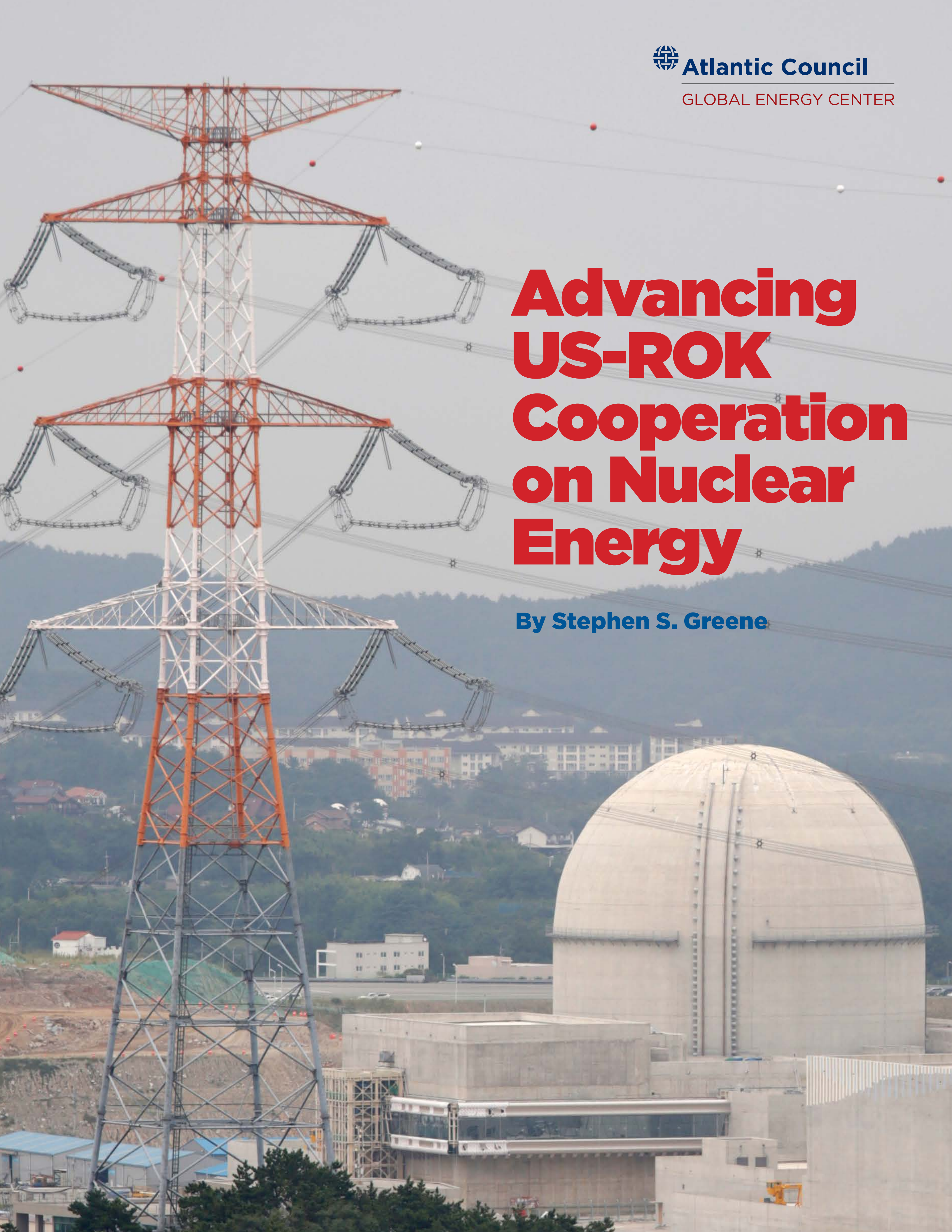
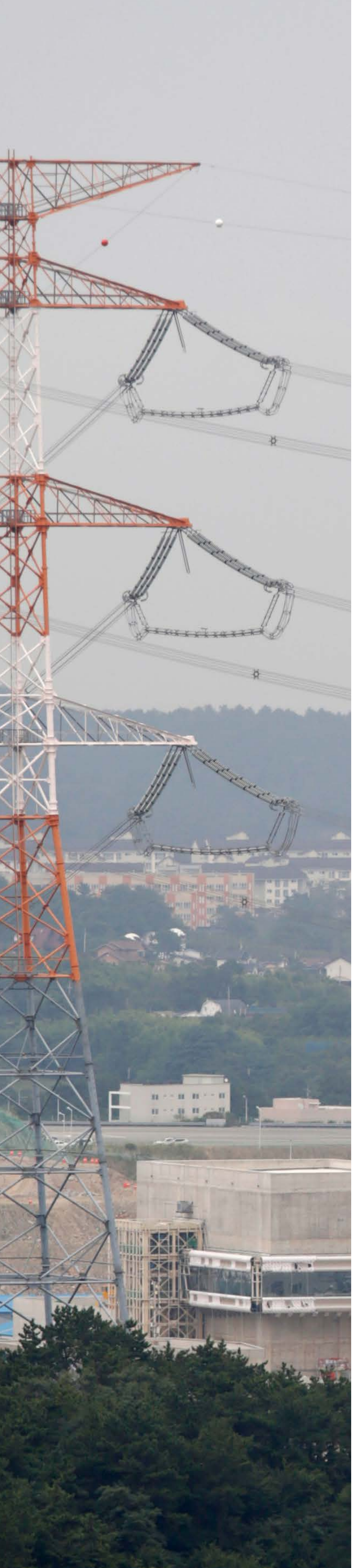
Atlantic Council
GLOBAL ENERGY CENTER

Advancing US-ROK Cooperation on Nuclear Energy

By Stephen S. Greene





Atlantic Council
GLOBAL ENERGY CENTER

The Global Energy Center promotes energy security by working alongside government, industry, civil society, and public stakeholders to devise pragmatic solutions to the geopolitical, sustainability, and economic challenges of the changing global energy landscape.

Cover: The Shin Kori Number 4 reactor of state-run utility Korea Electric Power Corporation (KEPCO) is seen in Ulsan, South Korea. Picture taken September 3, 2013. REUTERS/Lee Jae-Won

This report is written and published in accordance with the Atlantic Council Policy on Intellectual Independence. The authors are solely responsible for its analysis and recommendations. The Atlantic Council and its donors do not determine, nor do they necessarily endorse or advocate for, any of this report's conclusions.

Atlantic Council
1030 15th Street NW, 12th Floor
Washington, DC 20005

For more information, please visit
www.AtlanticCouncil.org.

ISBN-13: 978-1-61977-152-9
March 2021

This report was designed by Donald Partyka.

This work was supported by the Korea Atomic Energy Research Institute.

Atlantic Council
GLOBAL ENERGY CENTER

Advancing US-ROK Cooperation on Nuclear Energy

By Stephen S. Greene

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The United States and the Republic of Korea (ROK) are longstanding civil nuclear partners, with the potential to intensify their collaboration, especially as global markets for nuclear energy expand. However, both the US and South Korean domestic nuclear industries are facing challenges that are unique to each country. In the US, an ageing reactor fleet is struggling to remain online in the face of the rapid growth of renewable generating capacity and historically low natural gas prices. Although nuclear power provided 30 percent of South Korea's nuclear power in 2016, South Korean President Moon Jae-in took office in 2017 having run a campaign that emphasized planned reductions in the role of nuclear energy.

However, there is reason to anticipate revitalization in each country's respective nuclear industry, which will only be strengthened by increased bilateral cooperation. The US government has taken a renewed interest in nuclear innovation, which has been expressed in bipartisan legislation that provides funding for demonstrating advanced reactors and streamlines the regulatory process. The US has also taken steps to shore up its civil nuclear export program through reauthorizing the US Export-Import (Ex-Im) Bank and lifting the US International Development Finance Corporation (DFC) ban on nuclear project finance. At the same time, the ROK-led consortium that is building the Barakah project in the United Arab Emirates (UAE) successfully brought the first of four reactors online in 2020, which will likely be a selling point for future international projects.

To overcome their challenges and capitalize on their successes, the US and ROK should seek opportunities for collaboration in the following areas: bilateral trade in which US suppliers provide components and services to projects in South Korea, and ROK firms supply components to the United States; a key subset of bilateral trade supporting the demonstration and deployment of advanced nuclear technology; cooperation in research and development to jointly pursue goals in new nuclear technologies; and collaboration in third countries, in which US and South Korean entities work together to deliver projects that deliver improved value to the host country through collaboration and bring meaningful value to suppliers in both countries. To make collaboration along these lines more effective, both countries should consider the following policy recommendations:

- Commercial and government entities in the US and ROK should identify opportunities for joint participation in third-country projects, especially with an eye toward advanced reactor projects.
- Both countries should invest in export financing so that they can secure the long-term geopolitical relationships that accompany the sale of nuclear energy technologies.
- The US and ROK governments should pursue cooperation on civil nuclear research, including the potential for cost-sharing on the US Versatile Test Reactor (VTR).
- The nuclear energy industries in both countries should increase commercial cooperation on advanced reactors in order to strengthen the supply chain for initial deployment.
- ROK nuclear firms should restore opportunities for US firms to participate in the ROK's domestic nuclear energy infrastructure.

INTRODUCTION: US-ROK CIVIL NUCLEAR COOPERATION

Cooperation between the United States and the ROK on civil nuclear energy began in the earliest years of nuclear power generation. The United States and South Korea first signed a Nuclear Cooperation Agreement on the Non-Military Uses of Nuclear Energy in 1956, and the first nuclear power plant in the ROK, Kori 1, was a Westinghouse unit that began operating in 1978.[1]

Today, that history of cooperation takes on even more importance. With nations around the world increasing their demands for energy, and the world focused on the challenge of decarbonization, global interest in nuclear power is expanding in many countries, even as the nuclear industry faces challenges in some geographies where it has historically been strong. For example, nuclear generation plays a key role in the International Energy Agency (IEA) 2020 scenarios that achieve carbon emission objectives; in the case of achieving net-zero emissions by 2050, primary energy demand from nuclear power increases by 35 percent.[2]

Furthermore, the relationships that the United States and South Korea will build around the world in the context of civil nuclear power extend into the realm of geopolitics, and can be very long lasting, since the export of nuclear technology is the start of a century-long relationship that includes security and nonproliferation, training, regulatory support, and ongoing services and supplies.[3] Russia and China are also pursuing these openings, using the tools of state-owned, vertically integrated enterprises, but without US discipline on nonproliferation and safety.[4] Therefore, it is all the more important that the United States and South Korea work together on international civil nuclear matters, both to counter the influence of Russia and China and to overcome the challenges that the United States and South Korea both face in their domestic nuclear industries.

1 Jeffrey C. Crater and George David Banks, "The U.S.-Republic of Korea Nuclear Relationship—an Indispensable Alliance," American Council for Capital Formation, December 2016, http://accf.org/wp-content/uploads/2017/04/ACCF-U.S.-ROK-Report-FINAL.pdf; "Nuclear Power in South Korea," World Nuclear Association, last updated November 2020, https://world-nuclear.org/information-library/country-profiles/countries-o-s/south-korea.aspx.

2 "World Energy Outlook 2020," International Energy Agency, October 2020, https://www.iea.org/reports/world-energy-outlook-2020.

3 "Leading on SMRs," Nuclear Innovation Alliance, October 2017, https://www.nuclearinnovationalliance.org/leading-smrs/.

4 *Restoring America's Competitive Nuclear Energy Advantage: A Strategy to Assure U.S. National Security*, US Department of Energy, https://www.energy.gov/sites/prod/files/2020/04/f74/Restoring%20America%27s%20Competitive%20Nuclear%20Advantage_1.pdf.

STATE OF THE NUCLEAR INDUSTRY IN THE UNITED STATES

Despite a renewed focus on decarbonizing the electricity sector, US nuclear power—which in 2019 provided 20 percent of US electric generation and 55 percent of its carbon-free electric generation—is in decline.[5] Since 2013, more than 8,400 megawatts (MW) of nuclear generation have retired prematurely, and another 8,300 MW are projected to close by 2025, according to public announcements. A further 13,800 MW of potential closures were avoided through state policy actions.[6] Construction of new generation, which seemed promising prior to the Fukushima Daiichi nuclear accident, has fizzled. Two new reactors at the Vogtle nuclear power plant in Georgia are being completed, but they are many years delayed, and will cost almost twice the initial estimate.[7] The abandoned construction of two new reactors at the VC Summer plant in South Carolina led to the demise of SCANA Corp, the former parent of South Carolina Electric & Gas Company.[8]

US nuclear power is being pressed by several factors that are particular to US electric markets, including the rapid growth of natural gas and renewable generating capacity, historically low natural gas prices driven by shale gas production, and the specific structures of energy markets governed by independent system operators (ISOs). US natural gas prices for electric generation averaged $2.50 per thousand cubic feet in the twelve months through July 2020, resulting in an equivalent fuel cost component for modern natural gas combined cycle generation of less than $17 per megawatt hour.[9] Furthermore, because fuel represents more than 80 percent of the operating cost of generation from gas-fired units, increased variable renewable generation has less of an impact on gas-fired generators than on nuclear generation.[10] In 2018, the Union of Concerned Scientists concluded that 35 percent of US nuclear power plants, representing 22 percent of US nuclear capacity, were "at risk for early closure or slated to retire."[11] Exelon Generation, which operates the largest US nuclear fleet, has said that it expects to retire two generating stations in Illinois in fall 2021, and that two more Illinois plants are at risk.[12]

US nuclear suppliers have been severely weakened, and the US industry has relied on multinational companies and investors for manufacturing and financial support. Westinghouse Electric Company, which had been constructing the Vogtle and VC Summer reactors, was forced into bankruptcy, was purchased by

5 "Net Generation, United States, All Sectors, Monthly," US Energy Information Administration, https://www.eia.gov/electricity/data/browser/.

6 "Closing Panel—Christopher Crane, Exelon," Federal Energy Regulatory Commission, September 25, 2020, https://www.ferc.gov/media/closing-panel-christopher-crane-exelon.

7 Sonal Patel, "How the Vogtle Nuclear Expansion's Costs Escalated," *Power*, September 24, 2018, https://www.powermag.com/how-the-vogtle-nuclear-expansions-costs-escalated/.

8 Alex Crees, "The Failed V.C. Summer Nuclear Project: A Timeline," Choose Energy, December 4, 2018, https://www.chooseenergy.com/news/article/failed-v-c-summer-nuclear-project-timeline/.

9 US Energy Information Administration data and author calculations; incorporates EIA's "benchmark" heat rate of 7,000 BTU/kWh.

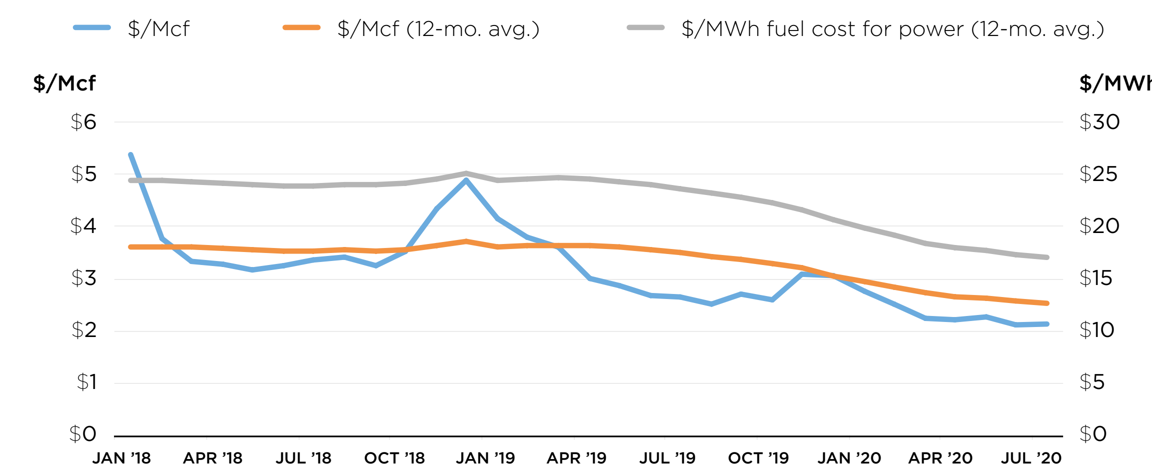
10 Zeke Hausfather, "Mapped: The US Nuclear Power Plants 'at Risk of Shutting Down,'" *CarbonBrief*, July 24, 2018, https://www.carbonbrief.org/mapped-the-us-nuclear-power-plants-at-risk-of-shutting-down.

11 "The Nuclear Power Dilemma: Declining Profits, Plant Closures, and the Threat of Rising Carbon Emissions," Union of Concerned Scientists, October 9, 2018, https://www.ucsusa.org/resources/nuclear-power-dilemma.

12 David Roeder, "In 'Power Play,' Exelon Vows to Close Byron and Dresden Nuclear Plants," *Chicago Sun-Times*, August 27, 2020, https://chicago.suntimes.com/business/2020/8/27/21403463/exelon-vows-close-byron-dresden-nuclear-plants; Aaron Larson, "Exelon Makes Plans to Retire Byron and Dresden Nuclear Plants in 2021," *Power*, August 27, 2020, https://www.powermag.com/exelon-makes-plans-to-retire-byron-and-dresden-nuclear-plants-in-2021/.

FIGURE 1

US Natural Gas and Marginal Fuel Cost for Power



SOURCE: US ENERGY INFORMATION ADMINISTRATION

NOTE: Natural gas price is the US average natural gas for electric generation (https://www.eia.gov/opendata/qb.php?sdid=NG.N3045US3.M). Fuel cost for power incorporates the "benchmark" heat rate of 7,000 British thermal units (BTU) per kilowatt hour (kWh) used in the US Energy Information Administration (EIA) daily price reporting (see https://www.eia.gov/todayinenergy/prices.php).

Brookfield Business Partners in 2018, and is primarily focused on providing services.[13] The United States has lost its ability to forge the pressure vessels for large light water reactors (LWRs); Doosan Heavy Industries and Construction (Doosan) fabricated the pressure vessels and steam generators for the Westinghouse AP1000 reactors at the Vogtle units in Georgia.[14] General Electric (GE) reorganized its nuclear business into an alliance with Hitachi, now GE Hitachi Nuclear Energy (GE Hitachi or GEH).[15] The United States once provided the entire world outside the former Soviet Union and its allies with nuclear fuel, but no longer has any enrichment production using US technology. The only enrichment production located in the United States is UUSA, a subsidiary of Urenco, which is owned by European governments and government-supported entities and uses European technology.[16]

The decline of the US nuclear industry has consequences for national security.[17] Reductions in manufacturing and service work for civilian nuclear power place a greater burden on the military to maintain support for businesses with capabilities and qualifications that meet nuclear standards. It is more difficult to attract military personnel to work in nuclear fields if there are fewer civilian nuclear jobs, or if those jobs are less attractive because of a poor outlook for

13 "Brookfield Business Partners Completes Acquisition of Westinghouse Electric Company," Brookfield, press release, August 1, 2018, https://bbu.brookfield.com/en/press-releases/2018/08-01-2018-211711827; "Our Vision and Values," Westinghouse, https://www.westinghousenuclear.com/about/vision-and-values.

14 Matt Bowen, *Strengthening Nuclear Energy Cooperation between the United States and Its Allies*, Columbia School of International and Public Affairs, July 28, 2020, https://www.energypolicy.columbia.edu/research/report/strengthening-nuclear-energy-cooperation-between-united-states-and-its-allies.

15 "About Us," GE Hitachi, https://nuclear.gepower.com/company-info/about-ge-hitachi.

16 "UUSA: The National Enrichment Facility," Urenco, https://www.urenco.com/global-operations/uusa.

17 Atlantic Council Task Force on US Nuclear Energy Leadership, *US Nuclear Energy Leadership: Innovation and the Strategic Global Challenge*, Atlantic Council, May 20, 2019, https://www.atlanticcouncil.org/in-depth-research-reports/report/us-nuclear-energy-leadership-innovation-and-the-strategic-global-challenge-2/.

the industry.[18] Nuclear exports enable US leadership worldwide in nuclear safety and nonproliferation.[19]

In contrast to the specter of retirements and the poor near-term outlook for new nuclear power plants, operations at existing power plants have been stellar. Improvements in refueling and other aspects of operations have increased capacity factors (the percentage of output available throughout the year) from 70 percent in the early 1990s to an average of more than 93 percent in 2019, which translates proportionally into increased generation output.[20] In addition, the industry has been able to achieve power uprates at existing plants of more than 2,000 MW since 2010 and almost 4,000 MW since 2001.[21]

Furthermore, there is increasing optimism around the prospects for several advanced nuclear power technologies being developed throughout the United States. Recently, many innovative technology startups, as well as established nuclear leaders, have begun to pursue approaches to nuclear power that are very different from the current generation of gigawatt-sized reactors, with their attendant long construction times and significant risk of cost overruns. These technologies use a variety of technical approaches, but all focus on modular construction, factory fabrication, shorter construction times, and passive safety.[22] As of October 2019, there were more than seventy projects to develop advanced nuclear technologies being pursued in the United States and Canada.[23]

Two developers have begun the process of obtaining license approvals from the US Nuclear Regulatory Commission (NRC). NuScale Power is working with Utah Associated Municipal Power Systems (UAMPS) to construct a modular 720-MW project on a Department of Energy (DOE) site in Idaho.[24] The DOE recently approved a cost-share award of up to $1.4 billion to support the construction of this project.[25] NuScale received its Final Safety Evaluation Report from the NRC in August 2020, clearing the way for UAMPS to pursue a construction and operating license.[26] Oklo Power is seeking to build a 1.5-MW micro nuclear reactor at an Idaho National Laboratory site; in June 2020, the NRC accepted its application for a combined license review.[27]

The US government has recently taken several steps to support advanced reactor development. The Nuclear Energy Innovation Capabilities Act of 2017 (NEICA) and the Nuclear Energy Innovation and Modernization Act (NEIMA) received bipartisan support and became law in 2018 and 2019, respectively, providing research support for, and reinforcing regulatory changes to facilitate, advanced nuclear development.[28] The Nuclear Energy Leadership Act (NELA) was proposed, and passed by the Senate, as an amendment to the National Defense Authorization Act for Fiscal

18 Robert F. Ichord, Jr., and Bart Oosterveld, *The Value of the US Nuclear Power Complex to National Security,* Atlantic Council, October 2019, https://www.atlanticcouncil.org/wp-content/uploads/2019/10/Nuclear-Power-Value-IB-final-web-version.pdf.

19 Jane Nakano, "The Changing Geopolitics of Nuclear Energy: A Look at the United States, Russia, and China," Center for Strategic and International Studies, March 12, 2020, https://www.csis.org/analysis/changing-geopolitics-nuclear-energy-look-united-states-russia-and-china.

20 "U.S. Nuclear Industry Capacity Factors," Nuclear Energy Industry, https://www.nei.org/resources/statistics/us-nuclear-industry-capacity-factors.

21 "U.S. Nuclear Industry Yearly Power Updates and Capacity Additions," Nuclear Energy Industry, https://www.nei.org/resources/statistics/us-industry-yearly-uprates-and-capacity-additions.

22 See, e.g., "Advanced Nuclear Energy: Need, Characteristics, Projected Costs, and Opportunities," Clean Air Task Force, April 2018, https://www.catf.us/wp-content/uploads/2018/04/Advanced_Nuclear_Energy.pdf.

23 John Milko, Jackie Kempfer, and Todd Allen, "2019 Advanced Nuclear Map," Third Way, October 17, 2019, https://www.thirdway.org/graphic/2019-advanced-nuclear-map.

24 "UAMPS Carbon Free Power Project," Fluor, https://www.fluor.com/projects/carbon-free-power. UAMPS is a joint-action governmental agency that provides energy services to forty-six community-owned power-system members located throughout the intermountain western states.

25 Larry Pearl, "DOE Approves Up to $1.4B to Test 12-Module NuScale Reactor," *Utility Dive,* October 19, 2020, https://www.utilitydive.com/news/doe-approves-up-to-14b-to-test-12-module-nuscale-reactor/587265/.

26 "NuScale Power Makes History as the First Ever Small Modular Reactor to Receive U.S. Nuclear Regulatory Commission Design Approval," NuScale, press release, August 28, 2020, https://newsroom.nuscalepower.com/press-releases/news-details/2020/NuScale-Power-Makes-History-as-the-First-Ever-Small-Modular-Reactor-to-Receive-U.S.-Nuclear-Regulatory-Commission-Design-Approval/default.aspx.

27 Sonal Patel, "NRC Accepts Crucial Advanced Nuclear Applications from Centrus, Oklo," *Power*, June 25, 2020, https://www.powermag.com/nrc-accepts-crucial-advanced-nuclear-applications-from-centrus-oklo/.

28 Nuclear Energy Innovation Capabilities Act of 2017, S.97 (2017), https://www.congress.gov/bill/115th-congress/senate-bill/97; Nuclear Energy Innovation and Modernization Act, S.512 (2017), https://www.congress.gov/bill/115th-congress/senate-bill/512.

Year 2021, and it provided the basis for the portions of the Energy Act of 2020 that address advanced nuclear energy.[29] It would facilitate funding for advanced nuclear development and enable the federal government to purchase power from advanced nuclear projects.[30] The Nuclear Energy Research and Development Act (NERDA) has been introduced in the House. Moving forward on this legislation potentially enables President Biden to obtain bipartisan support for an element of his climate agenda. The proposed American Nuclear Infrastructure Act of 2020 (ANIA) would support advanced nuclear development and, in particular, remove restrictions on foreign funding for nuclear investments.[31]

Congress has funded advanced reactor demonstrations, appropriating $230 million in the fiscal year (FY) 2020 budget.[32] With this funding, DOE is embarking on an Advanced Reactor Demonstration Program with the intent of demonstrating two reactors so that they can be operational within the next five to seven years. Under this program, the DOE has awarded $80 million each to TerraPower and X-energy to build demonstration plants.[33] In addition, the Department of Defense has contracted with three teams to begin design work on mobile nuclear reactor prototypes to support defense logistics, with the expectation that at least one will be built out.[34]

In addition, Congress and the administration have strengthened support for US exports of nuclear goods and services. In 2019, with bipartisan support, Congress reauthorized the US Ex-Im for an additional seven years, representing the longest reauthorization in the agency's history.[35] Additionally, in 2020, the US DFC changed its Environmental and Social Policy and Procedures (ESPP) to enable the support of nuclear power projects.[36] This change was one of the key recommendations of the United States Nuclear Fuel Working Group established in 2019.[37]

The 2020 US elections could introduce changes in objectives, policies, and implementation that could hamper or reverse some of the support that nuclear power has recently received. However, the recognition that nuclear power is likely to be needed as a component of the effort to decarbonize energy supply, in the United States and worldwide, makes that less likely.[38]

IMPLICATIONS OF THE US ELECTION

President Biden's energy plan commits to a carbon-pollution-free power sector by 2035.[39] To achieve that, the plan recognizes the need to continue to leverage the carbon-free energy provided by existing nuclear power plants. His energy and climate plans both acknowledge the need for innovation to address the challenge of climate change and,

29 "Advanced Reactors in the Energy Act of 2020 and the New Administration," Nuclear Innovation Alliance, January 2021, https://nuclearinnovationalliance.org/advanced-reactors-energy-act-2020-and-new-administration.

30 A portion of NELA was passed by the Senate as an amendment to the National Defense Authorization Act for Fiscal Year 2021 (NDAA, S 4049); see "US Senate Passes Nuclear Energy Leadership Act," *World Nuclear News,* July 27, 2020, https://www.world-nuclear-news.org/Articles/US-Senate-passes-Nuclear-Energy-Leadership-Act; Jackie Kempfer, "Raising the Next Generation of Nuclear: A Road Map for Deployment," Third Way, October 17, 2019, https://www.thirdway.org/memo/raising-the-next-generation-of-nuclear-a-road-map-for-deployment.

31 "Barrasso Releases Draft Legislation to Revitalize America's Nuclear Infrastructure," US Senate Committee on Environment and Public Works," press release, July 29, 2020, https://www.epw.senate.gov/public/index.cfm/2020/7/barrasso-releases-draft-legislation-to-revitalize-america-s-nuclear-infrastructure.

32 "U.S. Department of Energy Launches $230 Million Advanced Reactor Demonstration Program," US Department of Energy Office of Nuclear Energy, press release, May 14, 2020, https://www.energy.gov/ne/articles/us-department-energy-launches-230-million-advanced-reactor-demonstration-program.

33 "US DOE Selects Advanced Reactor Designs for Demonstration Plants," *World Nuclear News,* October 14, 2020, https://www.world-nuclear-news.org/Articles/US-DOE-selects-advanced-reactor-designs-for-demons.

34 "DOD Awards Contracts for Development of a Mobile Microreactor," US Department of Defense, March 9, 2020, https://www.defense.gov/Newsroom/Releases/Release/Article/2105863/dod-awards-contracts-for-development-of-a-mobile-microreactor/source/GovDelivery/.

35 "President Donald J. Trump Signs Historic Seven-Year Long-Term Reauthorization of EXIM," Export-Import Bank of the United States, press release, December 20, 2019, https://www.exim.gov/news/president-donald-j-trump-signs-historic-seven-year-long-term-reauthorization-exim-0.

36 "DFC Modernizes Nuclear Energy Policy," US Internal Development Finance Corporation, July 23, 2020, https://www.dfc.gov/media/press-releases/dfc-modernizes-nuclear-energy-policy.

37 *Restoring America's Competitive Nuclear Energy Advantage.*

38 Josh Siegel, "Biden Pledges to Eliminate Carbon from Power Plants by 2035 as Part of $2 Trillion Clean Energy Plan," July 14, 2020, https://www.washingtonexaminer.com/policy/energy/biden-pledges-to-eliminate-carbon-from-power-plants-by-2035-as-part-of-2-trillion-clean-energy-plan.

39 Biden for President, "The Biden Plan to Build a Modern, Sustainable Infrastructure and an Equitable Clean Energy Future," accessed December 16, 2020, https://joebiden.com/clean-energy/.

in particular, to recognize the need to pursue the "future of nuclear energy" to achieve climate objectives, and the opportunity presented by advanced reactors.[40] It is relevant that while the Trump administration has made significant strides in support of advanced reactors, such as through the Advanced Reactor Demonstration Program, the Department of Energy's initial steps on this effort were begun during the Barack Obama administration, when Biden was vice president.[41]

Furthermore, Biden's climate plan recognizes the value of exporting clean energy technologies, for both his climate objectives and US economic growth. In addition to the bipartisan legislation on nuclear energy mentioned in the previous section, moving forward on more recent pieces of legislation—especially NERDA and ANIA—may enable Biden to obtain bipartisan support for an element of his climate agenda, especially if a Republican-controlled Senate limits his plans for broader climate legislation.

Biden also appears likely to seek international cooperation in pursuit of his objectives on energy and climate. His record and the foreign policy team he has announced both indicate that he will aim to achieve policy objectives through engagement with US allies. Additionally, his appointment of former Secretary of State John Kerry as his administration's special envoy for climate indicates that he views climate policy and diplomacy as inextricably linked. Such an approach is likely to enhance the opportunities for cooperation described in this paper.

US President Joe Biden listens as former US Secretary of State John Kerry, his special envoy for climate appointee, speaks as President Biden announces his national security nominees and appointees at his transition headquarters in Wilmington, Delaware, November 24, 2020. SOURCE: REUTERS/Joshua Roberts

40 Biden for President, "Climate: Joe Biden's Plan for a Clean Energy Revolution and Environmental Justice," accessed December 16, 2020, https://joebiden.com/climate/.

41 "Obama Administration Announces $450 Million to Design and Commercialize U.S. Small Modular Nuclear Reactors," US Department of Energy, press release, March 22, 2012, https://www.energy.gov/articles/obama-administration-announces-450-million-design-and-commercialize-us-small-modular.

STATE OF THE NUCLEAR INDUSTRY IN THE REPUBLIC OF KOREA

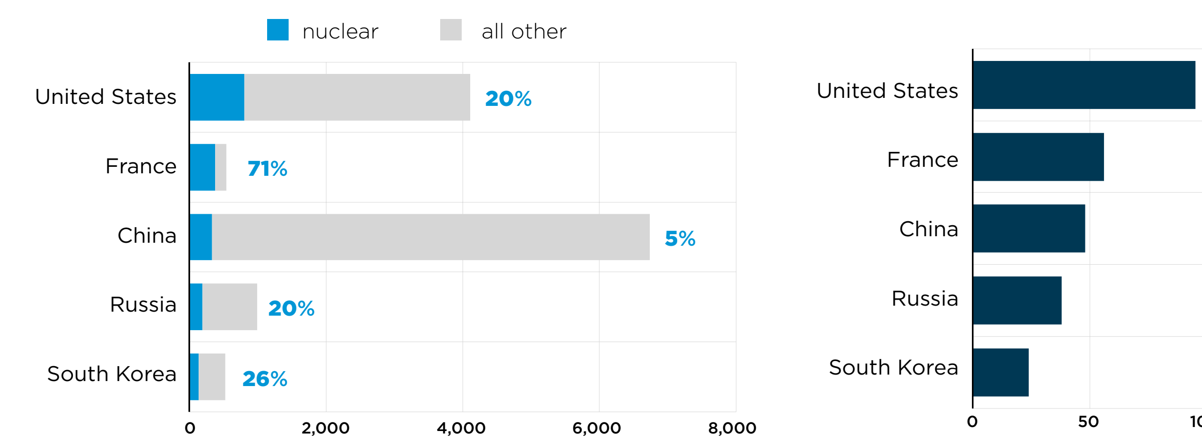
Nuclear power provided 30 percent of South Korea's electricity in 2016, and its nuclear-generating capacity has continued to grow.[42] South Korea was the world's eighth-largest energy consumer in 2017, and 87 percent of that consumption was powered by fossil fuels, almost entirely imported.[43] Given its dependence on imported energy, South Korea's substantial nuclear-generating sector is an important counterweight. Shin Kori 3 and 4, the first domestic units to use Korea Electric Power Corporation's (KEPCO) APR-1400 design, were added to the grid in 2016 and 2019.[44] By 2019, South Korea was the fifth-largest nuclear power generator in the world.[45]

However, the growth of nuclear generation, including the completion of the Shin Kori units, belies a fundamental change in the trajectory of nuclear power in South Korea that began with events in 2011 and 2012. In 2011, the tsunami in Japan, and the resulting failure of the Fukushima nuclear power plant, caused a reassessment of nuclear power around the world, including in South Korea.[46] In 2012, the South Korean nuclear industry's credibility was damaged as a result of scandals including forged safety certificates for parts in some South Korean nuclear plants, which led to extensive investigations.[47]

FIGURE 2

Share of total annual electricity generation from nuclear, top five nuclear power producers (2019)

Number of operational nuclear reactors (2020)



SOURCE: US ENERGY INFORMATION ADMINISTRATION

42 "South Korea," US Energy Information Administration, last updated November 6, 2020, https://www.eia.gov/international/analysis/country/KOR.

43 Ibid.

44 "Nuclear Power in South Korea."

45 "Today in Energy," US Energy Information Administration, August 27, 2020, https://www.eia.gov/todayinenergy/detail.php?id=44916.

46 Josh Gabbatiss, "The Carbon Brief Profile: South Korea," *CarbonBrief,* April 6, 2020, https://www.carbonbrief.org/the-carbon-brief-profile-south-korea.

47 Fred F. McGoldrick, et al., "ROK-U.S. Civil Nuclear and Nonproliferation Collaboration in Third Countries," Brookings, January 2015, https://www.brookings.edu/wp-content/uploads/2016/06/ROK-US-Civil-Nuclear-and-Nonproliferation-Collaboration-in-Third-Countries.pdf; Gabbatiss, "The Carbon Brief Profile: South Korea"; Choe Sang-Hun, "Scandal in South Korea Over Nuclear Revelations," *New York Times,* August 3, 2013, https://www.nytimes.com/2013/08/04/world/asia/scandal-in-south-korea-over-nuclear-revelations.html; Max S. Kim, "How Greed and Corruption Blew Up South Korea's Nuclear Industry," *MIT Technology Review,* April 22, 2019, https://www.technologyreview.com/2019/04/22/136020/how-greed-and-corruption-blew-up-south-koreas-nuclear-industry/.

Moon Jae-In took office in 2017 having campaigned, in part, on a reduction in the role of nuclear power. In June 2017, the government closed Kori 1, South Korea's oldest nuclear unit, and on that occasion Moon announced, "We will withdraw existing plans to build new nuclear power plants and not extend the lifespan of nuclear power plants."[48] In late 2017, the government adopted the 8th Basic Plan for Long-Term Electricity Supply and Demand, which incorporates determinations that several planned nuclear units would not be constructed, and that life extension would not be pursued on fourteen reactors. Originally, the plan would have abandoned the Shin Kori 5 and 6 nuclear reactors, which are currently under construction, but an in-depth opinion poll conducted by a special government committee showed support for both completing construction of the two units and the overall phase-out plan.[49]

The overall impact of the phase-out will be limited. By 2030, nuclear-generating capacity is planned to be reduced by only 2 gigawatts (GW) from the 22.5 GW operating in 2017, but this is the net result of 9 GW of planned retirements offset by 7 GW of new nuclear generation, some of which is still under construction. The plan anticipates meeting its greenhouse gas objectives through environmental dispatch, adding renewable capacity "faster than nuclear power generation is shrinking," and targeting a 13-percent reduction in electricity consumption from the grid in 2030 compared to the reference case, to be achieved through improved efficiency, energy management systems, and onsite solar generation.[50] The intentional phase-out of nuclear power is in contrast to international calls to preserve existing nuclear power as a significant contributor of zero-carbon generation that will be difficult to replace.[51] In addition, researchers have highlighted the need for dispatchable zero-carbon energy resources, such as nuclear power, to balance the variability of renewable generation as it becomes a growing part of the generation portfolio.[52]

Furthermore, the targeted reduction in electricity consumption potentially puts the plan at odds with decarbonization strategies that commonly incorporate a shift toward electrification of greater portions of energy use, including for transportation, buildings, and industry.[53] The plan anticipates about one million electric vehicles will be in service by 2030, which the plan projects will result in an increase in winter peak demand of only 0.3 GW, but incorporates no other explicit movement toward electrification.[54]

In April 2020, Moon's Democratic Party won a landslide in the elections for the National Assembly, supporting a continuation of his policies.[55] In March 2020, the administration announced a "New Deal" package including a "Green New Deal," under which South Korea would aim to reach net-zero carbon emissions by 2050, reduce domestic fine-dust emissions 40 percent by 2040, and cease financing coal power plants overseas.[56] Moon recently announced that the country would shut half of its coal-fired plants by 2034.[57]

Despite the planned domestic nuclear phase-out, the administration has pledged continued support for nuclear exports.[58] That effort will be hampered by the history of scandals—including the resulting concern for component quality and safety—and the phase-out itself.[59] For example, some manufacturers of nuclear power plant components are giving up on their Korea Electric Power Industry Code (KEPIC) certifications, citing the phase-out.[60] However, a consortium led by KEPCO is in the process of constructing the four-unit Barakah project in the UAE. While there have been delays in bringing the units into operation, the construction is generally viewed as successful, and the South Korean consortium will likely rely heavily on that success as a selling point for future projects.

Another path towards nuclear exports may be represented by the SMART reactor. SMART is a 330 MW-thermal (approximately 100 MW-electric) pressurized-water reactor with advanced safety features that received standard design approval (SDA) in Korea in July 2012.[61] In early 2020, South Korea's Ministry of Science and ICT and Saudi Arabia's King Abdullah City for Atomic and Renewable Energy (KA-CARE) signed a revised pre-project engineering (PPE) contract to establish a joint entity for construction of its SMART reactor in Saudi Arabia. Under the PPE contract, South Korea has been leading projects to refine the SMART design and license its use for deployment, as well as promote the export of the technology to other countries.[62] Saudi Arabia is considering SMR technologies for process heat applications such as water desalination, and the two countries have been collaborating on the SMART reactor since at least 2015.[63]

In addition to the move to phase out nuclear power, the disposal and storage of spent nuclear fuel is a key policy concern in South Korea. Reactor site spent fuel storage is becoming full, and the construction of new, dedicated interim spent fuel storage facilities is unpopular.[64] In part due to the desire for a solution to spent nuclear fuel, the Korea Atomic Energy Research Institute (KAERI) has sought to investigate pyroprocessing, an approach to recovering useful elements of spent fuel. However, this has led to a disagreement with the United States regarding the potential proliferation risks associated with pyroprocessing, and ultimately resulted in KAERI's participation in a ten-year joint study on pyroprocessing (the "Joint Fuel Cycle Study") at the Idaho National Laboratory, which began in 2011 and will conclude in 2021.[65]

48 "South Korea's President Moon Says Plans to Exit Nuclear Power," Reuters, June 19, 2017, https://www.reuters.com/article/us-southkorea-nuclear-president/south-koreas-president-moon-says-plans-to-exit-nuclear-power-idUSKBN19A04Q.

49 Se Young Jang, "South Korea's Nuclear Energy Debate," *Diplomat,* October 26, 2017, https://thediplomat.com/2017/10/south-koreas-nuclear-energy-debate/.

50 "The 8th Basic Plan for Long-term Electricity Supply and Demand (2017–2031)," Ministry of Trade, Industry and Energy No. 2017 – 611, December 29, 2017 https://www.kpx.or.kr/www/downloadBbsFile.do?atchmnflNo=30051.

51 Geert De Clercq, "IEA Rings Alarm Bell on Phasing out Nuclear Energy," Reuters, May 27, 2019, https://www.reuters.com/article/us-nuclearpower-iea/iea-rings-alarm-bell-on-phasing-out-nuclear-energy-idUSKCN1SX1XW.

52 Nestor A. Sepulveda, et al., "The Role of Firm Low-Carbon Electricity Resources in Deep Decarbonization of Power Generation," *Joule* 2, 11, November 21, 2018, https://doi.org/10.1016/j.joule.2018.08.006.

53 See, e.g., "United States Mid-Century Strategy For Deep Decarbonization," White House, November 2016, https://unfccc.int/files/focus/long-term_strategies/application/pdf/mid_century_strategy_report-final_red.pdf; Trieu Mai, et al., "Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States," National Renewable Energy Laboratory, June 2018, https://www.nrel.gov/docs/fy18osti/71500.pdf.

54 "The 8th Basic Plan for Long-term Electricity Supply and Demand (2017–2031)," 28.

55 Choe Sang-Hun, "In South Korea Vote, Virus Delivers Landslide Win to Governing Party," *New York Times,* April 15, 2020, https://www.nytimes.com/2020/04/15/world/asia/south-korea-election.html.

56 Troy Stangarone, "South Korea's Green New Deal," *Diplomat,* May 29, 2020, https://thediplomat.com/2020/05/south-koreas-green-new-deal/.

57 Darrell Proctor, "South Korea Will Close Half Its Coal-Fired Fleet," *Power,* September 8, 2020, https://www.powermag.com/south-korea-will-close-half-its-coal-fired-fleet/.

58 Sylvie Cornot-Gandolphe, "South Korea's New Electricity Plan," *Institut Français des Relations Internationales,* February 28, 2018, https://www.ifri.org/sites/default/files/atoms/files/cornotgandolphe_south_korea_electricity_2018.pdf.

ADVANCING US-ROK COOPERATION ON NUCLEAR ENERGY

59 Dan Yurman, "Delays in Startup of 1st UAE Nuclear Reactor Linked to Problems with South Korean Firms Building All Four Units," *Energy Central,* April 27, 2019, https://energycentral.com/c/ec/delays-startup-1st-uae-nuclear-reactor-linked-problems-south-korean-firms.

60 Jung Min-hee, "S. Korea's Ecosystem of Nuclear Power Plant Industry Collapsing," *Business Korea,* January 23, 2020, http://www.businesskorea.co.kr/news/articleView.html?idxno=40500.

61 "South Korea and Saudi Arabia Strengthen Cooperation on SMART Reactor," Nuclear Engineering International, January 9, 2020, https://www.neimagazine.com/news/newssouth-korea-and-saudi-arabia-strengthen-cooperation-on-smart-reactor-7591629.

62 "Korea, Saudi Arabia Progress with SMART Collaboration," World Nuclear News, January 7, 2020, https://www.world-nuclear-news.org/Articles/Korea-Saudi-Arabia-progress-with-SMART-collaborati.

63 Noura Mansouri, "The Saudi Nuclear Energy Project," King Abdullah Petroleum Studies and Research Center, March 25, 2020, https://www.kapsarc.org/research/publications/the-saudi-nuclear-energy-project/; "Korea, Saudi Arabia to Cooperate on SMART Deployment," World Nuclear News, September 20, 2019, https://www.world-nuclear-news.org/Articles/Korea,-Saudi-Arabia-to-cooperate-on-SMART-deployme.

64 Mark E. Manyin, et al., "U.S.-South Korea Relations," Congressional Research Service, May 23, 2017, 41, https://fas.org/sgp/crs/row/R41481.pdf.

65 "U.S. and South Korean Cooperation in the World Nuclear Energy Market: Major Policy Considerations," Congressional Research Service, June 25, 2013, https://crsreports.congress.gov/product/pdf/R/R41032.

US-ROK CIVIL NUCLEAR COOPERATION

Civil nuclear cooperation between the United States and its allies has helped support civil nuclear development in much of the world that shares US approaches to nuclear safety and nonproliferation. Today, civil nuclear development worldwide depends on a global supply chain for major components. Developing advanced reactors as part of global efforts to address climate change could be further facilitated through civil nuclear cooperation, which would also enable greater competitiveness in third-country development, especially as a counterweight to efforts from Russia and China to sell advanced nuclear technologies in emerging markets.[66] The civil nuclear cooperation between the United States and South Korea is deep and long-standing, so continuing and strengthening US-ROK civil nuclear cooperation could be particularly beneficial.

FRAMEWORK FOR COOPERATION

In 2015, the United States and South Korea signed a successor agreement for civil nuclear cooperation under Section 123 of the Atomic Energy Act (frequently referenced as a "123 agreement"); the previous agreement had been signed in 1973.[67] A State Department fact sheet on the agreement remarks that it allows "for the continuation and expansion of our robust and mutually beneficial trade relationship."[68] The fact sheet emphasizes that "The ROK is one of the United States' strongest partners on nonproliferation and has consistently reiterated its commitment to nonproliferation." It also references expected benefits from "the continuation and expansion of our robust and mutually beneficial trade relationship," including: from US sales of enrichment to South Korea; from South Korean sales of reactor components to the United States; and from the contract on the Barakah project that had already brought "hundreds of new jobs and approximately $2 billion in additional revenue to U.S. nuclear suppliers."

The 2015 agreement established a High Level Bilateral Commission (HLBC), "as a senior level forum to facilitate peaceful nuclear and strategic cooperation in areas of mutual interest related to civil nuclear energy."[69] Under the HLBC are four working groups covering spent fuel management (reflecting the continued ROK focus on this topic), the promotion of nuclear exports and export control cooperation, assured fuel supply, and nuclear security. Meetings of the HLBC have been infrequent; the last meeting was in August 2018, and that was only the second plenary meeting since the HLBC's creation.[70]

A further forum for cooperation is the Joint Standing Committee on Nuclear Energy Cooperation (JSCNEC), which was established in 1980. The JSCNEC has served as a forum to address environmental issues, waste management, research and development, fuel cycle issues, and nuclear safeguards and proliferation.[71]

66 Bowen, *Strengthening Nuclear Energy Cooperation between the United States and Its Allies*.

67 Daniel Horner, "S. Korea, U.S. Sign Civil Nuclear Pact," Arms Control Association, July/August 2015, https://www.armscontrol.org/act/2015-07/news/s-korea-us-sign-civil-nuclear-pact; "U.S. and South Korean Cooperation in the World Nuclear Energy Market: Major Policy Considerations."

68 "U.S.-Republic of Korea (R.O.K.) Agreement for Peaceful Nuclear Cooperation," US Department of State, January 20, 2017, https://www.state.gov/remarks-and-releases-bureau-of-international-security-and-nonproliferation/u-s-republic-of-korea-r-o-k-agreement-for-peaceful-nuclear-cooperation/

69 "Co-Chairs of the United States-Republic of Korea High Level Bilateral Commission Convene in Washington," US Department of Energy, January 11, 2017, https://www.energy.gov/articles/co-chairs-united-states-republic-korea-high-level-bilateral-commission-convene-washington.

70 "Deputy Secretary Brouillette Hosts U.S.-Republic of Korea High Level Bilateral Commission Meeting," *Breaking Energy*, August 20, 2018, https://breakingenergy.com/2018/08/20/deputy-secretary-brouillette-hosts-u-s-republic-of-korea-high-level-bilateral-commission-meeting/.

71 Fred McGoldrick, "New U.S.-ROK Peaceful Nuclear Cooperation Agreement: A Precedent for a New Global Nuclear Architecture," Center for U.S.-Korea Policy, November 2009, https://asiafoundation.org/resources/pdfs/McGoldrickUSROKCUSKP091130.pdf.

US-ROK High Level Bilateral Commission meetings in August, 2018. This photograph was reprinted from former US Secretary of Energy Dan Brouillette's Twitter with the permission of the US Department of Energy.

The JSCNEC's thirty-seventh meeting occurred in December 2018.[72]

The 2015 agreement, the HLBC, and the JSCNEC—along with the trade relationships underpinning them—create a robust framework for potential future civil nuclear cooperation.

OPPORTUNITIES FOR COOPERATION

The opportunities for civil nuclear cooperation generally fall into four areas: bilateral trade in which US suppliers provide components and services to projects in South Korea, and ROK firms supply components to the United States; a key subset of bilateral trade supporting the demonstration and deployment of advanced nuclear technology; cooperation in research and development to jointly pursue goals in new nuclear technologies; and collaboration in third countries, in which US and South Korean entities work together to deliver projects that deliver improved value to the host country through collaboration and bring meaningful value to suppliers in both countries.

BILATERAL TRADE The United States has historically been a significant supplier to the South Korean civil nuclear program, and that supply relationship continues today. In 2016, Westinghouse and Korea Hydro & Nuclear Power (KHNP) signed a supply agreement establishing the terms of equipment supply for at least five years.[73] KHNP explained that, "in response to the Fukushima accident, it is seeking key foreign suppliers to strengthen the supply chain, as well as enhancing quality and technical standards." Westinghouse reported that it was supplying "major components (reactor coolant pumps and motors, reactor vessel internals), instrumentation and control equipment, man-machine interface systems, and technical and engineering support services." As of the timeframe of the agreement, Westinghouse had provided technology and major equipment to fourteen operating

72 "Country Nuclear Power Profiles: Republic of Korea," International Atomic Energy Agency, updated 2020, https://cnpp.iaea.org/countryprofiles/KoreaRepublicof/KoreaRepublicof.htm.

73 "Westinghouse Signs Supply Agreement with KHNP," *World Nuclear News*, February 29, 2016, https://www.world-nuclear-news.org/Articles/Westinghouse-signs-supply-agreement-with-KHNP.

plants and six plants then under construction in South Korea.

The 2015 civil cooperation agreement provides for mutual exchange of nuclear materials and was expected to create a more balanced trade flow than the historical relationship of the United States as exporter and South Korea as importer. Indeed, when the United States sought to resurrect its civil nuclear construction program, such as with the construction of Westinghouse AP1000 reactors in Georgia (and, until the project was terminated, South Carolina), the projects turned to foreign suppliers, including those in South Korea, for components for which qualified US suppliers were no longer available. For the AP1000 projects, ROK firms supplied reactor pressure vessels, steam generators, condensers, de-mineralizers, heat exchangers, and valves.[74]

The DOE report, *Restoring America's Competitive Nuclear Energy Advantage*, describes several steps intended to strengthen the front end of the nuclear fuel cycle in the United States. US-ROK cooperation could help support that effort. Specific information on sales of nuclear fuel are rarely made public, but South Korea had made large nuclear fuel purchases from US sources in the past.[75] Early this year, Russia's Tenex announced signing of a new ten-year contract with KHNP, and that its total portfolio of contracts with KHNP amounted to $2 billion, a substantial amount of fuel even for KHNP's nuclear fleet.[76] As the United States takes steps to strengthen its front-end fuel cycle capabilities, nuclear fuel sales to the ROK could represent an opportunity to further strengthen the US industry and, at the same time, strengthen US-ROK cooperation.

Dry-cask storage has become a common approach worldwide to addressing interim storage of spent nuclear fuel.[77] Although there are challenges implementing dry-cask storage in South Korea, it was implemented at the Wolsong site in 2010, and the government and KHNP are now seeking to expand the capacity there.[78] Several dry-cask systems, including those developed and sold by US firms, have been approved by the NRC.[79] These systems have been extensively implemented throughout the United States.[80] To the extent that South Korea considers dry-cask storage as part of a future approach to the challenge of spent fuel management, systems provided by US firms and approved by the NRC could represent a further opportunity for bilateral trade to strengthen US-ROK cooperation.

In addition to trade in nuclear materials, mutual benefit could be realized from bilateral trade in services. In particular, the US nuclear industry has obtained regulatory approval for extension of operating lifetimes to as long as eighty years for some domestic units, delivered thousands of megawatts in additional generating capacity through unit uprates, and substantially improved the capacity factor of its operating units to a current average of over 93 percent.[81] While life extension opportunities are currently precluded by the nuclear policy in South Korea, US firms could potentially support opportunities for improved operations through uprates and capacity factor improvements that could deliver substantial value. (For example, the capacity factor for ROK plants was 70.6 percent

74 "U.S.-ROK Cooperation on Nuclear Energy to Address Climate Change," Nuclear Innovation Alliance, November 2019, https://www.nuclearinnovationalliance.org/us-rok-cooperation-nuclear-energy-address-climate-change.

75 In 2007, US Enrichment Corporation signed a $400-million contract with South Korea that extended through 2013. See "U.S. and South Korean Cooperation in the World Nuclear Energy Market: Major Policy Considerations."

76 "TENEX Signs New Long-Term Contract with KHNP," TENEX, press release, January 20, 2020, https://www.tenex.ru/en/media-center/news/2020-01-20-tenex-khnp-en/.

77 "Dry Cask Storage Booming for Spent Nuclear Fuel," *Power,* February 1, 2015, https://www.powermag.com/dry-cask-storage-booming-for-spent-nuclear-fuel/.

78 Ferenc Dalnoki-Veress, et al., "The Bigger Picture: Rethinking Spent Fuel Management in South Korea," James Martin Center for Nonproliferation Studies and Monterey Institute of International Studies, 2013, https://www.files.ethz.ch/isn/161248/130301_korean_alternatives_report1.pdf; Jongwon Choi, "Spent Fuel Management and Storage in Korea," Korea Atomic Energy Research Institute, November 15, 2010, https://criepi.denken.or.jp/result/event/seminar/2010/issf/pdf/1-6_powerpoint.pdf; "S. Korea Moving to Build Additional Used Nuclear Fuel Storage," Yonhap, August 20, 2020, https://en.yna.co.kr/view/AEN20200820003100320.

79 "Dry Spent Fuel Storage Designs: NRC Approved for General Use," US Nuclear Regulatory Commission, https://www.nrc.gov/waste/spent-fuel-storage/designs.html.

80 "U.S. Independent Spent Fuel Storage Installations (ISFSI)," US Nuclear Regulatory Commission, https://www.nrc.gov/docs/ML1933/ML19337C178.pdf.

81 Sonal Patel, "NRC Issues First Subsequent License Renewals, Extends Nuclear Reactor Life to 80 Years," December 11, 2019, https://www.powermag.com/nrc-issues-first-subsequent-license-renewals-extends-nuclear-reactor-life-to-80-years/. See the earlier discussion of the US market.

in 2019, and averaged 77.4 percent for the five years prior to that, though operator decisions may have affected those figures).[82]

Over time, as the ROK pursues its nuclear phase-out policy, South Korean nuclear plants will need to be decommissioned. US firms have recently gained experience in expediting decommissioning of nuclear power plants. For example, the US firm EnergySolutions recently completed the accelerated decommissioning of Exelon's Zion 1 and 2 reactors in eight years, and has been engaged by Omaha Public Power District in Nebraska to decommission its Fort Calhoun plant.[83] The US firm Holtec Decommissioning International is currently decommissioning the Oyster Creek and Pilgrim plants.[84]

Benefits could continue to accrue from bilateral trade opportunities in nuclear materials and services. In the future, however, these opportunities may be challenged by the South Korean nuclear phase-out and the current limited prospects for development of large light water reactors in the United States.

ADVANCED NUCLEAR TECHNOLOGY Perhaps the most consequential area of potential cooperation is associated with the demonstration and deployment of advanced nuclear reactors. Developing and deploying a first-of-a-kind nuclear demonstration is expensive, especially because substantial costs must be incurred as part of the licensing review by the NRC. For example, NuScale estimated that as of December 2019, it had spent about $900 million in development costs out of an expected total of about $1.4 billion.[85] To help defray these substantial costs, to supply components (such as forgings) that can no longer be supplied in the United States, and to create a robust supply chain that can support the Idaho and future projects, NuScale entered into an agreement with Doosan through which DHIC would make a cash-equity investment in NuScale, and DHIC would supply key components for future NuScale plants. The companies estimated the total value of the supply commitment to be at least $1.2 billion.[86]

An agreement of this nature provides benefits to all parties, and is a clear example of the opportunities potentially created through civil nuclear cooperation. NuScale gains assured access to the well-qualified South Korean nuclear supply chain, and cash to defray its development costs. Doosan gains a known supply opportunity, and—perhaps equally importantly—is able to demonstrate a role in the advanced nuclear supply chain. The ROK nuclear ecosystem develops another channel for future growth.

The Doosan agreement with NuScale addresses issues common to developers of advanced nuclear technologies. The US Nuclear Industry Council regularly surveys developers on key issues of importance; in its 2020 survey, developers raised financing and manufacturing resources as among the top issues of concern.[87] Although not as obvious, the agreement also provides benefits to US suppliers. DOE's desire to restore the US nuclear supply chain is part of the rationale for the funding NuScale has received. NuScale has solicited interest from US suppliers, and as NuScale and other advanced nuclear developers create more demand, US suppliers are likely to make the investments necessary to supply those projects.[88] So, civil nuclear cooperation could help support the recovery of the US nuclear supply chain through the future growth of US-developed advanced nuclear projects.

In another example of cooperation on advanced nuclear technologies between US and ROK entities, KAERI and the ROK's Hyundai Engineering signed a memorandum of understanding (MoU) with the US company Ultra Safe Nuclear Corporation (USNC) in August 2020. The agreement will last for five years, and it delineates cooperation on the "development of technologies that enhance the ability of the USNC Micro Modular Reactor (MMR)," which uses a high-temperature gas-cooled reactor design to

82 "Capacity Factor & Availability," Korea Hydro & Nuclear Power," http://khnp.co.kr/eng/content/539/main.do?mnCd=EN03020103.

83 "World Nuclear Association Weekly Digest Archive 2019," World Nuclear Association, https://world-nuclear.org/our-association/publications/weekly-digest/archive/archive-2019.aspx.

84 "Giving the Next Generation a Cleaner Tomorrow," Holtec Decommissioning International, https://hdi-decom.com/.

85 Bowen, *Strengthening Nuclear Energy Cooperation between the United States and Its Allies*.

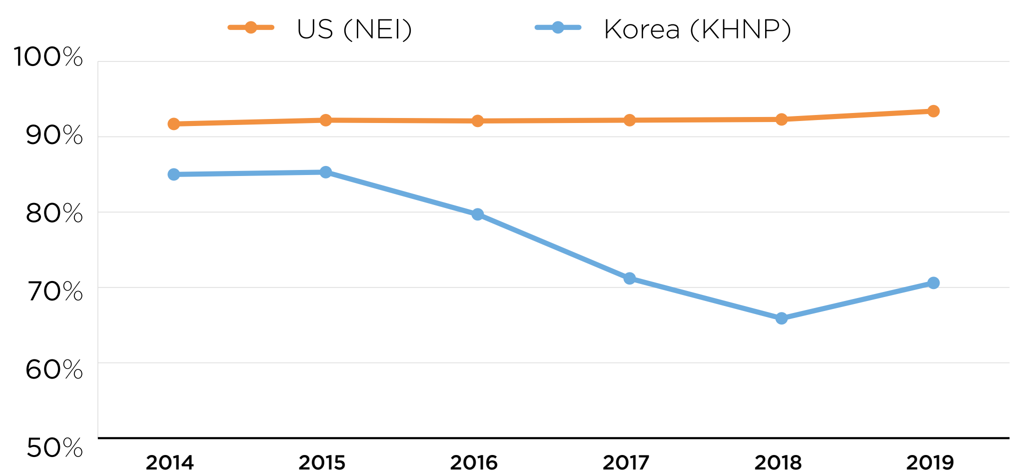
86 "Doosan NuScale Sign Agreements for SMR Cooperation," *World Nuclear News,* July 24, 2019, https://www.world-nuclear-news.org/Articles/Doosan,-NuScale-sign-agreements-for-SMR-cooperatio.

87 "USNIC Releases Results of 2020 Advanced Nuclear Industry Survey," US Nuclear Industry Council, press release, April 7, 2020, https://www.usnic.org/4-7-20-usnic-releases-results-of-20.

88 "NuScale Power Announces Campaign to Select Fabrication Partners," NuScale, press release, August 17, 2016, https://newsroom.nuscalepower.com/press-releases/news-details/2016/NuScale-Power-Announces-Campaign-to-Select-Fabrication-Partners/default.aspx.

FIGURE 3

Nuclear Generation Capacity Factor



THIS GRAPH WAS BASED ON DATA FROM THE NUCLEAR ENERGY INSTITUTE (NEI) AND KHNP, AND IT WAS REPRINTED WITH PERMISSION FROM NEI AND KHNP.

"produce and deliver carbon-free power, heat, and hydrogen."[89]

One question that arises in the context of these agreements is whether cooperation of this nature will be limited to one or a few developers, or whether it could be more widespread. A report from Columbia University, *Strengthening Nuclear Energy Cooperation between the United States and Its Allies*, identifies several reasons why investment in US advanced reactor development might be attractive.[90] The value of the opportunity to be in the supply chain will be applicable to other advanced nuclear designs, depending on the view of their market potential. Contributing to development in the United States enables sharing development costs with US firms that are already engaged, without taking on the full burden of independent development. Development in the United States permits investors to leverage the value of development incentives provided by the US government, such as the development funding being offered through DOE—and, potentially, the cost and time savings gained through the use of DOE sites and facilities, as may result from access to DOE lab and research facilities. Finally, advanced reactors developed in the United States will be licensed by the US NRC, which continues to be respected worldwide. The report also highlights that civil nuclear cooperation with US allies, including South Korea, will be more important given the 2018 policy change that constrained civil nuclear cooperation with China related to small modular reactors (SMRs) and other advanced technology, and, for example, caused TerraPower to cancel its plans for a $1-billion prototype in China.[91]

RESEARCH AND DEVELOPMENT The 2015 agreement reinforced the focus on the Joint Fuel Cycle Study to research options for addressing spent fuel management challenges, and highlighted cooperation on additional research and development efforts.[92] In 2014, Argonne National Laboratory and KAERI signed an MoU to develop a prototype sodium-cooled fast

89 "US, Korean Companies to Develop Micro Modular Reactors," *World Nuclear News,* August 5, 2020, https://world-nuclear-news.org/Articles/USNC-Korean-companies-to-develop-micro-modular-rea.

90 Bowen, *Strengthening Nuclear Energy Cooperation between the United States and Its Allies.*

91 Dan Yurman, "TerraPower to Leave China, but Bill Gates is Still in the Game," *Energy Central,* January 7, 2019, https://energycentral.com/c/ec/terrapower-leave-china-bill-gates-still-game.

92 "U.S.-Republic of Korea (R.O.K.) Agreement for Peaceful Nuclear Cooperation."

reactor (the Prototype Generation-IV Sodium-cooled Fast Reactor, or PGSFR).[93] The PGSFR would be a 150-MW advanced sodium-cooled fast reactor using metal fuel, which "enables inherent safety characteristics." Argonne and KAERI were to develop the reactor system and the South Korean engineering and construction firm KEPCO E&C was to design the balance of the plant; the project was expected to pursue design approval from the ROK licensing authority. However, little new information has been forthcoming on the PGSFR project since 2016, perhaps in part due to the ROK nuclear phase-out.

With commercial interest turning to development of advanced reactors, a future opportunity for cooperation could be in the context of the US development of the VTR.[94] The VTR would be a reactor-based fast-neutron source intended to support the development of advanced reactor technologies. DOE launched the development of the VTR in 2018 after passage of NEICA, and views it as important to keeping the US "technologically competitive" with China and Russia.[95]

However, the VTR would present a significant capital commitment and a budgetary challenge. Based on similar projects, initial DOE cost estimates for the VTR are in the range of $3 billion to $6 billion.[96] Obtaining a government funding commitment of this magnitude will be difficult when DOE is also seeking funding for advanced nuclear demonstration programs. Defraying the cost through contributions for shared research—or paid use by other countries—could be a meaningful way to improve the prospects for funding. In addition, cooperation could facilitate the use of relevant research, such as ROK research on sodium-cooled fast reactors, in the development of the VTR. The United States has had discussions with South Korea, France, and Japan regarding their interest in research with the VTR, though the project is still early in its development.[97] DOE recently approved moving the project to the engineering design phase and is seeking a $295-million appropriation for FY2021 to move forward with that effort.[98] However, the budget is still a work in progress, and the House Appropriations Committee recommended funding only $65 million for the VTR effort, similar to the FY2020 funding, and the Senate Appropriations Committee recommended a reduction in funding to $45 million.[99]

Development and deployment of advanced fuel technologies may also represent a potential opportunity for US-ROK cooperation. For example, Lightbridge Corporation recently received a patent for a method to manufacture its advanced fuel from the Korean Intellectual Property Office, and views South Korea as a potential market for the fuel.[100] Other manufacturers are also developing and testing advanced fuels, and South Korea could establish itself as a potential market for demonstration and future deployment.[101]

As US developers pursue advanced reactor technologies, and the US government supports those efforts through funding for research and demonstrations, DOE is also supporting the development of high-assay low-enriched uranium fuel (HALEU), which will be required by many of the advanced reactor

93 Angela Hardin, "Argonne, KAERI to Develop Prototype Nuclear Reactor," Argonne National Laboratory, press release, August 25, 2014, https://www.anl.gov/article/argonne-kaeri-to-develop-prototype-nuclear-reactor.

94 "Versatile Test Reactor," US Department of Energy Office of Nuclear Energy, https://www.energy.gov/ne/nuclear-reactor-technologies/versatile-test-reactor

95 Sonal Patel, "Versatile Test Reactor Program Selects Bechtel Team for Nuclear Design, Build Phase," *Power,* August 27, 2020, https://www.powermag.com/versatile-test-reactor-program-selects-bechtel-team-for-nuclear-design-build-phase/.

96 Ibid.

97 Jacqueline Toth, "DOE Nearing Decision Checkpoint on Versatile Test Reactor," Morning Consult, February 11, 2019, https://morningconsult.com/2019/02/11/doe-nearing-decision-checkpoint-on-versatile-test-reactor/.

98 The DOE approved "Critical Decision 1," which includes review by federal committees of the conceptual design, schedule, and cost range, and analysis of potential alternatives. See "Energy Department Green Lights Critical Decision 1 for Versatile Test Reactor Project," US Department of Energy Office of Nuclear Energy, September 23, 2020, https://www.energy.gov/ne/articles/energy-department-green-lights-critical-decision-1-versatile-test-reactor-project.

99 Patel, "Versatile Test Reactor Program Selects Bechtel Team for Nuclear Design, Build Phase"; "Senate Releases FY21 Science Spending Proposals," American Institute of Physics, November 12, 2020, https://www.aip.org/fyi/2020/senate-releases-fy21-science-spending-proposals.

100 "Lightbridge Receives Patent from the Korean Intellectual Property Office for a Manufacturing Method for Its Metallic Fuel Rods," Lightbridge, August 24, 2020, https://www.ltbridge.com/news-media/press-releases/detail/295/lightbridge-receives-patent-from-the-korean-intellectual.

101 "Westinghouse and ENUSA Continue Expansion of EnCore Fuel Program with First Insertion at European Utility," Westinghouse Electric Company, press release, September 8, 2020, https://www.prnewswire.co.uk/news-releases/westinghouse-and-enusa-continue-expansion-of-encore-r-fuel-program-with-first-insertion-at-european-utility-813743228.html.

technologies, but which is not produced by existing uranium enrichment facilities.[102] DOE is conducting a demonstration of HALEU production with Centrus Energy Corp., using US-origin enrichment technology, but expansion of production after the demonstration is uncertain.[103] US-ROK cooperation could help support further deployment, and would be consistent with potential cooperation on advanced reactors.

In response to congressional direction, the US National Academies of Sciences, Engineering, and Medicine have commenced a study of nuclear fuel cycles, including waste implications of advanced nuclear reactors. Two reports will be produced as part of this study.[104] Following the results of this study, given the challenges both countries face in managing spent nuclear fuel, further work could be the subject of research in cooperation with South Korea.

COLLABORATION IN THIRD COUNTRIES Civil nuclear exports engender long-term international relationships. The DOE report, *Restoring America's Competitive Nuclear Energy Advantage*, states, "Establishment of nuclear infrastructure incorporates large scale cross-cutting economic, security, and geopolitical relationships between the purchasing nation and the technology providing nation for the ensuing 100 years."[105] Furthermore, exports of US nuclear technology support the host country's adoption of US-influenced safety and nonproliferation standards.[106]

With growing energy needs, a focus on low-carbon energy sources, and the prospect on the horizon for advanced reactors that may be a better fit for their electric grid, many countries may become candidates for nuclear development. Third Way's recent effort to identify global markets for advanced nuclear technology characterized thirty-seven countries as potential candidates for nuclear technology today, and another eleven that would potentially be ready by 2030.[107] As world participation in nuclear power grows, it will be even more essential to export safety and nonproliferation provisions consistent with US standards.

The growing international nuclear market represents a substantial economic opportunity. The US Department of Commerce (DOC) estimates the market is valued at $500-740 billion over the next ten years.[108] A recent study concluded that to meet the targets for nuclear capacity in the median Intergovernmental Panel on Climate Change (IPCC) scenario that limit the global temperature rise to 1.5 degrees Celsius by 2050, the cumulative nuclear expenditures would be $8.6 trillion (in 2019 dollars).[109]

However, the potential for US companies to participate in this growth has diminished over time as US capabilities to build new large-scale nuclear plants have eroded. Furthermore, the United States must face competition from Russia and China, which have a history of using energy and state-sponsored investment as tools to further their foreign policy objectives.[110]

In this context, civil cooperation with South Korea in third-country nuclear projects could improve the position of the United States to participate in worldwide commercial nuclear development, and continue to play a valuable role in nuclear safety and nonproliferation. The ROK's first foray into international nuclear projects was the development of the four-unit, 5,400-net-MW Barakah project in the UAE. Commercial operation of the four Barakah units was originally expected in 2017, 2018, 2019, and 2020.

102 "What is High-Assay Low-Enriched Uranium (HALEU)?" US Department of Energy Office of Nuclear Energy, April 7, 2020, https://www.energy.gov/ne/articles/what-high-assay-low-enriched-uranium-haleu.

103 "Department of Energy Preps to Fuel Advanced Reactors," US Department of Energy Office of Nuclear Energy, August 4, 2020, https://www.energy.gov/ne/articles/department-energy-preps-fuel-advanced-reactors.

104 "Merits and Viability of Different Nuclear Fuel Cycles and Technology Options and the Waste Aspects of Advanced Nuclear Reactors," National Academies of Sciences, Engineering, and Medicine, https://www.nationalacademies.org/our-work/merits-and-viability-of-different-nuclear-fuel-cycles-and-technology-options-and-the-waste-aspects-of-advanced-nuclear-reactors.

105 *Restoring America's Competitive Nuclear Energy Advantage*.

106 Ibid.

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

108 *Restoring America's Competitive Nuclear Energy Advantage*.

109 "Global Nuclear Market Assessment Based on IPCC Global Warming of 1.5 C Report," Nuclear Energy Institute, July 2020, https://www.nei.org/resources/reports-briefs/uxc-global-nuclear-market-assessment-report.

110 *Restoring America's Competitive Nuclear Energy Advantage* states, "Russia is advancing its economic and foreign policy influence around the world with $133 billion in foreign orders for reactors, with plans to underwrite the construction of more than 50 reactors in 19 countries. China, a strategic competitor that uses predatory economics as a tool of statecraft, is currently constructing four reactors abroad, with prospects for 16 more reactors across multiple countries, in addition to the 45 reactors built in China over the past 33 years, and the 12 reactors currently under construction in China."

Construction of Unit 1 was completed in March 2018, although delays in the comprehensive Operational Readiness Review postponed the start of operations. Unit 1 was connected to the grid in August 2020.[111] The project announced at that time that construction of Unit 2 was complete, and that Units 3 and 4 were 93 percent and 86 percent complete, respectively. The relatively close adherence to the original construction schedule stands in stark contrast to the substantial delays incurred in other recent large nuclear construction projects.

The 2009 shortlist of bidders for the Barakah project, in addition to the ROK consortium led by KEPCO, included a French consortium led by Areva (now Framatome) and a consortium led by GE Hitachi. KEPCO attributed the success of its proposal to high projected capacity factors and the lowest construction cost and shortest construction time among the bidders.[112] Westinghouse was not on the shortlist, but it became part of the KEPCO consortium. As a result, Westinghouse and other US companies provided equipment and services including reactor coolant pumps, reactor components, controls, engineering services, and training. The contributions from US suppliers, as well as the presence of US diplomats and nuclear executives on the UAE's International Advisory Board and the board of directors of the Emirates Nuclear Energy Corporation, maintained an ongoing connection between the US diplomatic and nuclear community and the project.

Cooperation could also bring joint benefits in the transition to safe operations. The delay in startup of Barakah Unit 1 was attributed to additional time required for operational readiness and regulatory approvals, including ensuring adequate communications among the staff.[113] The US nuclear industry has been responsible for the transfer of nuclear technology around the world, working with partners to facilitate the education and training of local staff.[114] US support for the transition to operations could help address one of the few problem areas in the Barakah project and strengthen a combined offering in third countries.

For cooperation in third-country projects to be successful, US and ROK companies must be able to bring elements of government support that are competitive with those from Russian and China. Rosatom, the single Russian entity responsible for nuclear energy and nuclear exports, is vertically and horizontally integrated, and provides "reactor technology, plant construction under an EPC contract, fuel, operational capability (including training), maintenance services, decommissioning, spent nuclear fuel reprocessing, and regulatory support, as well as generous financing (debt and equity)."[115] China can use major capital projects, and the financing for those projects, as a means to cement long-term geopolitical relationships.[116]

The United States and South Korea may not be able to compete head to head with every element of Russian and Chinese offerings. However, working with US and ROK suppliers may provide other offsetting benefits. The United States has a strong reputation for operational expertise, safety, and technology transfer, and South Korean suppliers have a reputation for efficient construction gained at Barakah, as well as an acknowledged strong supply chain.[117] Potential partners will also consider geopolitical alignment as they make decisions about support for civil nuclear development.[118] Stronger combined financial support from the United States and South Korea could continue to close the gap. For the Barakah project, the Export-Import Bank of Korea (KEXIM) provided $2.5

111 David Dalton, "Barakah / Unit 1 is Connected to Grid and Dispatching Electricity," NUCNET, August 19, 2020, https://www.nucnet.org/news/unit-1-is-connected-to-grid-and-dispatching-electricity-8-3-2020.

112 "Nuclear Power in the United Arab Emirates," World Nuclear Association, https://www.world-nuclear.org/information-library/country-profiles/countries-t-z/united-arab-emirates.aspx.

113 Ibid. Also see Dan Yurman, "Delays in Startup of 1st UAE Nuclear Reactor Linked to Problems with South Korean Firms Building All Four Units," *Energy Central,* April 27, 2019, https://energycentral.com/c/ec/delays-startup-1st-uae-nuclear-reactor-linked-problems-south-korean-firms.

114 "U.S. Nuclear Technology Exports and Africa," *NEI Nuclear Notes,* August 8, 2014, https://neinuclearnotes.blogspot.com/2014/08/us-nuclear-technology-exports-and-africa.html.

115 Nakano, "The Changing Geopolitics of Nuclear Energy: A Look at the United States, Russia, and China."

116 Ibid.

117 McGoldrick, et al., "ROK-U.S. Civil Nuclear and Nonproliferation Collaboration in Third Countries"; "U.S. Nuclear Technology Exports and Africa."

118 Jennifer T. Gordon, "International Co-financing of Nuclear Reactors between the United States and Its Allies," Atlantic Council, January 9, 2020, https://atlanticcouncil.org/in-depth-research-reports/issue-brief/international-co-financing-of-nuclear-reactors-between-the-united-states-and-its-allies/.

The flags of South Korea and the UAE are displayed at the Barakah Nuclear Power Plant in Abu Dhabi, UAE.
SOURCE: Emirates Nuclear Energy Corporation

billion and the US Ex-Im Bank provided $2 billion in loans. KEPCO also provided an equity commitment.[119] The United States strenghtened its ability to support combined nuclear export financing through the reauthorization of the Ex-Im Bank and the removal of the prohibition on nuclear financing by the DFC. Given the strength and scope of government support by Russia and China, US cooperation with South Korea in nuclear export projects, including co-financing, could help level the playing field.[120]

Cooperation in third-country projects strengthens the overall team presented to the host country. Even if, as in the case of Barakah, US participation is as part of a South Korean team, the project can generate substantial economic benefit for the United States. In future projects, especially to the extent that hosts are interested in more technically advanced reactors such as the Westinghouse AP1000, GE Hitachi ABWR, or one of the US advanced reactors under development, US companies may have the opportunity to lead a consortium. However, ROK participation may be critical, as it has been at Vogtle or is expected with Doosan's support of of NuScale. In either case, US policy objectives will be advanced through exports that maintain standards for safe operation, leadership of global nonproliferation, and trade relationships that support US foreign policy.[121]

CHALLENGES TO COOPERATION

The 2015 successor 123 agreement with the ROK came after some delay and extensions of the prior agreement due, in part, to ROK interest in obtaining—and US reticence to provide advance consent for—South Korea to engage in pyroprocessing. The ROK government is expected to review the results of the Joint Fuel Cycle Study on pyroprocessing upon its completion, with no further action on the technology until after that review.[122] In the current climate for nuclear power in South Korea, it is unclear whether the administration would provide substantial funding for further demonstrations of pyroprocessing, and certainly for further pursuit of a fast reactor in South Korea, which would be an essential component of a spent fuel solution using pyroprocessing. If, after its review, the ROK government decides to pursue pyroprocessing in South Korea, that would reopen the issues encountered in the pursuit of the 2015 agreement and could hamper efforts toward further cooperation.

In addition, the context for the agreement on civil nuclear cooperation included expectations of mutual benefits—including from US sales of enrichment to South Korea, from ROK sales of reactor components to the United States, and from joint participation in third-country projects such as Barakah.[123] However, the prospects for ongoing benefits of this nature may now be challenged. Westinghouse continued to provide components, such as reactor coolant pumps, for recently completed ROK reactors including Shin Kori 3 and 4, as it did for the Barakah project.[124] However, the newest South Korean reactors, Shin Hanul 1 and 2, will use locally made coolant pumps and control systems, further reducing the US content.[125] Thus, whether US components will be required for future ROK export projects similar to Barakah—and, therefore, whether US suppliers would be part of those projects—could be in doubt.

Regarding supply to the United States, Doosan provided components for Vogtle, but with the difficulties encountered at that project and the abandonment of VC Summer, the prospects for future large light water reactors (LWRs) in the United States—and, therefore, the prospects for South Korean suppliers to participate in the supply chain for large LWRs—is cloudy at best. However, the supply chain for advanced reactors could serve as an offsetting opportunity, though one that may take time to develop.

Frictions in the recent history of third-country nuclear opportunities may be an impediment to improved civil nuclear cooperation. Ultimately, the US diplomatic effort to establish a nuclear cooperation agreement with the UAE led to a primarily South Korean consortium, with the benefit of strong experience constructing nuclear projects in the ROK, winning the opportunity to build the Barakah project with US-licensed technology. Westinghouse benefitted from participation in the consortium, but it was not shortlisted with its own reactor technology.

More recently, when Toshiba Corporation faced financial difficulties after placing Westinghouse in bankruptcy, the fate of the NuGeneration (NuGen) project at the Moorside site in Cumbria, United Kingdom (UK), for which Toshiba was the sole remaining sponsor, was put into question. KEPCO entered discussions with Toshiba to acquire the project. Under Toshiba, the project was conceived as using the Westinghouse AP1000 technology, which had received UK regulatory approval. If KEPCO proceeded with the acquisition, it intended to change the project technology to the APR-1400 design it was in the process of constructing at Barakah, which would have required restarting the UK approval process.[126] Ultimately, KEPCO decided not to pursue the acquisition, and Toshiba cancelled the project because it was unable to find a buyer and could not justify the ongoing costs.[127]

US nuclear export policies are at the heart of simmering tensions involving US and South Korean commercial nuclear vendors and Saudi Arabia's potential interest in nuclear energy. The Saudi government first announced its potential interest in nuclear power in 2009, and subsequently established the King Abdullah City for Atomic and Renewable Energy (KA-CARE) to pursue this interest. In 2017, KA-CARE announced that it was soliciting proposals for nuclear projects from South Korea, China, Russia, and Japan.[128] US companies are also pursuing the potential Saudi projects and, in 2017, the Department of Energy granted Part 810 authorizations for US companies to "engage in discussions, including marketing, with the Saudi government regarding its civil nuclear program."[129]

However, the export of nuclear fuel and major reactor equipment requires a 123 agreement. Discussions between the United States and Saudi Arabia on a potential 123 agreement are stalled over potential restrictions on enrichment and reprocessing facilities in the Kingdom, as well as the current lack of a

119 "Nuclear Power in South Korea."

120 Gordon, *International Co-financing of Nuclear Reactors between the United States and Its Allies.*

121 Atlantic Council Task Force on US Nuclear Energy Leadership, *US Nuclear Energy Leadership: Innovation and the Strategic Global Challenge*, Atlantic Council, May 2019, https://www.atlanticcouncil.org/in-depth-research-reports/report/us-nuclear-energy-leadership-innovation-and-the-strategic-global-challenge-2/.

122 Email from Dong Hoon Lee, Washington, DC Representative, KAERI, September 29, 2020.

123 "U.S.-Republic of Korea (R.O.K.) Agreement for Peaceful Nuclear Cooperation."

124 McGoldrick, et al., "ROK-U.S. Civil Nuclear and Nonproliferation Collaboration in Third Countries."

125"Nuclear Power in South Korea."

126 "Kepco Named Preferred Bidder for UK's NuGen," *World Nuclear News*, December 7, 2017, https://www.world-nuclear-news.org/C-Kepco-named-preferred-bigger-for-UKs-NuGen-07121704.html.

127 Adam Vaughan, "UK Nuclear Power Station Plans Scrapped as Toshiba Pulls Out," *Guardian*, November 8, 2018, https://www.theguardian.com/environment/2018/nov/08/toshiba-uk-nuclear-power-plant-project-nu-gen-cumbria.

128 "Nuclear Power in Saudi Arabia," World Nuclear Association, last updated August 2020, https://world-nuclear.org/information-library/country-profiles/countries-o-s/saudi-arabia.aspx.

129 "Prospects for Enhanced U.S.-Saudi Nuclear Energy Cooperation," Congressional Research Service, last updated August 13, 2020, https://crsreports.congress.gov/product/pdf/IF/IF10799.

Saudi commitment to the International Atomic Energy Agency's Additional Protocol.[130] The US government's position has been that there is US technology in the APR1400 and, thus, US export control requirements exist regarding its potential export to Saudi Arabia.[131] Depending upon the resolution of these issues, and which reactors and suppliers are ultimately selected for Saudi Arabia's nuclear power program, the outcome could potentially put a damper on future US-ROK civil nuclear cooperation.

This situation highlights a recognized dilemma for US policymakers. While the United States seeks to pursue strong nonproliferation standards, Russia and China are competing with US and allied suppliers, including the ROK, to supply the Saudi interest, and can use flexibility regarding nonproliferation controls to their advantage.[132] If the United States and Saudi Arabia can come to an agreement, and US-origin reactors are supplied to Saudi Arabia, they will incorporate US safety certifications and technical approaches to nonproliferation. There are many potential markets for future nuclear-export opportunities. And, although the potential for future enrichment will not be an issue in many of them, circumstances similar to those in Saudi Arabia may well arise again.

130 Ari Natter, "U.S. Says Saudis Must Forgo Enrichment for Nuclear Sharing Deal," Bloomberg, September 18, 2019, https://www.bloomberg.com/news/articles/2019-09-19/u-s-says-saudis-must-forgo-enrichment-for-nuclear-sharing-deal.

131 "U.S. and South Korean Cooperation in the World Nuclear Energy Market: Major Policy Considerations."

132 Taylor Luck, "Why US Wants Saudis to Follow UAE's Path to Nuclear Energy," *Christian Science Monitor,* September 3, 2020, https://www.csmonitor.com/World/Middle-East/2020/0903/Why-US-wants-Saudis-to-follow-UAE-s-path-to-nuclear-energy.

ADVANCING US-ROK COOPERATION ON NUCLEAR ENERGY

CONCLUSIONS AND RECOMMENDATIONS

Civil nuclear cooperation between the United States and ROK could yield economic benefits from bilateral trade, mutual benefits in research and development, and better opportunities for the demonstration and deployment of advanced nuclear technologies. In addition, cooperation could enable a strengthened, more competitive presence in third-country projects, reflecting the complementary technical, operating, and financial capabilities of both countries, which would yield geopolitical and economic benefits. Actions on the part of US and South Korean commercial entities and governments could improve the opportunity to achieve these results.

- Commercial entities and governments in both countries should reconsider the value of joint participation in third-country projects. Separate from the technical requirements, there is value in the contribution of both US and ROK content and expertise that will bring with them improved operational, safety, regulatory, and financing capabilities, and will strengthen both countries' influence on the political and economic relationships that civil nuclear investment helps foster. Advanced reactors could become part of this effort, which would extend cooperation into the future of nuclear technology.

- The US and ROK governments should make greater investments in export financing for nuclear projects. Nuclear exports have always been a valuable means of creating long-term geopolitical relationships, and today are a key opportunity to support clean energy development in third countries. The steps recently taken by the United States to reauthorize the Ex-Im Bank and eliminate restrictions on nuclear projects in DFC financing have helped preserve the capability; now the resources need to be applied.

- The US and ROK governments should pursue greater cooperation on joint research, including potential shared funding of the US VTR and cooperation on associated research opportunities for which testing of proprietary technologies does not impose constraints.

- US and South Korean commercial entities should increase commercial cooperation on advanced reactors that will strengthen the supply chain for initial deployment and expand sources of funding for development and deployment, subject to the continued focus of developers and government funding of rebuilding the US supply chain as deployment expands. If the approach is thoughtful and balanced, initial support from the ROK supply chain and investment can support the recovery of the US supply chain, and both countries can benefit.

- The ROK nuclear establishment should restore opportunities for US firms to participate in the domestic South Korean nuclear infrastructure. ROK nuclear firms have made great strides toward creating a relatively self-sufficient domestic nuclear ecosystem. However, that may not be optimal from the perspective of civil nuclear cooperation. Even if South Korea continues on its path toward a domestic nuclear phase-out, there are potential opportunities for US firms to contribute to operational improvements, spent fuel storage, and decommissioning.

- While the United States by itself cannot resolve the issues impeding potential nuclear cooperation agreements, it should strive to make progress on those agreements through reasonable compromise.[133] Nonproliferation considerations represent a delicate balance, but US failure to

133 For example, see "KSA 123 Non-Proliferation Letter to US Congress," Nuclear Innovation Alliance, April 2018, https://www.nuclearinnovationalliance.org/ksa-123-non-proliferation-letter-us-congress; Robert Einhorn, "US-Saudi Civil Nuclear Negotiations: Finding a Practical Compromise," *Bulletin of the Atomic Scientists,* January 12, 2018, https://thebulletin.org/2018/01/us-saudi-civil-nuclear-negotiations-finding-a-practical-compromise/.

establish cooperation agreements with third countries will not only limit opportunities for cooperation between the United States and South Korea, as well as other potential partners, but will create a vacuum that will invite Russia and China to grow their own nuclear exports, with potential safety and nonproliferation consequences, and gain increased geopolitical influence.

- The US and ROK governments could benefit from greater use of the HLBC, including more frequent meetings, as a means of improving communications, facilitating the steps identified above, and resolving issues that may arise.

Both the US and ROK domestic nuclear industries are confronted with challenges. However, the growing international interest in nuclear energy technologies—mainly as a means to increase energy demand while also reducing carbon emissions—provides an opportunity for US-ROK civil nuclear cooperation to improve industry prospects, support shared geopolitical goals, and help address global energy and climate objectives.

ABOUT THE AUTHOR

Stephen S. Greene

Stephen S. Greene is a Non Resident Senior Fellow at the Atlantic Council Global Energy Center. He is a former energy and finance executive with extensive experience in commercial and policy issues related to energy. Most recently, he served in senior finance roles, including as chief financial officer for Centrus Energy, a public company engaged in the sale of nuclear fuel and the development of nuclear enrichment technology. He led strategy for Progress Energy, an investor-owned electric utility, and served as practice-area leader for the consultant Pace Global Energy focused on energy markets and risk management. He arranged project financing for PG&E National Energy Group (US Generating Company), a leading independent power developer and energy trader, and subsequently developed the company's power market outlook to support project development. Early in his career, he worked at the US Environmental Protection Agency on air pollution rules. He holds a Masters in Public Policy from the Harvard Kennedy School and a BA in physics from Princeton University.

Atlantic Council

Board of Directors

CHAIRMAN
*John F.W. Rogers

EXECUTIVE CHAIRMAN EMERITUS
*James L. Jones

PRESIDENT AND CEO
*Frederick Kempe

EXECUTIVE VICE CHAIRS
*Adrienne Arsht
*Stephen J. Hadley

VICE CHAIRS
*Robert J. Abernethy
*Richard W. Edelman
*C. Boyden Gray
*Alexander V. Mirtchev
*John J. Studzinski

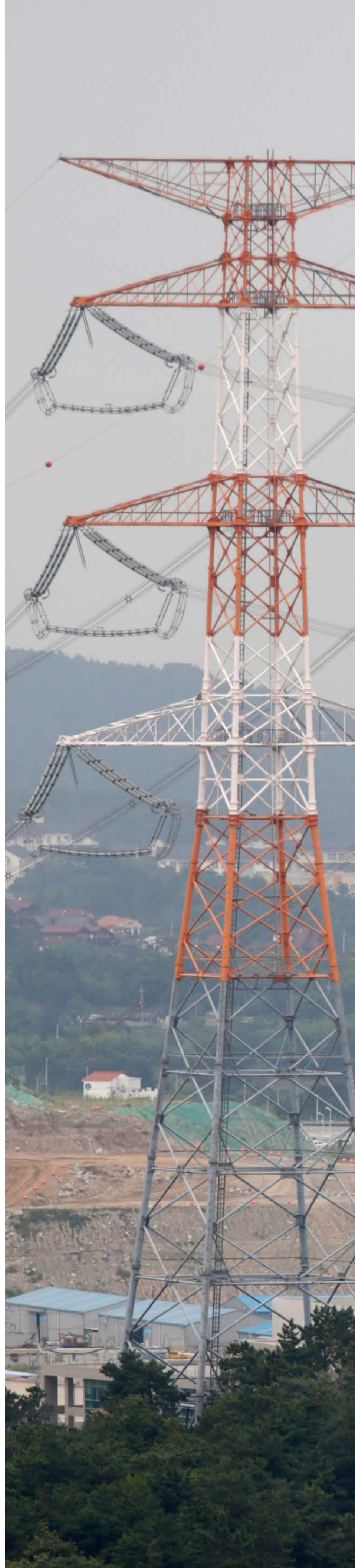
TREASURER
*George Lund

DIRECTORS
Stéphane Abrial
Todd Achilles
*Peter Ackerman
Timothy D. Adams
*Michael Andersson
David D. Aufhauser
Colleen Bell
*Rafic A. Bizri
*Linden P. Blue
Philip M. Breedlove
Myron Brilliant
*Esther Brimmer
R. Nicholas Burns
*Richard R. Burt
Michael Calvey
Teresa Carlson
James E. Cartwright
John E. Chapoton
Ahmed Charai
Melanie Chen
Michael Chertoff
*George Chopivsky
Wesley K. Clark
*Helima Croft
Ralph D. Crosby, Jr.
*Ankit N. Desai
Dario Deste
*Paula J. Dobriansky
Joseph F. Dunford, Jr.
Thomas J. Egan, Jr.
Stuart E. Eizenstat
Thomas R. Eldridge
*Alan H. Fleischmann
Jendayi E. Frazer
Courtney Geduldig
Thomas H. Glocer
John B. Goodman
*Sherri W. Goodman
Murathan Günal
Amir A. Handjani
Katie Harbath
Frank Haun
Michael V. Hayden
Amos Hochstein
*Karl V. Hopkins
Andrew Hove
Mary L. Howell
Ian Ihnatowycz
Wolfgang F. Ischinger
Deborah Lee James
Joia M. Johnson
*Maria Pica Karp
Andre Kelleners
Astri Kimball Van Dyke
Henry A. Kissinger
*C. Jeffrey Knittel
Franklin D. Kramer
Laura Lane
Jan M. Lodal
Douglas Lute
Jane Holl Lute
William J. Lynn
Mark Machin
Mian M. Mansha
Marco Margheri
Chris Marlin
William Marron
Neil Masterson
Gerardo Mato
Timothy McBride
Erin McGrain
John M. McHugh
H.R. McMaster
Eric D.K. Melby
*Judith A. Miller
Dariusz Mioduski
*Michael J. Morell
*Richard Morningstar
Dambisa F. Moyo
Virginia A. Mulberger
Mary Claire Murphy
Edward J. Newberry
Thomas R. Nides
Franco Nuschese
Joseph S. Nye
Ahmet M. Ören
Sally A. Painter
Ana I. Palacio
*Kostas Pantazopoulos
Alan Pellegrini
David H. Petraeus
W. DeVier Pierson
Lisa Pollina
Daniel B. Poneman
*Dina H. Powell McCormick
Robert Rangel
Thomas J. Ridge
Lawrence Di Rita
Michael J. Rogers
Charles O. Rossotti
Harry Sachinis
C. Michael Scaparrotti
Rajiv Shah
Wendy Sherman
Kris Singh
Walter Slocombe
Christopher Smith
James G. Stavridis
Michael S. Steele
Richard J.A. Steele
Mary Streett
*Frances M. Townsend
Clyde C. Tuggle
Melanne Verveer
Charles F. Wald
Michael F. Walsh
Gine Wang-Reese
Ronald Weiser
Olin Wethington
Maciej Witucki
Neal S. Wolin
*Jenny Wood
Guang Yang
Mary C. Yates
Dov S. Zakheim

HONORARY DIRECTORS
James A. Baker, III
Ashton B. Carter
Robert M. Gates
James N. Mattis
Michael G. Mullen
Leon E. Panetta
William J. Perry
Colin L. Powell
Condoleezza Rice
Horst Teltschik
John W. Warner
William H. Webster

**Executive Committee Members*

List as of February 8, 2021



The Atlantic Council is a nonpartisan organization that promotes constructive US leadership and engagement in international affairs based on the central role of the Atlantic community in meeting today's global challenges.

© 2021 The Atlantic Council of the United States. All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means without permission in writing from the Atlantic Council, except in the case of brief quotations in news articles, critical articles, or reviews. Please direct inquiries to:

Atlantic Council
1030 15th Street, NW, 12th Floor,
Washington, DC 20005
(202) 463-7226, www.AtlanticCouncil.org