictions on some materials used to produce semiconductors and displays. A South Korean interviewee suggested that this incident "woke up" South Koreans and called existing high-tech value chains into question. This individual argued that the United States would be the best partner for South Korea as it seeks to diversify its supply chains and limit dependencies on Japan. While such sentiments might lend greater momentum to U.S.–South Korea R&D cooperation and trade, they clearly undercut wider U.S. objectives to strengthen collaboration among these two allies.

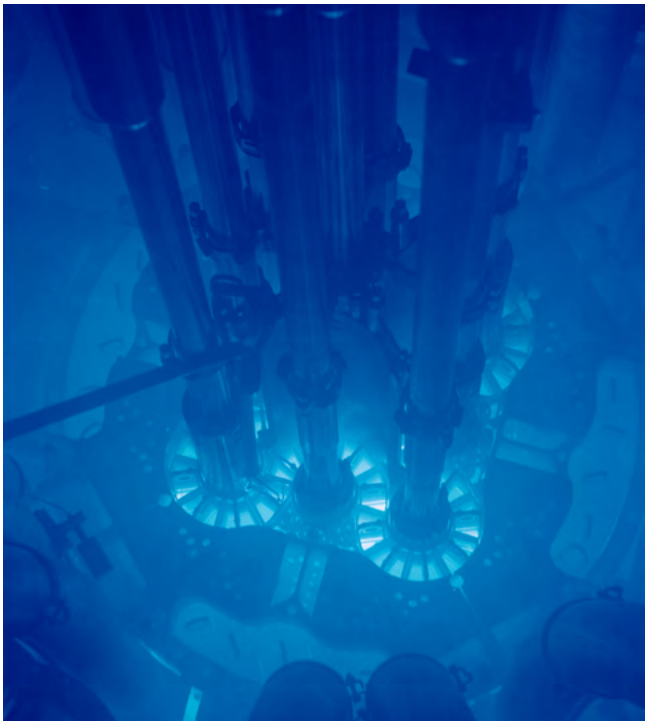
6. Opportunities

Few opportunities for U.S.-Japan, U.S.–South Korea, or trilateral cooperation in researching, developing, and ultimately deploying new energy technologies will be simple to pursue or without costs and limitations. Moreover, not everyone sees potential opportunities the same way—a consideration that is especially important for this study, which relies heavily on interviews with policymakers and experts. With this in mind, this section presents a broad overview of potential opportunities in various energy technology sectors as well as in cross-cutting and functional areas.

Advanced nuclear technology

In the United States, as in Japan and South Korea, traditional large-scale nuclear power plants have little political support. However, both Republicans and Democrats have increasingly backed pursuing smaller advanced designs, which many see as essential to sustaining U.S. technical leadership as well as to rebuilding a position in the global nuclear marketplace that will provide Washington with greater influence over international nonproliferation standards. Others see U.S. leadership on nonproliferation as more important, even if it comes at the expense of America's market position.

Some new reactors have already won Nuclear Regulatory Commission design approval, such as NuScale's small modular reactor, an advanced and scaled-down version of existing pressurized water reactors.[122] Others, like Oklo's passive fast micro-reactor, use different technologies that have not advanced equally far through U.S. regulatory processes but have made important progress toward demonstration.[123] Many of these technologies are inherently much safer than traditional nuclear power plants and also help to address waste and cost concerns.



Credit: Idaho National Laboratory/U.S. Nuclear Regulatory Commission

The Advanced Test Reactor at Idaho National Laboratory, pictured above, dates from 1967. Idaho National Laboratory is leading the U.S. effort to build a Versatile Test Reactor, which will play a critical role in testing advanced nuclear fuels and materials. Japan and South Korea have each expressed interest in the project. DOE states that the Versatile Test Reactor could be completed as early as 2026.

Notwithstanding their domestic political debates surrounding nuclear energy, both Japan and South Korea have expressed interest in cooperating with the United States on advanced nuclear technologies, including through the Versatile Test Reactor, a new research reactor under development by the Department of Energy.[124] In addition, interviewees in both nations hold on to the possibility that their nuclear policies could change

in the future. One U.S. interviewee argued that advanced nuclear reactors could help with this, as they address many safety and waste concerns.

Despite security-related concerns, forward-looking engagement on advanced nuclear designs—including the regulatory standards that will shape their deployment—seems promising. Some Japanese interviewees also stressed the utility of dialogue surrounding the longer-term role of nuclear power in low-carbon energy systems, with higher penetration of variable renewable energy (requiring balancing electricity generation) as well as new demand for clean industrial process heat, energy for hydrogen production, and resilience and security. In South Korea, interviewees pointed out that greater cooperation with the United States could be politically significant in sustaining capabilities that could otherwise erode rapidly.

Carbon capture, utilization, and storage

Without regard to U.S., Japanese, or South Korean domestic policies surrounding fossil fuels—all of which seem likely to evolve more slowly than many might hope or expect—China, India, and others will probably continue generating large shares of their considerable electricity needs with coal for quite some time,[125] and China will continue to build large numbers of coal plants outside its borders. CCUS technologies will be a necessity in reducing greenhouse gas emissions, and given intensifying global competition, the United States has much to gain from leading in the development and deployment of CCUS technologies in partnership with its allies.

The United States and Japan have participated in government-run joint research projects on CCUS, and U.S. and Japanese companies have already successfully worked together to build and demonstrate a commercial carbon capture facility, at NRG's Petra Nova coal plant.[126] Moreover, Japan is developing its own carbon capture and storage demonstration project in Tomakomai, in its northernmost prefecture, Hokkaido.[127]

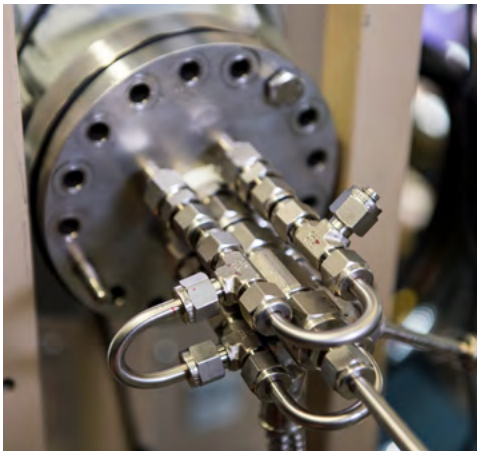
U.S. interviewees noted that South Korea's current government is considerably less interested in cooperating with the United States on CCUS technology than its predecessor, and it has largely stalled such interaction in recent years. South Korean interviewees pointed out that public and political concerns surrounding a perceived link between underground CO_2 storage and earthquakes has slowed CCS demonstration efforts in the country. (Japanese and other South Korean interviewees reported that unlike the United States, neither country's geography is well-suited to storing CO_2 underground.) That said, several of South Korea's major power companies have visited Petra Nova,[128] and KEPCO is currently testing carbon capture and storage technology.[129]

Hydrogen and Fuel Cells

Both Japan and South Korea have put hydrogen at the center of plans for their future low-carbon energy systems. In addition, the Department of Energy maintains a substantial program of hydrogen-oriented research, and U.S., Japanese, and South Korean firms are working together[130] and even advocating together, as in the U.S.-based Fuel Cell & Hydrogen Energy Association, an industry group.[131] Japanese and South Korean interviewees each noted that America's extensive natural gas resources could become an important source of hydrogen for their economies; some saw this as contributing to their energy security (because the United States would be a reliable supplier), while others did not see energy security gains (since this would merely replace one form of imported energy with another).[132] Making this a reality requires affordable and clean processes to produce hydrogen from natural gas.

Industry interviewees estimate that a large-scale commercial role for hydrogen in the power sector is at least 10 to 15 years away—a time frame that could ease research cooperation by removing commercial pressures in the near to medium term.[133] While one Japanese interviewee described Tokyo's enthusiasm about hydrogen power as "a bubble" that might burst, an American interviewee saw Japan's hydrogen research laboratories as "the best in the world" and thus as a powerful justification for cooperative work. In addition to research, wider discussions to harmonize standards are underway.

Most fuel cells rely on hydrogen, though others use different chemical processes. Regardless, fuel cell technologies (which use chemical reactions to produce electricity directly) and hydrogen combustion technologies (which burn hydrogen to produce steam that spins turbines to generate electricity or to drive an engine that moves a vehicle) are at different stages and will accordingly require different collaborative approaches.



Credit: Pacific Northwest National Laboratory

Developing components suitable for transporting and burning hydrogen is key challenge for utility-scale hydrogen power systems. Pacific Northwest National Laboratory uses the MTI Hydrogen Furnace to test how hydrogen affects various materials.

Batteries, critical minerals, and recycling

Batteries could be another priority area for cooperation, both for grid-level storage—especially as variable renewable electricity generation grows—and in electric vehicles. America's national security community is increasingly preoccupied by China's expanding position in international markets; this anxiety could and should motivate steps to compete more effectively, including in partnership with high-tech allies like Japan and South Korea. Since batteries are already a commercial technology, joint research would prioritize new approaches to developing more powerful, efficient, and compact systems. One interviewee reported that the U.S. and Japanese governments have already been negotiating on battery technology; other work suggests that the U.S. and South Korean private sectors are well-positioned to develop energy storage technologies.[134]

Battery manufacturing separately highlights risks to rare earth mineral supply chains, though rare earths and other critical minerals are also key components in many other high-tech and clean energy products. Access to critical minerals has been a concern in Washington, Tokyo, and Seoul in the wake of China's limits on rare earth exports to Japan following a 2010 maritime dispute[135] and recent suggestions that Beijing could curtail such exports to America in the context of escalating trade and technology disputes.[136]

In the United States, anxiety surrounding critical mineral supply chains prompted the Trump administration to launch programs like its Energy Resource Governance Initiative, a multilateral project to link critical mineral producers and consumers, improve mining and management practices, and strengthen supply chains.[137] One Japanese interviewee pressed for a broader global framework to protect critical mineral supplies from political disruption, especially in view of likely increases in demand for these minerals. Technologies to recycle batteries or other systems or components that utilize critical minerals could also be a valuable area for greater collaborative work.

Solar and wind power

While Japan and South Korea have each emphasized solar and wind power as important components of their strategies to reduce power sector greenhouse gas emissions, Japanese and South Korean interviewees pointed out that their respective countries have only moderate to poor solar and wind resources. One Japanese interviewee noted that solar power's land use requirements pose difficulties in Japan, where land is scarce. Another pointed out that the Japan's mountainous terrain slows wind speeds.

Indeed, solar irradiance and wind speed maps suggest solar and wind resources comparable to the least desirable regions of the United States—the Pacific Northwest and the Northeast.[138] The sole exceptions are offshore wind, where wind speeds surrounding Japan are comparable to those in America's Plains and speeds surrounding South Korea are similar to (somewhat lower) levels in the U.S. Midwest. However, as one American interviewee pointed out, neither Japan nor South Korea has an extensive continental shelf; the lack of continental shelf requires expensive floating wind turbines. A South Korean interviewee said that officials are weighing offshore wind turbines west of the Korean Peninsula, in the Yellow Sea.

Limited solar and wind resources in Japan and South Korea contribute to high prices, which in turn slows development, though one Japanese interviewee complained that Tokyo's policies had also made solar power more expensive than it might be otherwise. Still, joint research and development to improve the efficiency of solar and wind power generation could help over time to reduce prices—and subsidies—and thus assist both governments in reaching their solar and wind generation targets. Researchers at the U.S. National Renewable Energy Laboratory have developed an experimental solar cell with record-setting efficiency, approaching 50%.[139] NREL conducted a five-year collaborative project with India, the Solar Energy Research Institute for India and the United States, from 2012 to 2017;[140] solar research could provide a useful vehicle for America, Japan, and South Korea to engage together with India.

Moving beyond energy production and storage technologies, other technologies and programs are important in supporting and managing energy systems, establishing and building markets for new clean technologies, and sustaining deep engagement in energy technology R&D. U.S., Japanese, and South Korean interviewees highlighted the following as useful areas for further cooperative work:

Smart cities, grid security, artificial intelligence, and data science

Japanese organizations and companies have already worked on smart city projects in the United States; Japan's New Energy and Industrial Technology Development Organization (NEDO) completed a smart grid demonstration project in New Mexico in 2015.[141] NTT is currently working with the state of Nevada and the city of Las Vegas to demonstrate its Smart City technologies.[142]

Integrating energy systems in a manner that allows for more efficient management of supply and demand, provides robust protection from cyberattacks, and also contributes to resilience following attacks or natural disasters is a high priority for the United States, Japan, and South Korea. South Korea's government has perhaps established the most ambitious goals, in defining a Digital New Deal as a foundation of its policy. As Japanese interviewees observed, Japan's government and firms increasingly see these management systems as an area of potential comparative advantage in competing with China's large-scale manufacturing and construction enterprises, especially in Southeast Asia.

Several Japanese interviewees saw computing as a fruitful area for joint R&D, though one argued that U.S. capabilities in the narrow field of quantum computing are sufficiently advanced relative to Japan's (and South Korea's) as to make collaboration difficult. Engagement surrounding the intersection between energy technologies, on one hand, and information and communication technologies, on the other, also provides a natural context in which to discuss perceived threats and risks and—to the extent possible—to harmonize policies, safeguards, and standards to address them. This engagement could in turn facilitate deeper cooperation in developing and deploying these technologies.

Global development projects

The United States and Japan have each focused on competing with China's Belt and Road Initiative development projects as well as Beijing's related Global Energy Interconnection initiative.[143] The U.S. Asia EDGE initiative reflects this effort, as does similar work within the broader development and commercial portfolios of the Japan International Cooperation Agency and the Japan Bank for International Cooperation, broadly analogous to the U.S. Agency for International Development and the U.S. Development Finance Corporation, respectively. The Korea International Cooperation Agency and the Export-Import Bank of Korea pursue comparable missions. Though its focus is on developing regional electricity markets rather than building infrastructure, the Japan-U.S. Mekong Power Partnership suggests some of the ways in which Washington and its allies can work together.[144]

A number of interviewees pointed out the challenges in competing with China's state financing and the low up-front cost of Chinese development projects. However, as a Japanese interviewee observed, China's requirements to use Chinese labor and to apply its financing toward Chinese firms and products also provide opportunities for the United States, Japan, and South Korea. Nevertheless, this interviewee added, grant-based U.S. assistance programs do not link easily to Japan's (and South Korea's) system of concessionary loans. The Japan-U.S. Strategic Energy Partnership and the U.S.-ROK Energy Security Dialogue are useful formats to pursue further policy coordination on development and development finance.

Cooperative financing arrangements could also have value beyond development work and merit further discussion in that broader context.[145] Anticipated slowdowns in China's overseas development projects in the post-COVID-19 global economic environment[146] may offer a window of opportunity to coordinate more closely among the three governments and other allies.

Research integrity

As U.S. government scrutiny of academic collaboration with China grows, and U.S. universities implement new policies responsive to official concerns, the gap between U.S., Japanese, and South Korean perspectives could pose new complications for institutionalized cooperation among U.S., Japanese, and South Korean universities and between universities and U.S. national laboratories. Addressing these issues proactively, through a trilateral public-private (track 1.5) dialogue on research integrity could help to avoid or manage such difficulties, while also providing a forum for governments, universities, and other stakeholders to share perspectives and more closely align their policy approaches where feasible.

Intellectual property

Many interviewees remarked that the United States and Japan have developed a broad and deep technological partnership that generally manages intellectual property issues well, and noted that Japan and the United States are highly regarded for their intellectual property protections. Still, intellectual property issues appear to remain an obstacle in U.S.–South Korea collaboration on energy technology R&D. Sustained, direct, and result-oriented dialogue surrounding intellectual property could help to advance U.S.–South Korea discussions across multiple technology areas, especially in nuclear technology, where the issue appears to have been most difficult. Like discussion of research integrity, such a dialogue would ideally occur in a public-private format that includes universities, businesses, and other stakeholders.

Credit: Wikiemirati

The South Korean utility KEPCO's contract to build the Barakah Nuclear Energy Plant, shown under construction in 2017, has been a source of tension between Washington and Seoul over U.S. intellectual property concerns.

7. Conclusions

The United States, Japan, and South Korea share important common interests in successfully managing U.S.-China competition, navigating a global energy transition, and addressing climate change. They likewise share important strengths, including their democratic values, free and innovation-based economies, and advanced industrial capabilities. To the extent that each has weaknesses, which all do, these can often be offset by another country's strength; the United States, for example, is providing growing LNG supplies to its two allies, and Japan and South Korea might aid America in some areas of research and manufacturing.

Greater collaboration in research, development, demonstration, and deployment of clean energy technologies—and related opportunities in systems architecture, computing, standards, and development cooperation—can usefully advance mutual interests in many important areas. This progress could provide a foundation for wider multilateral efforts, derive from wider partnerships, or advance in narrower bilateral formats. Trilateral U.S.-Japan–South Korea cooperation may be especially valuable on some issues, despite political obstacles.

As a longer-term proposition, U.S. international leadership rests heavily on America's ability to continue developing innovative technologies—especially energy technologies, which quite literally power everything else in the U.S. economy. China is poised to become a formidable competitor in this respect, with an economy that is comparable in scale and a large, dynamic, and increasingly well-educated population. While all three countries, including the United States, should and will continue to cooperate with China, deeper engagement with U.S. allies in energy technology (and other areas) can contribute importantly to America's national interests. As leaders in a strategic region, Japan and South Korea can be valuable partners.

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Acknowledgements

I am deeply grateful the the Japan Foundation Center for Global Partnership and to the Korea Foundation for their grants to Energy Innovation Reform Project, which made this work possible, and to the roughly two-dozen U.S., Japanese and South Korean officials and experts who spoke to me in off-the-record interviews.

In addition, I would like to thank EIRP research interns Joshua Fischbach, Amelia Gilchrist, Eden Kinlock, Lianne Pinto, and Miles Yun for their invaluable help in exploring U.S.-Japan and U.S.-South Korea energy relations and technology cooperation—each contributed importantly. Finally, I am indebted to Anne Himmelfarb for her exacting editing and to Gabriella Turrisi for her attractive and readable design.

As the author, I am solely responsible for the contents, including any errors or omissions.

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