ISSUE BRIEF

US Nuclear-Power Leadership and the Chinese and Russian Challenge

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Despite the ascendancy of natural gas and renewable energy, nuclear power continues to play a significant role in the global energy transition, providing about 10 percent of global electricity production in 2016.[1] Nuclear, besides being a significant carbon-free source of electricity, is also critically important from a strategic and defense standpoint. While the United States has the largest number of nuclear plants in the world, the US global leadership position is declining as efforts to build a new generation of reactors have been plagued by problems, and aging plants have been retired or closed in the face of economic, market, and financial pressures. The situation is not unique to the United States; except for the UK, major US allies are closing (Germany), scaling back (France and South Korea), or debating the reopening (Japan) of their nuclear-power plants.[2] In contrast, China and Russia are continuing to develop their nuclear industries and aggressively pursuing global markets, especially in critical regions such as the Middle East and South Asia.

In the December 2017 National Security Strategy (NSS2017), the Donald Trump administration states its intention to "embrace energy dominance" by pursuing five main actions: reducing barriers to US energy development; promoting exports of energy, technology, and services; ensuring the energy security of the United States and its allies; attaining universal energy access; and furthering the US technological edge in energy.[3] Although there is clearly a strong fossil-fuels orientation behind

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1 *World Nuclear Industry Status Report* (Paris: Mycle Schneider Consulting, 2017), Figure 1, p. 24, https://www.worldnuclearreport.org/.

2 Germany plans to close all its reactors by 2022; France is looking to scale back the role of nuclear from 75 to 50 percent by 2025; South Korea is scaling back its plans for new nuclear, and considering phasing out nuclear; and Japan, which has opened five of forty-eight reactors after the Fukushima accident, is considering opening an additional four of the twenty-one reactors that have submitted applications to reopen.

3 White House, *National Security Strategy of the United States of America* (Washington, DC: White House, 2017), pp. 22–23, https://www.whitehouse.gov/wp-content/

the "energy dominance" theme, it is important to consider whether, and how, nuclear power fits into this strategy, and the implications of developments in the United States for the US competitive position vis-à-vis China and Russia.

This issue brief continues the dialogue initiated at an Atlantic Council November 2017 nuclear-power roundtable, by examining the challenges facing the US nuclear industry and the geopolitical implications for the United States presented by domestic and international nuclear developments in China and Russia. The brief recognizes the strategic nature of nuclear power, and identifies key policy issues ripe for further work.

STATUS AND PROSPECTS FOR NUCLEAR POWER IN THE UNITED STATES

Energy diversification is generally recognized as a central means of increasing energy security, reducing vulnerabilities, and enhancing the resilience of the power system. The NSS2017 states: "The United States will support the diversification of energy sources, supplies, and routes at home and abroad."[4] Furthermore, US Secretary of Energy Rick Perry argues in his September 28, 2017, letter to the Federal Energy Regulatory Commission that "America's greatness depends on a reliable, resilient electric grid powered by an 'all of the above' mix of generation resources." He warns that the United States should guard against the threat of energy outages that could result from the loss of traditional baseload capacity.[5]

Nuclear power is an important component of a diversified US energy mix. There are ninety-nine operational reactors at sixty sites in the United States, amounting to 97,728 megawatts (MW) generating 805,694 megawatt hours (MWh) in 2016, accounting for about 20 percent of US total electricity supply and nearly 60 percent of carbon-free electricity, avoiding an estimated 554 million tons of carbon.[6,7] Forty-seven percent was supplied by independent nuclear-power producers, and the rest by integrated utilities.[8]

These nuclear reactors provide reliable baseload power generation at a reasonable cost.[9] In 2016, average reliability was 92.5 percent, and average generation cost was $33 per MWh. Exelon, which accounts for nearly one-quarter of US nuclear capacity with its twenty-three reactors with 23,300 MW, reported that its plants ran at a record average-capacity factor of 94.6 percent in 2016.[10]

Although US nuclear plants are aging, with 40 percent of the plants more than forty years old, the US Nuclear Regulatory Commission (NRC) since 2000 has extended licenses from forty to sixty years for more than 85 percent of operating US reactors. The industry argues that these plants have many years of useful life remaining, and the first license application for eighty years has been submitted. Generators have invested heavily in upgrading their equipment and safety systems, especially after the 2011 Fukushima accident, and have steadily improved their operating efficiency and capacity utilization.

However, faced with competition from gas and renewables generators, operating companies and utilities have closed reactors and, absent financial relief, announced plans for further closures. Between 2002 and 2016, the United States saw 4,666 MW of nuclear-generating capacity close, while Secretary's Perry letter to the FERC indicates eight reactors with 7,167 MW of capacity have announced plans for retirement, and another seven reactors have only kept operating due to support at the individual state level.[11] Given these developments, the share of nuclear in the US electricity mix may fall 3-4 percent over the next decade, to around 16-17 percent of US electricity supply, if demand remains level.

Pressured by cheap gas and renewable generation, and beset by continued problems related to financing, nuclear plants are most affected in regions with unbundled, competitive, independent system operators (ISO) and regional transmission system operators (RTO). The industry argues that these markets do not value the clean generation, reliability, security, and diversity of supply that nuclear provides. Even in areas with formal capacity markets, nuclear has had difficulty competing with gas in capacity auctions (e.g., in the PJM Interconnection region auctions, where the clearing price of $76.53 per megawatt day in its May 2017 base residual auction for 2020-21 capacity was too low for Exelon's Three Mile Island and Quad Cities plants to clear).[12,13]

The future of US nuclear power is also clouded by the difficulties and huge cost overruns in completing the four Generation III Westinghouse AP-1000 units in Georgia and South Carolina, and the resulting financial difficulties that pushed Toshiba-Westinghouse into bankruptcy. In 2017, the Georgia regulator approved Georgia Power's proposal to proceed with the completion of the two Georgia Vogtle reactors, but South Carolina decided to cancel the plans to complete its two plants. Westinghouse is coming out of bankruptcy, and has been purchased by a Canadian firm.[14] The Department of Energy also announced its willingness to provide an additional $3.7 billion in loan guarantees for the Vogtle completions, and Congress has approved the extension of the production tax credit (PTC) for advanced nuclear reactors.[15,16]

While these challenges are substantial, the consequences of a dramatic reduction of nuclear power in the United States—or even its end—would be dramatic, and the costs of premature shutdown would be significant. This cautionary tale is playing out in US-allied countries, including Germany and Japan, where there has been a large downgrading in utilities' financial position from closures. In Germany, utilities have sought to recover more than 20 billion euros in lost profits.

The benefits lost from a decline in domestic nuclear power would be substantial.

While any lost capacity in the United States could likely be covered from a supply standpoint—given the surplus electricity-generation supply conditions in many regions, and the minimal growth of electricity demand—it would cost tens of billions of dollars and, depending on the renewable-energy component of the replacement capacity, could increase emissions levels. Officials at the state level, notably in New York, Illinois, Ohio, Pennsylvania, New Jersey, and Connecticut, have been concerned about these potential economic impacts, as well as the increased emissions implications of nuclear-plant closures. New York and Illinois have approved zero-emissions credit (ZEC) schemes to support nuclear power, which have allowed nuclear generators to extend plant operations. The courts have, thus far, upheld these actions.[17]

The benefits lost from a decline in domestic nuclear power would be substantial. The Nuclear Energy Institute calculates that the ninety-nine US reactors support 475,000 jobs, provide $60 billion in benefits to the US economy, account for $12 billion in federal and state tax revenues, and undertake capital investment of $6.3 billion

uploads/2017/12/NSS-Final-12-18-2017-0905.pdf.

4 Ibid., p. 21.

5 Rick Perry, "Secretary of Energy's Direction that the Federal Energy Regulatory Commission Issue Grid Resiliency Rules Pursuant to the Secretary's Authority Under Section 403 of the Department of Energy Organization Act," September 29, 2017, p. 1, https://energy.gov/sites/prod/files/2017/09/f37/Secretary%20Rick%20Perry%27s%20Letter%20to%20the%20Federal%20Energy%20Regulatory%20Commission.pdf.

6 US Energy Information Administration, "What is US Electricity Generation by Energy Source?" April 18, 2017, https://www.eia.gov/tools/faqs/faq.php?id=427&t=3.

7 Nuclear Energy Institute, "Environment: Emissions Prevented," https://www.nei.org/Knowledge-Center/Nuclear-Statistics/Environment-Emissions-Prevented.

8 US Energy Information Administration, *Electric Power Annual 2016* (Washington, DC: EIA, 2017), Table 1.1, https://www.eia.gov/electricity/annual/pdf/epa.pdf.

9 Baseload power is power from plants that operate on a continuous basis at a high capacity factor, and do not follow changes in the demand curve.

10 Exelon Corporation, *Corporate Sustainability Report 2016* (Chicago: Exelon, 2016), http://www.exeloncorp.com/sustainability/Documents/dwnld_Exelon_CSR%20(1).pdf.

11 Ibid., p. 3.

12 Jeff St. John, "PJM's Latest Capacity Auction: A Tough Market for Nuclear and Demand Response," *Greentech Media*, May 24, 2017, https://www.greentechmedia.com/articles/read/pjms-capacity-auction-a-poor-showing-for-nuclear-and-demand-response#gs.bqlRP9A.

13 World Nuclear Association, "Nuclear Power in the USA," http://www.world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-power.aspx; Rory D. Sweeney and Rich Heidorn Jr., "Updated: Capacity Prices Down in Most PJM in 1st Year of 100% CP," *RTO Insider*, May 23, 2017, https://www.rtoinsider.com/pjm-capacity-auction-capacity-performance-emaac-43440/.

14 Anastaciah Ondieki, "Canadian Firm to Purchase Former Vogtle Lead Contractor Westinghouse," *Atlanta Journal-Constitution*, January 8, 2018, http://www.myajc.com/news/canadian-firm-purchase-former-vogtle-lead-contractor-westinghouse/FU9UtNTW1Ljw6WIlUWRVeL/.

15 Darrel Proctor, "DOE Offers Another $3.7 billion in Loan Guarantees for Vogtle Project," *Power*, September 29, 2017, http://www.powermag.com/doe-offers-another-3-7-billion-in-loan-guarantees-for-vogtle-project/.

16 Georgia Power, press release, "Georgia Power Praises Move by US Congress to Extend Production Tax Credits for Vogtle Nuclear Expansion," February 9, 2018, https://www.prnewswire.com/news-releases/georgia-power-praises-move-by-us-congress-to-extend-production-tax-credits-for-vogtle-nuclear-expansion-300596383.html.

17 Adrienne Thompson and Christopher Zentz, "Federal District Court Dismisses Challenges to New York ZEC Program," *Washington Energy Report*, July 31, 2017, https://www.troutmansandersenergyreport.com/2017/07/federal-district-court-dismisses-challenges-new-york-zec-program/.

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per year.[18] Nuclear supply and services companies also play significant roles in support to the US military and defense industry, as well as contributing to US exports. The Energy Futures Initiative (EFI), chaired by former US Secretary of Energy Ernest Moniz, has identified more than seven hundred companies in forty-four states that provide products or services in direct support of the US nuclear-energy industry, with Pennsylvania, California, Texas, Illinois, and Ohio leading the way. According to EFI, the US nuclear supply chain has been eroding, and domestic nuclear-equipment manufacturing capability has declined, with limited or no domestic fabrication capacity for reactor pressure vessels, steam generators, pressurizers, main condensers, turbine generators, specialized valves, and passive residual-heat removal.[19]

In September 2017, the Trump administration sought to bolster the finances of existing nuclear plants, as well as coal plants, by proposing to the Federal Energy Regulatory Commission (FERC) a rule that would provide full cost recovery for secure-fuel plants that enhance reliability and resilience. The FERC rejected the proposed rule as discriminatory and inadequately supported. Instead, it directed further consideration of the issues of reliability and resilience in specific markets.[20]

Looking ahead on the technology front, research and development (R&D) funded by the US Department of Energy ($500 million in fiscal year 2017 (FY17)) and some private venture capital sources are proceeding on both Generation IV large reactors and small modular reactors (SMR). Secretary Perry has expressed support for nuclear R&D, and the NSS2017 contains a general reference to support for new nuclear-reactor designs. However, without large-scale US government support, it is unclear whether this work can proceed at a meaningful pace. The Nuclear Regulatory Commission is reviewing a design-certification application from one Energy Department recipient, NuScale, for an SMR design. Based on an initial January 2018 NRC decision on NuScale power supply, a much quicker licensing process for SMRs appears likely.[21] However, there seems to be limited US market interest in these reactors at the moment. Considerable US technical cooperation on new designs is occurring with China, for example with Bill Gates' TerraPower, as discussed below.

CHINESE AND RUSSIAN NUCLEAR-POWER EXPANSION

In sharp contrast to developments in the United States, China and Russia are pushing to expand their nuclear industries, develop complete fuel cycles, and build and commercialize new reactors for both domestic and international markets. The results of these efforts are striking—nearly two-thirds of the new reactors under construction worldwide are estimated to be using designs from China and Russia.[22]

Driven by domestic environmental and energy-supply concerns, and a desire to boost its global commercial and climate leadership, China under President Xi Jinping has charted a path to diversify its energy economy away from coal and reduce its carbon intensity.[23] In December 2017, the State Council approved a nationwide cap-and-trade system, to go into effect in 2019, involving 1,700 power companies accounting for more than three billion tons of carbon dioxide (CO2) annually, representing one-third of China's total carbon emissions and making it the largest cap-and-trade system in the world.

China is the third-largest generator of nuclear power in the world as of 2016, after the United States and France, with thirty-seven operating reactors and a capacity of 32 gigawatts (GW).[24,25] China has the largest nuclear construction program in the world by far, with twenty (20.5 GW) of the fifty-three total reactors under

18 Nuclear Energy Institute, NEI supplemental material for annual 2017 briefing to financial community, p. 10, https://www.nei.org/Issues-Policy/Economics/Financial-Analyst-Briefings/NEI-2017-Wall-Street-Briefing.

19 Energy Futures Initiative, *The U.S. Nuclear Enterprise: A Key National Security Enabler* (Washington, DC: Energy Futures Initiative, 2017), p. 9, https://static1.squarespace.com/static/58ec123cb3db2bd94e057628/t/5992f7e0bf629ad8f9d575ec/1502803938248/EFI+Nuclear+Report+FINAL+08.2017.pdf.

20 US Federal Energy Regulatory Commission, "Order Terminating Rulemaking Proceeding, Initiating New Proceeding, and Establishing Additional Procedures," January 8, 2018, https://www.ferc.gov/CalendarFiles/20180108161614-RM18-1-000.pdf.

21 Nuclear Energy Institute, "NRC Approves NuScale Design Innovation," January 11, 2018, https://www.nei.org/News-Media/News/News-Archives/2018/NRC-Approves-NuScale-Design-Innovation.

22 Maria Korsnick, "Nuclear Power is Critical Infrastructure," 2017 Wall Street briefing, February 9, 2017, https://www.nei.org/News-Media/Speeches/Nuclear-Power-is-Critical-Infrastructure.

23 For a discussion of China's power-sector transition, see Robert F. Ichord, Jr., *Transformation the Power Sector in Developing Countries: The Critical Role of China in Post-Paris Implementation* (Washington, DC: Atlantic Council, 2017), http://www.atlanticcouncil.org/publications/reports/transforming-the-power-sector-in-developing-countries-the-critical-role-of-china-in-post-paris-implementation.

24 World Nuclear Association, "Nuclear Share Figures, 2006-2016," April 2017, http://www.world-nuclear.org/information-library/facts-and-figures/nuclear-generation-by-country.aspx.

25 World Nuclear Industry Status Report, p. 98.

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construction worldwide.[26] However, nuclear power still accounts for only 4 percent of total generation in China. The Thirteenth Five-Year Plan (2016-2020) calls for 58 GW of nuclear capacity online by 2020-2021, and an additional 30 GW under construction at that time—although this target is viewed as ambitious, given delays in construction and fewer new starts, with just two in 2016 and none in the first half of 2017. Given the size and projected growth of the Chinese electricity system, currently 1645 GW, nuclear will remain well below 10 percent of electricity generation in 2020, despite the additions. For comparison, China added 52 GW of solar and wind capacity in 2016; solar additions alone were forecasted to jump from 34 GW to 54 GW in 2017.[27]

> Nearly two-thirds of the new reactors under construction worldwide are estimated to be using designs from China and Russia.

China's nuclear strategy has been to establish joint ventures with Western companies (Toshiba-Westinghouse, Frametome-AREVA, SNC-Lavalin, Energoatom) to build and evaluate different technologies (AP-1000, EPR, Candu, VVER-1000), and to incorporate this experience into its own indigenous designs. Although cost estimates are difficult to obtain, China has seemingly been able to build reactors quicker, and at lower cost, than Europe, the United States, and even South Korea. A 2015 report from the Organisation for Economic Co-operation and Development (OECD) Nuclear Energy Agency (NEA) estimates that (without financing) the average overnight costs for nuclear power in China is about $3,500/kilowatt (kW). This is more than one-third less than the $5,500/kW cost in the European Union, with multiple units at Chinese sites reducing costs by a further 15 percent. While South Korea has had relatively stable costs, which are 25 percent lower than those in the European Union, they are also higher than China's.[28]

Despite the Chinese government's commitment to nuclear, the falling costs of renewables pose an economic challenge for Chinese companies and officials. As Steve Thomas of the University of Greenwich comments: "The challenge for the Chinese nuclear industry is to do what no other nuclear industry worldwide has been able to do: to bring the cost of nuclear generation down to levels at which it can compete with other forms of generation, particularly renewables."[29]

China brings a complete package of design, construction, labor, technology, and financing, which improves the economics compared to industries in the West. However, it is clear that the six imported nuclear plants (four from Toshiba/Westinghouse and two from AREVA) have experienced difficulties. The four AP1000s from Westinghouse have been delayed three to four years, in part due to a national safety reassessment after the Fukushima accident halted construction. Chinese planners are no doubt interested in maintaining a favorable price of electricity to their industries for reasons of global competitiveness. Therefore, whether China's diversification strategy will continue to stress the large increases in nuclear capacity will indicate something about how it views the relative economics of the sector. But, as in many other countries, nuclear-power decisions in China are heavily driven by political considerations and international implications.

China has become an international test bed for advanced nuclear development. State funding for nuclear research, development, and demonstration has supported a wide range of efforts on large and small designs, including high-temperature gas-cooled reactors (HTGR), small modular reactors (SMR), and new Canada Deuterium Uranium (CANDU) designs. One pioneering project involves the construction by the China Nuclear Engineering Construction Corporation of a 2x105-MW, high-temperature, gas-cooled, pebble-bed nuclear plant (HTGR) in Shandong Province, south of Beijing. The plant is nearing completion and, if commercially viable, will be scaled up to 600 MW. An HTGR 600-MW unit is planned for Ruijin city in Jiangzi

26 Ibid., p. 15.

27 Joshua S. Hill, "BNEF Elevates China 2017 Solar Installation Forecast to 54 Gigawatts," *Clean Technica,* November 22, 2017, https://cleantechnica.com/2017/11/22/bnef-elevates-china-2017-solar-installation-forecast-54-gw/.

28 World Nuclear Association, "The Economics of Nuclear Power," August 2017, http://www.world-nuclear.org/information-library/economic-aspects/economics-of-nuclear-power.aspx.

29 Steve Thomas, "China's Nuclear Power Plans Melting Down," *Diplomat*, October 29, 2016, https://thediplomat.com/2016/10/chinas-nuclear-power-plans-melting-down/.

Province.[30] The HTGR-type reactors are especially suited to industrial applications with large process-heat needs, such as petrochemical industries.

One of the most publicized efforts is Microsoft founder Bill Gates' establishment of TerraPower, a private company pursuing a traveling-wave reactor (TWR) design that is sodium cooled, uses depleted uranium, eliminates the need for fuel reprocessing, and keeps the fuel in the reactor for up to forty years.[31] It is also evaluating a molten-chloride reactor approach. TerraPower has teamed up with companies from China, India, Russia, and France to develop the approach, and concluded a joint venture with the China National Nuclear Corporation (CNNC) that will demonstrate the TWR design in a project in Hebei Province.[32] In a different approach, the Canadian firm SNC-Lavalin concluded a joint venture with the CNNC and the Shanghai Electric Group in 2016 to develop a new, 700-MW advanced-fuel CANDU reactor (AFCR) that can use recycled fuel from light-water reactors (China has more than thirty-three LWRs).[33]

Chinese nuclear companies are also working on several SMR designs. The CNNC is developing a small, 125-MW ACP100 unit in Hainan Province, which operates at lower temperatures and pressures. China General Nuclear Corporation is also developing a 60-MW APR505 reactor for remote and offshore applications, currently under construction for a floating installation at a drilling platform in the Bohai Sea. This development has been viewed with concern, in the context of tensions with the United States and other countries over Chinese militarization of islands in the South China Sea.[34]

While China's relationship with nuclear power is relatively new—with its first nuclear plant completed in 1991—Russia's long history with nuclear power dates to 1954, when the first reactor was commissioned in Obninsk, followed by larger-scale commercial reactors in 1963–1964. The industry has since grown to thirty-five reactors, totaling 26.9-GW capacity.[35] Nuclear generation reached a record of 196.366 terawatt hours (TWh) in 2016, accounting for 17 percent of domestic electricity generation, and further increased to 202.868 TWh and 19.9 percent in 2017.[36]

Russia has seven reactors under construction, and envisions about 30 GW of new installations by 2030, although reports indicate that Rosatom may delay some plants due to low electricity demand and surplus power capacity in Russia.[37] Financial difficulties have also caused delays, such as with the two new-generation VVER-1200-491s under construction in Saint Petersburg, and reduced oil and gas revenues have led to a drop in the state budget for nuclear—from $2.4 billion in 2013 to $1 billion in 2017, and to $898 million in the proposed September 2017 budget—resulting in construction delays.[38]

Russia is also active in developing nuclear technology, including a third-generation reactor, the VVER-1200, and is close to commissioning the first VVER-1200-V392M unit in Novovoronezh. China is also testing—and nearly ready to commission—its first Toshiba-Westinghouse AP1000, so the race to operate the first third-generation system is very close.

Like China and the United States, Russia is also working on a variety of advanced reactor designs. Russia's vision of the future revolves around the development of fast-breeder reactors and a closed fuel cycle. The Proyv

30 "China Expands Uses and Markets for its HTGRs," *World Nuclear News*, March 18, 2017, https://neutronbytes.com/2017/03/18/china-expands-uses-markets-for-its-htgrs/; Richard Martin, "China Could Have a Meltdown-Proof Nuclear Reactor Next Year," *MIT Technology Review*, February 11, 2016, https://www.technologyreview.com/s/600757/china-could-have-a-meltdown-proof-nuclear-reactor-next-year/.

31 TerraPower, "The Traveling Wave Reactor: Bringing Nuclear Technology to its Fullest Potential," http://terrapower.com/uploads/docs/The_TWR_Bringing_Nuclear_Technology_to_Its_Fullest_Potential_030713.pdf.

32 Stephen Stapczynski, "Nuclear Experts Head to China to Test Experimental Reactors," *Bloomberg Technology*, September 21, 2017, https://www.bloomberg.com/news/articles/2017-09-21/nuclear-scientists-head-to-china-to-test-experimental-reactors.

33 SNC Lavalin, press release, "SNC Lavalin signs an agreement in principle for a Joint Venture with China National Nuclear Corporation and Shanghai Electric Company," September 22, 2016, http://www.snclavalin.com/en/news/2016/snc-lavalin-signs-agreement-principle-joint-venture-china-national-nuclear-corporation-shanghai-electric-company.

34 David Stanway, "China Close to Completing First Offshore Nuclear Reactor," *Reuters*, October 30, 2017, https://www.reuters.com/article/us-china-nuclearpower-offshore/china-close-to-completing-first-offshore-nuclear-reactor-idUSKBN1D0048; Sonal Patel, "China Starts Building SMR-Based Floating Nuclear Plant," *Power*, January 1, 2017, http://www.powermag.com/china-starts-building-smr-based-floating-nuclear-plant/.

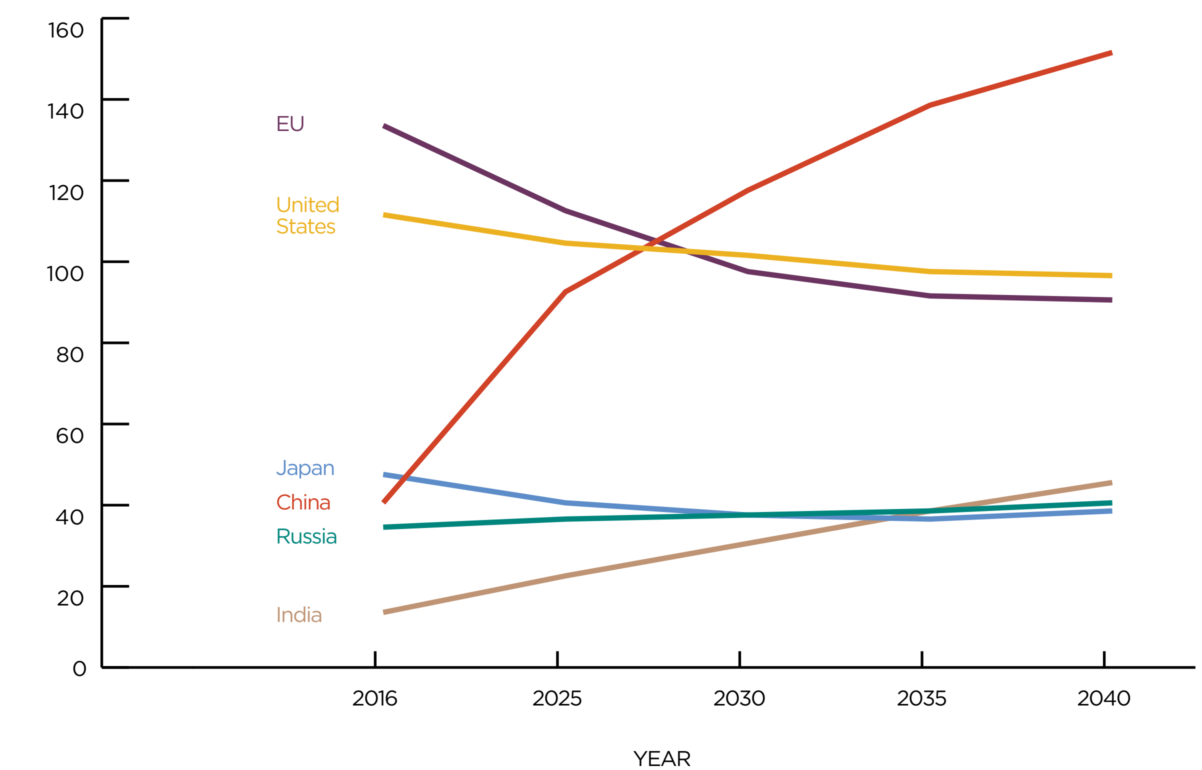
35 World Nuclear Association, "Nuclear Power in Russia," http://www.world-nuclear.org/information-library/country-profiles/countries-o-s/russia-nuclear-power.aspx.

36 Rosatom, press release, "Russia's Nuclear Electricity Share Increased up to 19.9% in 2017," January 12, 2018, http://www.rosatom.ru/en/press-centre/news/russia-s-nuclear-electricity-share-increased-up-to-18-9-in-2017/.

37 "Rosatom Considers Delaying Reactor Commissioning," *Nuclear Engineering International*, October 30, 2017, http://www.neimagazine.com/news/newsrosatom-considers-delaying-reactor-commissioning-5959916.

38 World Nuclear Industry Status Report, p. 235.

Figure 1. Projected Installed Nuclear Generation Capacity (GW) in Selected Countries and EU, 2016–2040



Source: Figure created from data in International Energy Agency, World Energy Outlook 2017, Selected Country Annexes, New Policies Scenario.

(Breakthrough) project is working in nine research centers to develop the BREST-300, BN-1200, SVBR-100, and other fast reactors that can recycle fuel. However, this project has experienced considerable problems, delays, and budget issues. In the context of President Vladimir Putin's aggressive military buildup in the Arctic, it is important to note that Russia is also developing small modular reactors, including floating reactors and barge- or ship-based units, for naval bases, icebreakers, and submarines.[39]

THE GLOBAL NUCLEAR MARKET AND US FOREIGN POLICY

While nuclear development is largely stalled in the United States, there is still a robust interest in nuclear power around the world, driven, in part, by Russian and Chinese externally facing efforts. While new nuclear-plant construction declined globally for the fourth year in a row in 2016, thirty-one countries operated nuclear reactors as of mid-2017.[40]

Whether the United States, or China or Russia, leads on nuclear power is important, as the International Energy Agency's *World Energy Outlook* for 2017 projects that nuclear will continue to maintain at least a 10-percent share of electricity through 2040, with an additional 273 GW in new nuclear capacity, even as 170 GW is forecast to be retired. China, Russia, and India are expected to account for the largest share of additions, while retirements continue in Germany, the United States, Japan, South Korea, and France. (See Figure 1).

Although the rapidly changing international power economics generally favor renewables, natural gas, and, in some cases, coal, nuclear development will be important in several strategic countries. Even in instances when there are more cost-effective alternatives,

39 World Nuclear Association, "Nuclear Power in Russia."

40 Ibid., p. 23.

countries are deciding to proceed with nuclear power, driven by security, diversity of supply, prestige, and environmental factors. Indeed, even Russia's Rosatom has begun promoting the climate benefits of nuclear power under its new head, Alex Likhachev.[41]

In addition to having an active nuclear program at home, China is seeking markets abroad, with financing from the Chinese Export-Import Bank. It has pursued three significant directions: investment and contracting for the construction of existing reactors (e.g., with EDF in the UK); marketing and construction of its indigenous Hualong design (e.g., with Pakistan, Argentina, Turkey, and the UK); collaboration with Candu Energy on new plants (e.g., Argentina and Romania) and in the joint development of an advanced CANDU reactor design.

President Xi's high-visibility "Belt and Road Initiative" involves an estimated $1.1 trillion for infrastructure, including power-plant construction.[42] The Belt and Road also concentrates on nuclear-power development in Pakistan, Turkey, and Romania, and China is looking to commercialize HTGR designs overseas, particularly in countries with large petrochemical and process-heat requirements, such as Saudi Arabia and Indonesia. While the economics of SMRs are currently uncertain, they may become attractive in smaller developing countries.

Meanwhile, Russia has supported nuclear-technology exports using resources from both the Russian budget and the Russia Wealth Fund, which was created when oil prices and revenues were high. However, these resources are declining, and are being stretched thin. While long-standing relations with Iran, Eastern Europe, and former Soviet republics continue to receive priority attention, over the past few years Russia has aggressively pursued deals in the Middle East and South Asia. In South Asia, Russia is building new reactors in India and Bangladesh. In the Middle East, Russia, is focusing on Turkey, Egypt, Jordan, and Saudi Arabia, in addition to its long-standing relationship with Iran.

The Middle East is emerging as an arena of intense nuclear competition and positioning, with the first South Korean nuclear units nearing completion in the United Arab Emirates, Jordan continuing to negotiate on financing for two Russian nuclear reactors, Egypt recently finalizing a deal with Russia, and Saudi Arabia announcing its intention to proceed with two reactors after years of delay. The Chinese, French, Russians, and South Koreans have submitted initial bids in Saudi Arabia, and a US consortium has also submitted a bid on this first phase of the process of shortlisting companies. The bid was approved by the US Department of Energy, even though the United States has not yet concluded a 123 nuclear-framework agreement with the Saudis, which would be necessary before a US export deal could be finalized. Although 123 agreements do not necessarily require that a country refrain from fuel-enrichment development or reprocessing of spent fuel, 123 agreements with the United Arab Emirates and Taiwan prohibit such development. During his December 2017 visit to Saudi Arabia, Secretary of Energy Perry held private discussions on nuclear cooperation, and formal discussions are expected to start in a couple of months, amid concerns in the United States about the Trump administration's possible willingness to lessen nuclear-proliferation safeguards.[43]

The Russians have actively pursued nuclear deals in the Middle East to advance their position in the region. In addition to its long-standing cooperation with Iran in building the Bushehr 1 nuclear plant and beginning a second unit, Russia is working to finalize a preliminary 2015 agreement with Egypt to build four nuclear units at Dabaa, on the Mediterranean.[44] Just days after President Trump's controversial December 6, 2017, announcement recognizing Jerusalem as Israel's capital, Putin visited Egypt and signed the final agreement for the $25 billion, 4800-MW nuclear-power project.[45]

Russia's support for Turkey's first nuclear plant at Akkuyu, as well as the Turkish Stream gas pipeline, is part of its strategic engagement with Turkey. Although work on the plant was momentarily halted following Turkey's downing of a Russian jet, Rosatom resumed construction, and the first unit is expected to be operational in 2023.[46] Looking to increase its security cooperation with Turkey at a time of tensions in the US-Turkey relationship, Russia achieved a major strategic advance in late 2017 when NATO member Turkey agreed to buy a S-400 surface-to-air missile-defense system from Russia in a deal reportedly worth $2.5 billion.[47]

Russia has also pushed for nuclear deals elsewhere, including in South Africa. However, the future of these plans appears in doubt, due to domestic politics in the country. Russia has also been pursuing nuclear agreements in Nigeria and Ghana. Elsewhere, Russia is continuing construction of two new VVER-1200 units in Belarus, and began construction of two similar units in Rooppur, Bangladesh in November 2017. In 2018, Russia is hoping to start construction of the Paks-II plant in Hungary, also a 2x VVER-1200 design.[48]

The Russians have actively pursued nuclear deals in the Middle East to advance their position in the region.

India—a central country in many ongoing debates about the future of energy demand—is an important arena for nuclear-power competition among Westinghouse, France's AREVA, and Russia's Rosatom; in June 2017, Indian Prime Minister Narendra Modi and Putin signed an agreement to proceed with two new reactors at Kudankulam.[49] Putin's nuclear diplomacy in India is especially interesting considering the Trump administration's effort to enhance bilateral trade and defense relationships with the Modi government. Although India had never signed the Nuclear Non-Proliferation Treaty, the United States concluded a 123 agreement with India (US-India Civil Nuclear Agreement) in 2006, which opened the way for Toshiba-Westinghouse and Hitachi-GE to pursue nuclear-power cooperation. In 2016—following years of obtaining international approvals from the IAEA and the Nuclear Suppliers Group, enactment of a law from Congress, and discussions on liability and other issues—Westinghouse announced a project for construction of six nuclear reactors at Kovvada in Andra Pradesh. The July 2017 communique from Prime Minister Modi's visit with President Trump cites the interests of the two leaders in seeing the conclusion of the agreements for the project.[50] Recent reports indicate that Westinghouse, after emerging from bankruptcy, is still interested in the project.[51]

The Chinese and Russian use of nuclear-power financing and technology as a means of expanding their overseas physical presence, and their foreign-policy influence in key countries, has important implications for the United States. On one hand, US companies are collaborating with China on building, developing, and demonstrating new reactors; GE has won tenders for the supply of turbine generators for new Russian-supplied units in Hungary and Turkey.[52] On the other hand, Russia and China are vying for expanded influence in countries critical to US diplomacy, namely Iran, Saudi Arabia, Turkey, Jordan, Egypt, and Pakistan. Although it is often difficult to know where President Trump stands on China and Russia, the recent NSS2017 is quite specific:

"China and Russia challenge American power, influence and interests, attempting to erode American security and prosperity. They are determined to make economies less free and less fair, to grow their militaries, and to control information and data to repress their societies and expand their influence."[53]

The two countries' overseas nuclear push challenges the post-World War II nuclear-safety and nonproliferation policy and legal framework, which were put in place through the combined efforts of the US government

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42 HSBC, "Belt and Road," http://www.business.hsbc.com/belt-and-road/infrastructure.

43 Michael R. Gordon, Timothy Puko, and Summer Said, "U.S. Chases a Saudi Nuclear Deal," *Wall Street Journal*, February 21, 2018, https://www.wsj.com/articles/saudi-interest-in-nuclear-standards-could-roil-u-s-reactor-deal-1519122600?tesla=y.

44 "Iran Begins Building Second Nuclear Plant – With Russian Help," *Associated Press*, September 10, 2017, https://www.nbcnews.com/news/world/iran-begins-building-second-nuclear-plant-russian-help-n646036.

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47 Tuvan Gumrukcu and Ece Toksabay, "Turkey, Russia Sign Deal on Supply of S-400 Missiles," *Reuters*, December 29, 2017, https://www.reuters.com/article/us-russia-turkey-missiles/turkey-russia-sign-deal-on-supply-of-s-400-missiles-idUSKBN1EN0T5.

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50 Douglas Busvine, "Washington Tells India Westinghouse Could be Sold by Year End: Sources," *Reuters*, July 2, 2017, https://www.reuters.com/article/us-usa-india-westinghouse/washington-tells-india-westinghouse-could-be-sold-by-year-end-sources-idUSKBN19N0Y1.

51 Kiran Stacey, "Westinghouse Recovery Boosts India Nuclear Power Programme," *Financial Times*, November 6, 2017, https://www.ft.com/content/d5ca519a-bf9d-11e7-b8a3-38a6e068f464.

52 "General Electric Wins Turbine Contract for Paks II," *World Nuclear News*, January 17, 2018, http://www.world-nuclear-news.org/C-General-Electric-wins-turbine-contract-for-Paks-II-17011801.html.

53 White House, *National Security Strategy of the United States of America*, p. 2.

and industry, as well as US leadership in international organizations like the IAEA, the Nuclear Suppliers Group, the Group of Seven (G7) Nuclear Safety and Security Group, and the World Association of Nuclear Operators. The strict standards for nuclear exports established in US 123 agreements, mandated by the Atomic Energy Act of 1954, and other regulations are key components of this framework. There are twenty-three agreements with countries that want to receive US nuclear technology, as well as other NRC and DOE export-licensing provisions. As a report by the EFI concludes: "Since building the world's first reactor, the global nuclear industry and the international regimes for safe, secure and proliferation-resistant peaceful uses of nuclear rested in US leadership."[54]

CONCLUSION AND ISSUES FOR FURTHER DISCUSSION

This paper describes an important policy problem facing the United States: the decline of the US nuclear-power industry and the challenge to US global nuclear leadership from China and Russia.

It postulates that nuclear power is an important strategic sector, and that US global leadership and engagement in nuclear power are vital to US national security and foreign-policy interests. US global nuclear engagement is critical—not only because it supports military needs and advances commercial interests, but also because it brings with it a culture that promotes safety, security of nuclear materials, and nonproliferation. It also represents a model of professional regulatory development and government-industry collaboration that is lacking in the state-monopoly and authoritarian systems in Russia and China. US nuclear engagement with countries forges a long-term relationship with counterpart governments and industries in a high-visibility and critical sector of the economy.

Nuclear power should be elevated in the Trump administration's US National Security Strategy, including its "energy dominance," defense-industry capacity development, and international partnership efforts with allies.

Given the strategic importance of the industry and the challenges at stake, the Atlantic Council should pursue the question of what should be the US government response to this challenge, and examine the costs and benefits of different strategies and actions.

Key issues that should be addressed include the following:

1. What actions, if any, should the government take to avoid the premature closure of US nuclear-power plants, reform electricity markets to better value nuclear attributes, and protect the domestic nuclear-industry supply chain?
2. What government budgetary resources and public-private partnerships are needed to accelerate research, development, and demonstration of advanced reactor designs? And, what international collaborative efforts are necessary to realize a new generation of commercially viable reactors?
3. Should new US government funding sources be developed to promote US technology exports and bolster US industry competition with Chinese and Russian companies? And, what should be the role of the Export-Import Bank?
4. Should the United States strengthen or modify its involvement in key international bodies dealing with nuclear-power exports, nuclear safety, physical security, and protection of nuclear materials?
5. Should the United States expand its efforts to help new nuclear-generating countries with the development of professional nuclear-regulatory agencies and frameworks?
6. Should the United States reduce its reliance on foreign uranium supplies and fuel-enrichment services for its nuclear-power plants?

A constructive dialogue bringing together industry leaders, policymakers, researchers, and other key stakeholders is urgently needed to address these, and other, issues.

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54 Energy Futures Initiative, *The U.S. Nuclear Enterprise: A Key National Security Enabler*, p. 19.

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