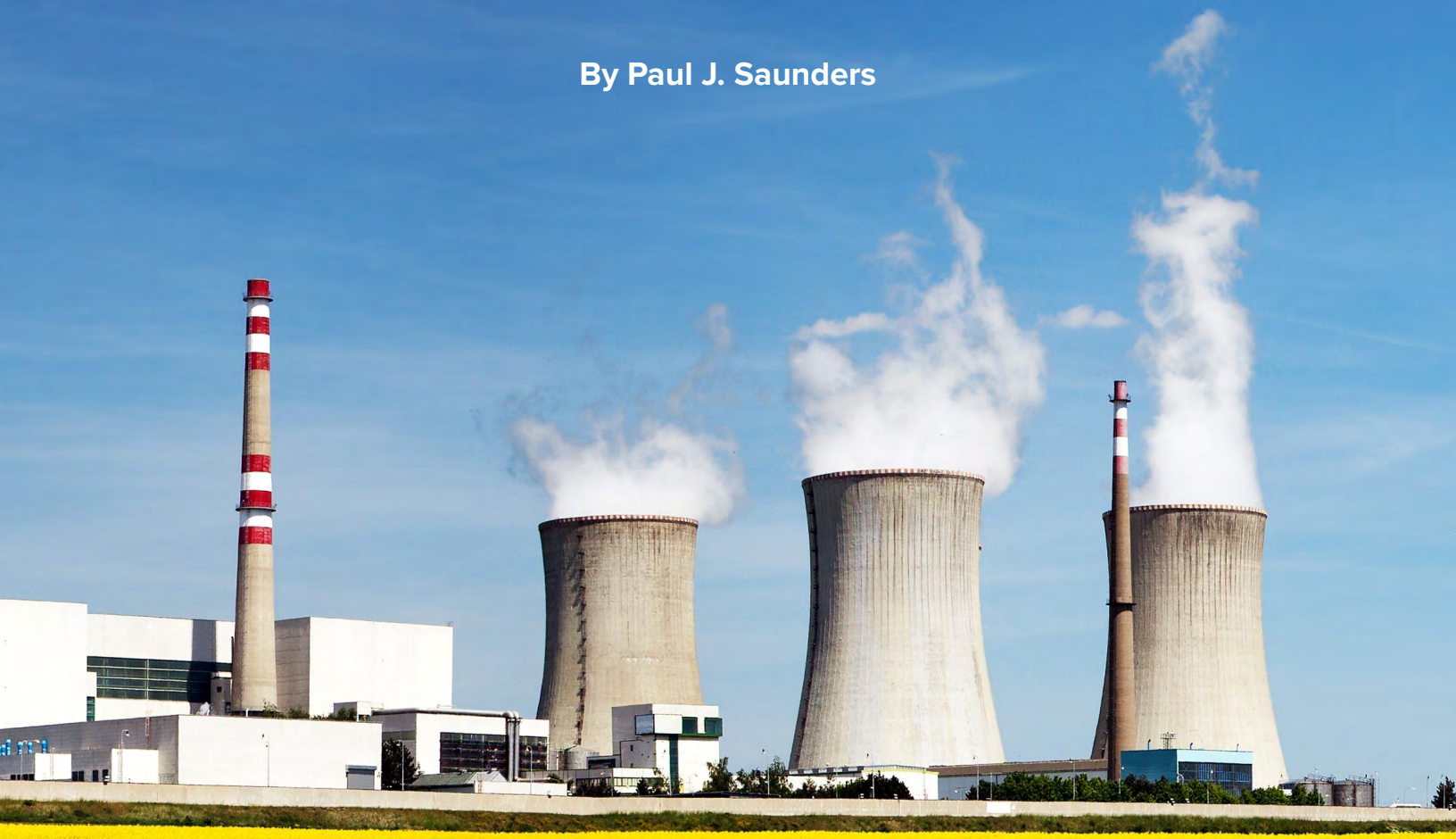
Restoring America's Nuclear Energy Leadership and Exports

By Paul J. Saunders



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Cover: The Soviet-era nuclear power station at Dukovany, in the Czech Republic. As governments in the former Soviet bloc have turned away from Russia as a nuclear provider, companies in the United States and allied countries have competed to capture these markets.

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

EIRP
ENERGY INNOVATION REFORM PROJECT

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Abbreviations

ARPA-E	Advanced Research Projects Agency-Energy
bcm	billion cubic meters
BIS	Bureau of Industry and Security
BRI	Belt and Road Initiative
COVID-19	Coronavirus disease of 2019
CURIE	Converting UNF Radioisotopes Into Energy program
DOE	Department of Energy
EU	European Union
Euratom	European Atomic Energy Community
EXIM	Export-Import Bank of the United States
FIRST	Foundational Infrastructure for Responsible Use of SMR Technology
HALEU	High-Assay Low-Enriched Uranium
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
KEPCO	Korea Electric Power Corporation
KHNP	Korea Hydro & Nuclear Power
LEU	Low-enriched uranium
LNG	Liquified natural gas
mt	metric ton
New START	New Strategic Arms Reduction Treaty
NNPA	Nuclear Nonproliferation Act of 1978
NPT	Nonproliferation Treaty
NRC	Nuclear Regulatory Commission
SMR	Small Modular Reactors
START	Strategic Arms Reduction Treaty
TENEX	Techsnabexport
UAE	United Arab Emirates
U.N.	United Nations
USSR	Union of Soviet Socialist Republics
VVER	Water-water energetic reactor

Executive Summary

Today's international environment is profoundly different from that of the Cold War era—a period of intense U.S.–Soviet competition, but also a time when the United States and its allies led in many technological fields and dominated the global economy—and its aftermath, when geopolitical rivalries eased. Yet many institutions and policies, domestic as well as international, originated in these periods, when circumstances, priorities, threats, and opportunities were different from those of today. As a result, many U.S. approaches are no longer suit America's needs.

The gap between institutions and policies, on one hand, and international realities, on the other, is especially stark where technological change has moved rapidly. One such area is nuclear energy; U.S. approaches to international civil nuclear cooperation have not kept up with new global realities. Indeed, changing geopolitics, technologies, policies, and markets have significantly outpaced U.S. approaches, which thus far fall well short of what the country needs to advance its national interests in today's world.

Consider these four dimensions of change.

- **Geopolitics.** Intensifying geopolitical competition is driving interest in nuclear energy as a path to energy security. The increasingly tense and uncertain international environment is simultaneously prompting new interest in nuclear weapons as a path to national security. These two developments strain existing nonproliferation institutions and policies. Nuclear technology sharing has reemerged as an instrument of geopolitical competition and strategic alignment.
- **Technology.** Technology is advancing, making nuclear energy more accessible. This is facilitating the wider deployment of nuclear energy and the wider development of nuclear technologies. Nuclear energy technologies are also diversifying in a manner that tests supply chains as well as regulations and policies established primarily to govern earlier technological approaches to nuclear energy.
- **Policy.** As greenhouse gas emissions have increased, and climate change impacts have become more obvious, governments have assigned increasing priority to clean energy, especially over the last decade. Russia's invasion of Ukraine, and sharp reductions in Russian natural gas deliveries to Europe, have prompted governments around the world to prioritize energy security too. Nuclear energy can address both aims.
- **Markets.** The United States has lost its place as a leading global supplier of nuclear reactors, as it was at the time when America laid the foundations for its civil nuclear cooperation and nuclear nonproliferation policies. State-owned companies in China and Russia are among the top market competitors for U.S. private firms.

Successfully executing a policy to reestablish U.S. leadership requires adapting to these changes. The recommendations in this report seek to advance four important goals for the U.S. civil nuclear sector, to *innovate*, to *accelerate*, to *facilitate*, and to *cooperate*.

- **Innovate.** As a foundation for leadership in the security, economic, and geopolitical aspects of nuclear energy and other civil nuclear technologies, the United States must *innovate*. This requires greater federal funding and other support for research, development, demonstration, and the deployment of key technologies.
- **Accelerate.** To build an industry capable of competing internationally, and to reduce greenhouse gas emissions more rapidly, the United States must adopt policies to *accelerate* domestic deployment of nuclear energy, including reactor and fuel supply chains to support domestic deployment and exports.
- **Facilitate.** To boost U.S. civil nuclear exports, the United States must *facilitate* international engagement by streamlining its bureaucratic procedures, providing greater support for exporters, and, where possible, aligning safety and licensing regulations with allies and partners.
- **Cooperate.** Because America is unlikely to win back its past dominance of global civil nuclear markets, the United States must *cooperate* with allies and partners as it pursues policies to *innovate*, *accelerate*, and *facilitate*. In addition, the United States must cooperate to manage inevitable tensions among allies and, where appropriate, provide jointly structured alternatives to Russian and Chinese companies for emerging and developing economies seeking to develop new nuclear energy projects. The United States should more assertively pursue new civil nuclear relationships.

The following policy recommendations are intended to articulate and operationalize these goals. Some are within the authority of the executive branch, while others would likely require action by the United States Congress.

Innovate	Continue the Advanced Reactor Demonstration Program and support appropriate next steps, including possible support for one micro-reactor design
	Increase funding for domestic research on used fuel reprocessing and related technologies, e.g., ARPA-E's CURIE program
	Expand bilateral and multilateral research programs with U.S. allies through U.S. National Laboratories
	Explore options to fully fund the Versatile Test Reactor, including through cooperation with interested allied governments
Accelerate	Assist U.S. and selected foreign (allied) companies working to rebuild the domestic nuclear supply chain; seek new roles for U.S. firms in strengthening allied supply chains
	Support Defense Department procurement of SMRs and micro-reactors for critical defense infrastructure, especially in remote or isolated areas
	Amend the Atomic Energy Act to permit partial foreign (allied) ownership of reactor licenses and enrichment facilities to increase investment in America's civil nuclear sector
	Provide additional financing to assist in the commercial deployment of new reactor and fuel technologies
	Review U.S. domestic laws, regulations, and policies on reprocessing to facilitate meeting advanced nuclear reactors' fuel demands, better manage used fuel, and enable future fuel takeback

Facilitate	Establish a single point of contact within the White House for U.S. companies seeking nuclear-related export opportunities and for foreign companies seeking U.S. partners; integrate existing export control information programs (e.g., DOE's Nuclear Nexus, Commerce BIS informational programs, NRC informational programs) into this entity to create unified guidance; harmonize department/agency approaches to avoid discouraging commercial reprocessing
	Increase Export-Import Bank and Development Finance Corporation resources and staff capacity for nuclear-related exports and assistance and press for World Bank finance for nuclear reactor projects (but not nuclear fuel projects)
	Expand the FIRST program to assist governments considering new nuclear energy programs in developing the necessary capacity
	Improve liability protections for the Export-Import Bank, for example, as proposed in the Civil Nuclear Export Act of 2023
	Explore bilateral and multilateral agreements for mutual recognition of civil nuclear safety and licensing standards among allies and civil nuclear partners
	Consider encouraging U.S. partners to review OECD nuclear subsidy rules with a view to improving competitiveness vis-à-vis Russia and China
Cooperate	Develop mechanisms for joint marketing of nuclear reactors, components, and services with interested U.S. allies when this can assist U.S. firms in competing with Russian and Chinese entities
	Develop mechanisms for joint financing of reactor construction with U.S. allies, especially in emerging markets and developing countries
	Reassess laws and policies addressing enrichment and reprocessing in allied states while maintaining strict nonproliferation controls
	Create and provide initial support to a quasi-governmental organization to link U.S. and allied companies in the civil nuclear sector

These recommendations are ambitious in their totality. Some will be more controversial or difficult to implement than others. However, if the United States does not act to bring its civil nuclear policies into greater alignment with global realities, America will likely face significant costs. Some will be economic—lost tax revenue for federal state and local governments, lost jobs for nuclear sector specialists and workers, and lost domestic or export revenue for companies. Others will be strategic, including lost opportunities to secure deep new partnerships as geopolitical competition intensifies as well as ceding those partnerships to U.S. rivals. Still others will be in national security, as the global nonproliferation regime increasingly frays under strategic and technological pressure. It is for U.S. leaders, and Americans generally, to decide whether they are prepared to accept the consequences of failure at this critical time.

1. Introduction

Change is one of the greatest challenges to human institutions—whether governments, companies, or other organizations—and to policies. Motives and circumstances shape institutions and policies, but motives and circumstances generally change more rapidly than either policies or institutions, which often contend with greater inertia. As a result, new systems[1] reflect the motives and circumstances at the time of their conception rather than their execution; even as they take shape, reality is moving forward. This problem becomes only worse over time, as systems continue to evolve more slowly than realities.

This challenge is especially significant in times of rapid change, in that systems fall further behind realities and may no longer effectively meet either their original goals or their designers' present needs. It may become even more severe when rapid change occurs across multiple dimensions simultaneously. The United States and other governments are confronting this problem today in trying to manage changing geopolitics and technologies, new problems like climate change, and the evolution and restructuring of the global economy.

Today's international environment is profoundly different from that of the Cold War era—a period of intense U.S.–Soviet competition, but also a time when the United States and its allies led in many technological fields and dominated the global economy—and its aftermath, when geopolitical rivalries eased. Yet many institutions and policies, domestic as well as international, originated in these periods, when circumstances, priorities, threats, and opportunities were different from those of today. As a result, many U.S. approaches are no longer fully appropriate to America's contemporary needs.

Since technology is changing so quickly in so many areas, this problem has been highly visible, especially with respect to information and communications technology, including artificial intelligence. Yet for the United States, the gap between systems and realities is also stark in international civil nuclear cooperation—specifically, in the institutions and policies for sharing nuclear energy technologies and for exporting nuclear reactors, which have not kept up with new global realities. Indeed, changing geopolitics, technologies, policies, and markets have significantly outpaced U.S. approaches, which thus far fall well short of what the country needs to advance its national interests in today's world.

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- **Policy.** As greenhouse gas emissions have increased, and climate change impacts have become more obvious, governments have assigned increasing priority to clean energy, especially over the last decade. Russia's invasion of Ukraine, and sharp reductions in Russian natural gas deliveries to Europe, have prompted governments around the world to prioritize energy security too. Nuclear energy can address both aims.
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While the United States has pursued some new approaches in response to these changes, many policies remain ill-suited to today's realities. The U.S.–South Korea civil nuclear relationship highlights some of the ongoing shortcomings in U.S. institutions, rules, and policies; this paper will illustrate those shortcomings with special attention to U.S.–South Korea relations. To do so, the paper will briefly review the history of America's nuclear sector and particularly U.S. systems for civil nuclear cooperation with other countries (section 2), explore the four dimensions of change and their implications (section 3), and propose new U.S. approaches and policies (section 4).

2. America's Civil Nuclear Policies

The United States began to regulate nuclear energy in 1946, when the U.S. Congress first passed the Atomic Energy Act, a law later amended and expanded many times. The act established the Atomic Energy Commission to oversee the U.S. nuclear sector; the commission had near-monopolistic control over nuclear technology, equipment, and materials—civilian as well as military—and established general procedures for exports.[2] These limits reflected policymakers' desire to maintain the strictest controls surrounding the materials and technologies developed during the Manhattan Project, America's World War II program to build the atomic bomb.

Cognizant of nuclear war's horrific destructiveness and looking for ways to promote non-military uses of nuclear technology while advancing U.S. public diplomacy goals, President Dwight Eisenhower launched his "Atoms for Peace" initiative with a United Nations address in 1953. Internationally, the speech prompted the creation of the International Atomic Energy Agency as a cooperative international body to promote nuclear energy while seeking to avoid the development of nuclear weapons.[3] Domestically, it stimulated substantial revisions to the Atomic Energy Act to facilitate nuclear energy development.

In 1954, the U.S. Congress amended and considerably expanded the Atomic Energy Act. This revised law created the legal and regulatory foundation for today's civilian nuclear sector in the United States.[4] In addition to delegating broader powers to the commission and writing more detailed rules for it to license civilian nuclear reactors, the law elaborated on the modern framework for civil nuclear cooperation with other governments. Most significantly, amendments eliminated the commission's authority to license nuclear exports and instead required Congressional review of an "agreement for cooperation" incorporating detailed terms and requirements for civil nuclear relationships with other governments.[5] This portion of the law, Section 123, gave its name to America's so-called "123 agreements," the U.S. agreements governing civil nuclear cooperation with other countries.

In the next decades, nuclear energy expanded rapidly in the United States, with fifty-nine new reactor grid connections in the 1970s and forty-seven in the 1980s, notwithstanding the Three Mile Island accident in 1979.[6] Indeed, the USSR's 1986 Chernobyl accident had a considerably greater impact on America's domestic reactor construction. Meanwhile, the U.S. Congress reorganized the domestic nuclear sector in 1974, renaming the Atomic Energy Commission as the Nuclear Regulatory Commission and transferring its military programs—manufacturing nuclear warheads—to a separate agency. This agency would merge into the new Department of Energy in 1977.

In parallel with these developments, the United States pursued 123 agreements with many of its close partners, including Canada and Taiwan (1955), Australia and South Korea (1956), the European Atomic Energy Community (Euratom, 1958), and Japan (1968).[7] Washington has continued to negotiate and sign new 123 agreements in the subsequent decades, though at a slower pace. In the fifty-five years since the U.S.–Japan agreement, America has signed fourteen new 123 agreements with other governments, including China and Russia as well as Egypt, Indonesia, Turkey, Ukraine, the United Arab Emirates, and Vietnam, among others. Meanwhile, the United States has gained twenty-one new civil nuclear cooperation partners simply through Euratom's gradual expansion from six to twenty-seven members

as the European Union has grown.[8] In late 2023, the United States signed a new 123 agreement with the Philippines; absent a Congressional vote of disapproval, the agreement will take effect in 2024.[9] The relative rarity of 123 agreements illustrates both how selective the United States has been in pursuing 123 agreements and how challenging it is for America to negotiate them.

Even as the United States and the Soviet Union shared civil nuclear technologies with their respective allies, the U.S. and Soviet governments increasingly found a common interest in preventing additional states from developing nuclear weapons. Limiting the spread of nuclear technologies to other nations served U.S. and Soviet national interests by maintaining the value of their nuclear arsenals and reducing the likelihood of a nuclear war among others. Each was also experiencing some discomfort with ostensible allies that possessed nuclear weapons. For the United States, France's continued insistence on its military and strategic independence complicated U.S. military planning; for the Soviet Union, differences with Beijing became especially disturbing after Chinese leader Mao Zedong rebuked the USSR for backing down during the Cuban Missile Crisis, in 1962, and China tested its first nuclear weapon, in 1964.

By 1968, the U.S. and Soviet governments, and others, had negotiated the Nonproliferation Treaty (NPT) to slow the spread of nuclear weapons technologies. Securing the agreement of non-nuclear weapon states to the NPT—through which they would give up the right to develop nuclear weapons—required the existing nuclear weapon states to accept three key principles: that all signatories to the treaty had the right to develop nuclear energy and associated technologies,[10] that the nuclear weapon states would work toward nuclear disarmament, and that nuclear weapon states would not share nuclear weapon technologies with others.[11]

In the years following India's 1974 nuclear test, the U.S. Congress considered and eventually adopted new measures to limit nuclear proliferation in the 1978 Nuclear Nonproliferation Act (NNPA). This was highly consequential at the time; as of 1971, the United States had supplied 90 percent of nuclear reactors in the West while also holding a commanding position in nuclear fuel markets.[12] At the time, U.S. policy choices powerfully shaped access to nuclear technology and materials outside the Soviet Union and its dependencies.

The NNPA has since become the foundation of U.S. nuclear export policy; it aimed to tighten controls on U.S. nuclear exports, to ensure that U.S. civil nuclear cooperation partners would be subject to International Atomic Energy Agency (IAEA) safeguards, and to discourage governments pursuing nuclear programs from developing a domestic fuel cycle by providing reliable access to nuclear fuel.[13]

One of the NNPA's most significant components was its definition of U.S. policy toward enrichment and reprocessing. The law explicitly bans the use of U.S. nuclear materials or technologies to research, develop, or build nuclear weapons.[14] Among its other implications, this rules out using U.S.-origin enrichment or reprocessing technologies to create nuclear weapon materials. Moreover, if the U.S. president determines that a U.S. civil nuclear partner has violated this restriction, violated an IAEA safeguards agreement, or detonated a nuclear device, the NNPA requires terminating all U.S. nuclear exports.[15] The president has the authority to avoid these requirements, with various restrictions, if the U.S. government resolves to provide active help to a foreign nuclear weapons program, negotiates appropriate agreements, and forswears its obligations under the NPT.[16]

No less important, however, was the NNPA's call for the creation of an International Nuclear Fuel Authority. This authority was intended to ensure secure access to nuclear fuel and discourage the development of enrichment and reprocessing capabilities by rendering them unnecessary and by linking access to assured international fuel supplies to acceptance of IAEA safeguards and commitments not to develop new enrichment or reprocessing facilities.[17] Forty-five years later, this effort has achieved only very minimal progress.

The IAEA's Low Enriched Uranium (LEU) Bank, located in Kazakhstan, holds just 90 metric tons of low enriched uranium hexafluoride,[18] not more than 5 percent of America's annual civilian power reactor demand.[19] The IAEA's International Uranium Enrichment Centre holds 120 tons of LEU in Russia,[20] though few U.S. allies would likely be willing to rely on this intended reserve LEU supply either today or in the foreseeable future. Indeed, the United States and its allies are generally working to eliminate existing dependencies on Russian nuclear fuel.

In practice, U.S. nuclear exports typically require approvals from the Department of Energy[21] (Part 810 Authorization to share proprietary or export-controlled technology or information, including in bids); the Department of Commerce[22] (export licenses for dual-use items that could be used in nuclear applications); and/or the Nuclear Regulatory Commission[23] (Part 110 export licenses for nuclear reactors, enrichment facilities, reprocessing plants, nuclear material, etc.).[24] The United States government recently added new restrictions to nuclear exports to China.[25]

The Export-Import Bank of the United States (EXIM) has long offered loans and loan guarantees to finance nuclear reactor and nuclear fuel exports; since 2020, the U.S. International Development Finance Corporation has also had authority to support nuclear projects.[26] EXIM's support can include financing to foreign governments or to domestic or foreign companies.[27] For example, in 2012, EXIM provided $2 billion in financing to a company in the United Arab Emirates (UAE) for the purchase of U.S. goods and services in connection with the UAE's Barakah Nuclear Power Plant.[28] More recently, EXIM has opened discussions for up to $3 billion in financing for U.S. small modular reactor exports to Poland.[29] That said, U.S. experts have argued that EXIM is too conservative in its lending and that its financing packages are less competitive than those offered by the Chinese and Russian governments.[30]

3. Four Changes

The United States had sound reasons for establishing its nuclear institutions and policies over the last seven decades. Yet no matter how sound the motives, or how compelling the circumstances, that defined existing systems, the world has changed across multiple dimensions, including the four set out here—geopolitics, technology, policy, and markets. More important, the gaps between U.S. systems and policies, on the one hand, and new realities, on the other, are undermining America's ability to defend and advance its national security, foreign policy, and economic interests.

Geopolitics

Building nuclear reactors typically incorporates other services, including construction, operations and maintenance, training, and fuel supply. Nuclear reactors' multi-decade lifespans require long-term commitments and in turn, reflect significant geopolitical alignments. As a result of this, and due to shared technologies associated with nuclear energy and nuclear weapons, civil nuclear competition was tightly linked to geopolitics during the Cold War. Notwithstanding some softening of this link in the post–Cold War era—including through the rapid growth in Russia's role as a nuclear fuel supplier to the United States and its allies—new competition is boosting civil nuclear cooperation's geopolitical significance.

Geopolitical tensions are increasing with the erosion of the U.S.–China trade, investment, and technology relationships; growing U.S.–China military tensions; and the emergence of an explicitly adversarial U.S.–Russia relationship. At the same time, both China and Russia are working to exploit frustration with U.S. and Western policies, and perceived Western hypocrisy, in many developing countries.[31] These tensions have important implications for America's civil nuclear cooperation with other countries due to competition for markets and political influence as well as the gradual erosion of key conditions underlying the NPT, especially the nuclear weapon states' responsibilities to pursue disarmament.

After signing the NPT, the United States and the Soviet Union reached several important arms control agreements. These included the Limited Test Ban Treaty (1963), the Anti-Ballistic Missile Treaty (1972), the Strategic Arms Limitation Treaty (1972), and the Intermediate-Range Nuclear Forces Treaty (1983), which eliminated an entire class of weapons. Only in 1991, the USSR's final year, did the two governments agree to cut their strategic nuclear arsenals. The Strategic Arms Reduction Treaty, known as START, entered force in 1994. The delay was necessary for Soviet successor states Belarus, Kazakhstan, Russia, and Ukraine to sign the Lisbon Protocol, through which Belarus, Kazakhstan, and Ukraine agreed to transfer their nuclear warheads to Russia.

Washington and Moscow continued to sign new nuclear arms reduction agreements in the post–Cold War era, most notably the Strategic Offensive Reductions Treaty (2003) and New START (2011). However, the United States announced its withdrawal from the Anti-Ballistic Missile Treaty in 2002, citing concerns over missile and nuclear weapons programs in "rogue states" such as Iran and North Korea.[32] Moscow reluctantly accepted this so long as the two governments continued to move forward with nuclear arms reduction agreements and in the context of a generally stable bilateral relationship.

Dynamics in U.S.–Russia arms control would worsen significantly as U.S.–Russia relations collapsed following Russia's seizure of Crimea and intervention in eastern Ukraine in 2014.

In 2018, the Trump administration withdrew from the Intermediate-Range Nuclear Forces Treaty over reported Russian violations[33] and to remove this constraint in managing the U.S.–China strategic balance. In the Indo-Pacific, the treaty's ban on ground-launched missiles with ranges from 500 km to 5,500 km had limited U.S. flexibility but also reassured leaders in Beijing that the United States would not deploy such systems in the region.[34] The Trump administration attempted unsuccessfully to engage China in a trilateral arms control negotiating process, but Chinese officials declined the offer and pointed to the considerably larger U.S. nuclear arsenal.[35] By 2021, China was constructing new missile silo fields in three locations.[36] China recently agreed to bilateral talks on strategic stability, though Beijing appears unlikely to accept numerical limitations on its nuclear warheads at this time.[37]

The United States and Russia renewed New START in 2021. Nevertheless, after Russia's full-scale invasion of Ukraine in 2022, and extensive U.S. and Western military assistance to Ukraine, Russian President Vladimir Putin stated that his country would "suspend" its participation in the agreement in early 2023 while continuing to observe its limits.[38] New START was the last bilateral U.S.–Russia nuclear arms agreement remaining in force. In late 2023, Russia revoked its ratification of the Comprehensive Nuclear-Test-Ban Treaty, which the United States had signed and observed but never ratified; Russian officials said that their government was adjusting its participation to align with America's.[39] In early 2024, Russia rejected new arms control discussions with the United States.[40]

The deterioration of U.S.–Russia relations and the unwinding of U.S.–Russia arms control have been closely interrelated. Where arms control agreements helped to establish greater predictability in U.S.–Soviet relations during the 1970s, 1980s, and 1990s, their erosion has stoked mutual distrust and encouraged worst-case assumptions about one another's motives and goals during the 2000s, 2010s, and 2020s. In shaping national security decision-making in Washington and Moscow, these attitudes have contributed to a downward spiral in bilateral relations and to real-world actions such as Russia's invasion of Ukraine.

Even as U.S.–Russia arms control has crumbled, other developments have undermined the NPT's principles and the reliability of its guarantees. These include China's ongoing nuclear buildup;[41] North Korea's 2003 withdrawal from the NPT, subsequent nuclear tests,[42] and continued production of fissile material that Pyongyang could use to enlarge its expanding nuclear arsenal; and Iran's apparent efforts to develop a nuclear weapon capability.[43] While China's nuclear arsenal remains smaller than either America's or Russia's, its expansion considerably complicates any future efforts at renewed U.S.–Russia nuclear arms control and undercuts nuclear weapons states' commitment to disarm. Iran's and North Korea's activities threaten other regional states; some, such as Saudi Arabia, are exploring developing nuclear energy—including domestic uranium enrichment[44]—precisely the path that Iran has followed in approaching a nuclear weapon capability.

In South Korea, the nuclear and conventional threat from North Korea, and anxiety surrounding U.S. extended deterrence and other military guarantees, have prompted domestic debate over acquiring nuclear weapons or hosting U.S. tactical nuclear weapons, which Washington removed shortly after the end of the Cold War. Russia's invasion of Ukraine exacerbated these concerns by demonstrating that the age of large-scale interstate wars has not ended—and leaders in nuclear weapon states might be more confident in launching wars on non-nuclear weapon states. In public opinion polling during the final weeks before Russia's invasion, over two-thirds of South Koreans supported developing an independent nuclear arsenal.[45] This would require South Korea's government either to withdraw from the NPT, like North Korea, or to violate its NPT commitment to forgo developing nuclear weapons.

Considering the absence of credible U.S.–Russia efforts to reduce their nuclear arsenals (and, in fact, their modernization),[46] China's efforts to expand its nuclear forces significantly,[47] the United Kingdom's decision to raise the numerical cap on its arsenal,[48] and France's nuclear missile modernization,[49] it could become increasingly difficult for nuclear weapon states to persuade non-nuclear weapon states that they are satisfying their obligations under the NPT. This could undermine a core element of the bargain between nuclear and non-nuclear states that provided the foundation for the NPT.

Russia's invasion of Ukraine—occurring nearly three decades after the latter surrendered the Soviet-era nuclear weapons (over which Kyiv had no operational control[50]) on its territory—further undermines the NPT by reinforcing the deterrent value of nuclear weapons and demonstrating the dangers that nuclear weapon states can pose to non-nuclear weapon states.[51] Ukraine's formal accession to the NPT as a non-nuclear weapon state was contingent on guarantees of its security and territorial integrity in the Budapest Memorandum, signed by the United States, the United Kingdom, Russia, and Ukraine; Kyiv submitted its formal NPT accession documents on the day that the Budapest Memorandum entered force.[52] Russian objections prevented agreement on a final document at the 2022 NPT Review Conference, a meeting of the 151 parties to the treaty.[53]

Finally, because energy is a strategic sector, geopolitics is remaking civil nuclear cooperation much in the way that it has shaped cooperation around other forms of energy. In the U.S.–China relationship, for example, Washington has limited sensitive technology-sharing and is pursuing a policy to reduce manufacturing supply chain dependencies. With respect to Russia, the United States and its allies have concentrated on slashing their reliance on Russian fuels, whether fossil fuels or nuclear fuel. Cheap Russian nuclear fuel became prevalent in U.S. and allied markets in large part through the combination of joint U.S.–Russian programs (long since terminated) to transform Russian warheads into nuclear fuel and low-cost Russian enrichment services.

Technology

Nuclear technology is both continually advancing and spreading. Each of these dynamics serves to increase the gap between existing institutions and policies, on the one hand, and global realities, on the other.

Civil nuclear cooperation was one among many elements of the Cold War competition between the United States and the Soviet Union. Most significantly, sharing civil nuclear technology meant sharing critical technologies that could also contribute to a nuclear weapons program if not adequately safeguarded or if the recipient was determined to pursue nuclear weapons despite the costs of such an effort. Indeed, some now believe that early U.S. nuclear technology cooperation with India, Pakistan, and other states may have contributed to their nuclear weapons development,[54] though U.S. officials believed that China knowingly aided Pakistan's nuclear weapons program.[55]

Curbing the dissemination of nuclear technologies has been important and challenging because key technologies can support both nuclear energy and nuclear weapons. Most significant from this perspective are uranium enrichment[56] and used fuel reprocessing.[57] All nuclear weapon states (declared and undeclared) have or previously possessed major weapons-related reprocessing technologies, which provide a less demanding path to nuclear weapons than uranium enrichment; among states not possessing nuclear weapons, only Japan currently has the capability for used fuel reprocessing.[58]

Efforts to prevent nuclear proliferation have had mixed success. Some governments have halted or abandoned nuclear weapons programs, including Argentina, Brazil, Libya, South Africa, Sweden, and Taiwan, though some did so under pressure, while others balked at the financial and technical obstacles.[59] With a combination of U.S. pressure and reassurance, South Korea stopped its nuclear

weapons program prior to signing the NPT in 1975.[60] Through the Lisbon Protocol to the START Treaty, and (in Ukraine's case) the Budapest Memorandum, Belarus, Kazakhstan, and Ukraine ceded the Soviet-era nuclear weapons which they lacked the ability to use.[61] All are now parties to the NPT, except Taiwan, due to its unique status.[62]

Nevertheless, several states have developed nuclear weapons despite the NPT. Some have done this after declining to sign the treaty, including India, Israel, and Pakistan.[63] Others, like North Korea, signed the NPT only to withdraw. Pyongyang signed the agreement in 1985, withdrew in 2003, and conducted six nuclear tests between 2006 and 2017.[64] Many believe that Iran is currently pursuing a nuclear weapons program while remaining a signatory to the Nuclear Nonproliferation Treaty by pursuing dual-use technologies like enrichment.

South Korea's geography and other circumstances have strongly influenced the U.S. approach to civil nuclear cooperation with Seoul. Most important was the experience of the Korean War, which occurred only three years prior to the date when the first U.S.–South Korea 123 agreement entered force, in 1956. Renewed war on the Korean Peninsula was far from unimaginable and Washington feared that North Korea could seize nuclear facilities in a hypothetical revival of the conflict. This concern exacerbated broader U.S. concerns about the possible emergence of new nuclear weapon states. Accordingly, U.S. officials insisted that South Korea forswear both uranium enrichment and used fuel reprocessing as conditions of American nuclear technology sharing. These conditions remained in place when the United States and South Korea reached a new 123 agreement in 1974.

In 2003, North Korean negotiators informed their U.S. counterparts in a U.S.–China–North Korea meeting that Pyongyang possessed nuclear weapons,[65] something that obviated one of Washington's original concerns. In a 2015 deal to extend the original 123 agreement, the United States agreed that South Korea could eventually pursue uranium enrichment, after further consultation with Washington. However, Washington continued to block used fuel reprocessing,[66] though it incorporated the joint study of pyro-processing, a reprocessing technology that South Korea has long sought to pursue. After concluding a new 123 agreement with the United Arab Emirates in 2009, U.S. officials appeared reluctant to yield substantive concessions that could undermine future U.S. efforts to replicate the so-called "gold standard" in 123 agreements, through which U.S. partners would commit not to enrich uranium or reprocess used fuel (as opposed to having the right to do so with U.S. approval).

In other cases, geopolitical changes can make this cooperation more complex. South Korea is an excellent example, in that recent official and public expressions of support for developing an indigenous nuclear weapons program have made it more difficult for Washington to accept South Korea's development of an enrichment or reprocessing capability. U.S. law discourages American support for enrichment and would forbid consent to reprocessing if U.S. officials believed that South Korea was pursuing a nuclear weapons program. U.S. law would block this because the first step in reprocessing would be to separate plutonium (used in manufacturing some nuclear warheads) from other used fuel materials.

New technologies could further complicate this situation. Many small modular and advanced reactor designs require high-assay low-enriched uranium (HALEU),[67] which contains between 5 percent and 19 percent uranium-235, the isotope used in most reactor designs.[68] SMR developers find HALEU attractive for smaller reactors because its higher concentration of uranium-235 releases more energy in a fixed volume.[69] Most existing reactors and reactors under construction use uranium enriched to 3–5 percent.[70]

To deploy SMRs domestically, or sell them internationally, South Korea would have to facilitate a secure HALEU supply either through domestic production or through foreign purchases. As of this writing, Russia's state nuclear company Rosatom is the only commercial HALEU supplier (through its subsidiary

TENEX); even if officials in Seoul concluded that Rosatom could be a reliable supplier, U.S. officials would not welcome such a relationship.

The U.S. company Centrus produced small quantities of HALEU in 2023 with support from a Department of Energy technology demonstration project and is working to expand production.[71] The U.S. subsidiary of Europe's Urenco has also offered to produce HALEU in the United States; the company operates the sole commercial uranium enrichment plant in America,[72] but lacks a license to produce HALEU.[73] The U.S. Department of Energy issued a new request for proposals for uranium enrichment in January 2024.[74]

Notwithstanding the work underway at Centrus, and Urenco's offer, future U.S. HALEU supplies remain uncertain. DOE projects that the United States could need over 40 metric tons by 2030 to achieve a 100 percent clean electricity system by 2035.[75] While America seems unlikely to move that aggressively toward clean electricity, Centrus plans to produce somewhat less than 1 mt of HALEU in 2024 under contract to DOE.[76] The company has stated that it could increase capacity to 6 mt/year within forty-two months of receiving sufficient financial commitments and that it could double this rate within an additional six months.[77] The central question is whether and when adequate demand will exist to support increased production. Synchronizing demand, financing, and production will be challenging; securing private funds to complement U.S. government support will be critical. South Korean firms could be one source for such investment.

Enrichment or reprocessing provide alternative pathways to producing HALEU, though either would require changes to current U.S. policy. While technically demanding, reprocessing could also provide a way to recycle used nuclear fuel—an attractive alternative to problematic long-term storage of high-level (highly-radioactive) waste.[78] From this perspective, while controversial, reprocessing might contribute to both nonproliferation and safety goals by creating pathways to consume used nuclear fuel and reducing transportation and storage requirements. In 2022, DOE's ARPA-E funded a dozen separate research projects studying aspects of used fuel reprocessing technologies.[79]

Policy

Geopolitical and technological change are each intertwined with widespread—if very uneven—policy changes that are stimulating greater interest in nuclear energy and in international civil nuclear cooperation. The most important drivers of these policy changes surround efforts to slow, stop, and even reverse climate change impacts and to promote energy security. Existing U.S. institutions and approaches are constraining the United States both in advancing U.S. interests and in supporting international goals.

In parallel with concerns surrounding climate change and energy security, U.S. public support for nuclear power has grown substantially in recent years. Since 2020, the share of Democrats and Democratic-leaning independents who say they favor more nuclear plants in America has increased from 37 percent to 50 percent; among Republicans and Republican-leaning independents, support has grown from 53 percent to 67 percent.[80] As a result, overall support for nuclear power has reached 57 percent—a solid majority. The Democratic Party's 2020 platform explicitly backed nuclear energy for the first time in almost fifty years.[81]

Though America's climate policy remains contested, domestic efforts to promote low- and zero-carbon energy sources have been underway for some time. Many U.S. states have incorporated nuclear power into their clean energy plans (and subsidized it); some, like New York, decided to incorporate existing nuclear plants into their clean energy goals after initial efforts to exclude nuclear energy highlighted the difficulty in meeting clean power targets without it.[82]

California—known for its anti-nuclear sentiment—has moved to extend the life of its last remaining nuclear plant, Diablo Canyon, despite earlier plans to shut down the facility in 2025.[83] The state's governor, who backed the earlier deal to close Diablo Canyon, has acknowledged the need to maintain electric grid reliability after the 2020 blackouts.[84] Advocates for clean power have highlighted the role that nuclear energy could have in repowering existing coal-fired electricity generation to provide continued access to firm, dispatchable power.[85]

At the federal level, the 2021 Bipartisan Infrastructure Law established a $6 billion Civil Nuclear Credit Program to assist nuclear plants moving toward shutdown (including Diablo Canyon) in remaining online.[86] In addition, the law provided $2.4 billion in new funding for the U.S. Department of Energy's Advanced Reactor Demonstration Program, mandated that at least one of the law's "hydrogen hubs" use nuclear energy to produce hydrogen (and provided support for that), and incorporated various bureaucratic reforms to ease advanced reactor deployment.[87] DOE's hydrogen hub selections ultimately included two projects that plan to incorporate nuclear energy, if the projects are ultimately completed.[88]

The Inflation Reduction Act, which became law in 2022, provided further support for domestic efforts to develop nuclear power. These included a production tax credit for existing nuclear plants, the choice between a production tax credit or an investment tax credit for new reactors, and $700 million for domestic production of HALEU.[89]

Globally, the International Energy Agency (IEA) foresees nearly 50 percent growth in nuclear energy generating capacity from 2022 to 2050 in its Stated Policies Scenario. In its Announced Pledges Scenario and Net Zero Emissions by 2050 Scenario, the IEA projects 85 percent growth and over 115 percent growth, respectively.[90] Notably, at the 2023 Conference of the Parties to the U.N. Framework Convention on Climate Change—the principal annual global climate summit—the United States, South Korea, and twenty-three other countries declared their aspiration to triple global nuclear capacity by 2050.[91] Neither China nor Russia was a party to the declaration, though each also has ambitious plans to deploy nuclear energy. The IEA cites nuclear (and other power sources) as having "a critical role in smoothing variability [of solar photovoltaic and wind power] across seasons."[92]

Even as climate policies have encouraged interest in nuclear energy, Russia's 2022 invasion of Ukraine has disrupted global oil and gas markets. This disruption—and resulting higher prices—has encouraged governments worldwide to give additional attention to energy security, both in ensuring adequate energy supplies and in mitigating vulnerability to price volatility.

With respect to oil, the United States and its allies sought to develop policies that would ensure continued Russian oil sales into global markets while blocking Russian oil imports into their own countries and seeking to limit Russian profits from oil sales elsewhere via the G7 price cap mechanism. Simultaneously, U.S. and Western governments have worked to undercut Russia's medium- to long-term oil production and exports by imposing sanctions intended to limit Russia's access to foreign investment and technology. While Russia has largely succeeded in finding new markets for its oil (especially in China and India), its ability to sustain prewar export levels over time appears increasingly uncertain.[93]

Oil prices have fallen significantly from the first half of 2022 as Russia has restructured its oil exports. Nevertheless, prices remain high by the standards of the last two decades.[94] Because oil is largely (but far from exclusively) a transportation fuel,[95] many governments are working to reduce oil consumption by converting vehicle fleets from internal combustion engines to electric motors. This will inevitably increase electricity demand, requiring new electricity generation. To the extent that governments are simultaneously working to reduce emissions, this creates pressure to phase out coal-fired generation in favor of natural gas, nuclear power, or renewable energy.

Natural gas markets are more complex than the oil market. Perhaps most important, only 56 percent of the world's natural gas trade is (theoretically) global; this is the share of the gas trade that occurred via liquified natural gas (LNG) in 2022.[96] The remaining 44 percent of the international gas trade moved by pipeline, a mode of transportation generally used only within geographical regions, e.g., within Eurasia, North America, or the Mediterranean. Pipeline gas exports are less geographically flexible, especially over short periods.

The uniquely extensive prewar Russia-Europe natural gas relationship—in 2021, Russia's overland natural gas exports to Europe accounted for about one-sixth of the world's natural gas trade[97]—relied upon massive pipeline systems developed across five decades. Moscow thus has fewer near-term options in exporting gas relative to oil.

After Russia's invasion of Ukraine, the European Union (EU) soon planned to wind down Europe's pipeline imports to reduce its dependence on Russian gas, which made up around one-third of Europe's gas consumption and 54 percent of its imports.[98] In its May 2022 REPowerEU plan, the European Commission explained that in addition to a 116 billion cubic meters (bcm) reduction in natural gas consumption through its Fit for 55 climate policy, EU members would save a further 59 bcm and find new sources to replace an additional 125 bcm.[99] Once Russia's leaders saw the looming end of their country's natural gas exports to Europe, they accelerated the EU's timeline through stepwise reductions in natural gas exports.[100]

Unlike the oil trade, Russia's gas exports cannot quickly adapt. Neither can Europe's imports. As a result, Russia is exporting less natural gas and Europe is consuming less. Intensified competition among LNG importers contributed to a 2022 spike in the EU's LNG import prices.[101] Though a U.S.-led effort to avoid a major energy crisis in Europe generally succeeded, re-routing LNG shipments originally intended for Japan and South Korea to Europe yielded a similar price spike for Asia's LNG imports.[102] In South Korea, the higher prices have strained government-owned electric utility KEPCO, which has sought to shield consumers—especially residential consumers—from soaring costs.[103]

Without substantially resuming the Europe-Russia gas relationship, increasing the availability of natural gas in global markets will take quite some time as gas-exporting nations build new infrastructure, whether pipelines or LNG terminals. Until then, governments that had relied upon natural gas imports in their energy planning will have to make alternative arrangements, such as greater use of coal, nuclear, or renewables—or reduce energy consumption. Using more coal has environmental and climate impacts, while renewable power may not be suitable for some manufacturing and can also face land-use challenges[104] in densely populated countries like South Korea. Green hydrogen—that is, hydrogen produced through electrolysis using renewable power—could be a future alternative but will not soon be available at the necessary scale. As a result, nuclear energy has become only more valuable as a source of zero-carbon electricity and heat.

Markets

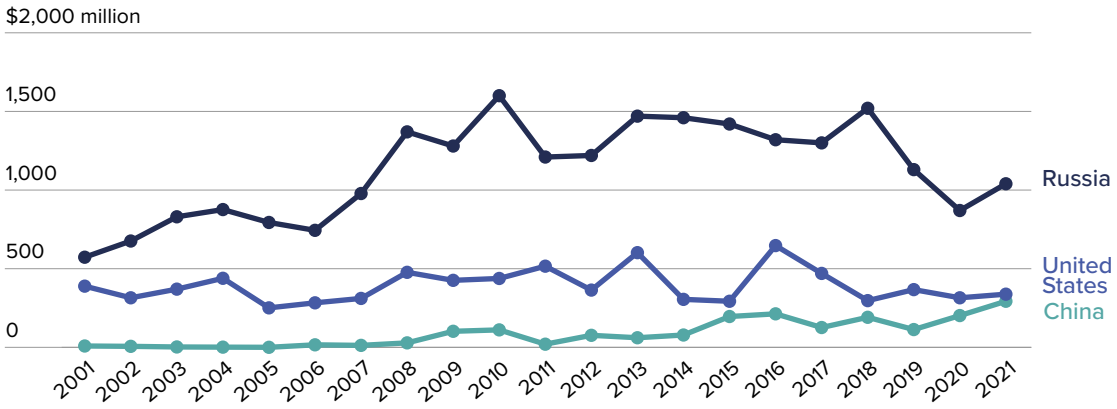
U.S. economic and technological competition with China and Russia has also escalated in recent years. The Nixon administration's 1972 opening to China successfully exploited deep divisions between Moscow and Beijing—most visible in their 1969 border war—and laid the foundation for a post–Cold War global economy with the U.S.–China economic relationship at its core. After a two-decade boom in U.S.–China trade and investment, however, U.S. officials and business leaders had become increasingly disturbed by various Chinese practices. In 2013, a respected bipartisan commission found that annual U.S. losses to China's intellectual property theft were likely comparable to all U.S. exports to Asia—at that time, $300 billion per year.[105]

During the Trump administration, U.S.–China trade relations deteriorated sharply, and U.S.–China technology cooperation virtually ceased, especially in the energy sector. China had previously been one of the Department of Energy's top three international partners, along with Japan (first) and South Korea (third).[106] In the nuclear sector, Chinese experts were the most frequent foreign visitors to the DOE's Oak Ridge National Laboratory every year from 2007 to 2015,[107] as the two governments sought to collaborate on clean energy and China worked to build its first AP1000 reactors under license with Westinghouse.[108] By 2018, however, DOE imposed new restrictions on nuclear technology sharing with China; U.S. officials asserted that China was using "illicit means" to access U.S. technology for economic advantage and military uses.[109]

While the dollar value of America's trade in nuclear goods has fluctuated around $400 million per year since 2001, the U.S. share in the nuclear trade declined from 17.4 percent in 2001 to 8.42 percent in 2021—an erosion of over one-half of America's market share. Figure 1 shows the annual dollar value of nuclear exports from the United States, Russia, and China, while Figure 2 presents their relative shares in the global market. By 2001, U.S. nuclear exports had already fallen very considerably from their peak in the early 1970s. In recent years, Russia's dominant global role as a supplier of nuclear technology, nuclear reactors, and nuclear fuel has been a leading concern for U.S. officials, as has China's expanding role in nuclear markets. Figures 1 and 2 demonstrate the expansion of China's nuclear exports from negligible levels fifteen years ago, in 2008, to nearly equal to America's in 2021. That said, while the United States has a diverse customer base, China's nuclear exports have overwhelmingly gone to a single nation: Pakistan.[110]

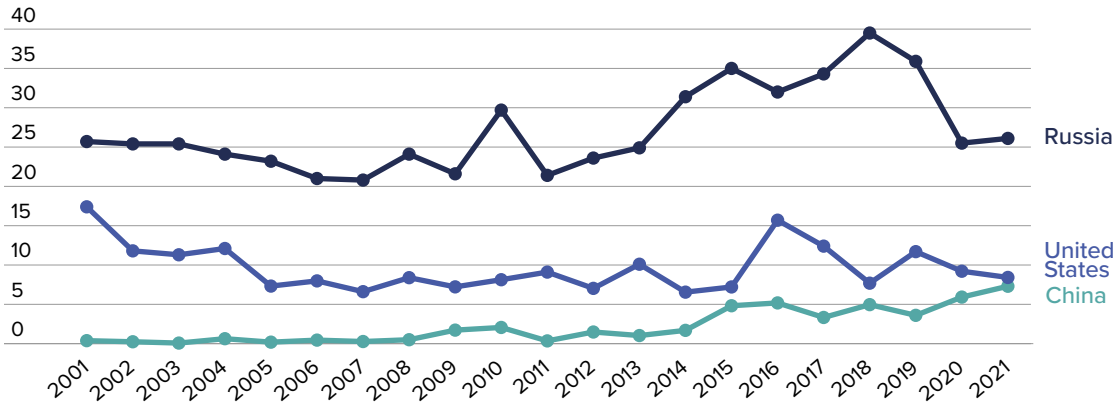
Importantly, nuclear reactors comprise only about one-third of the global nuclear trade; past estimates suggest that related supplies and services—uranium and nuclear fuel, maintenance, parts, and waste handling, among others—are roughly two-thirds of the international nuclear market.[111] This has important implications for the United States and other nuclear exporters, in that selling new reactors yields considerable commercial benefits that could extend for decades beyond the initial construction contracts. Figures 1 and 2 reflect the goods trade but not the trade in services, such as maintenance, enrichment services, or waste management. Russia dominates the market for enrichment services.[112]

Figure 1. Volume of U.S., Russian, and Chinese Nuclear Goods Exports



Source: Observatory of Economic Complexity, https://oec.world/en/profile/hs/nuclear-reactors?yearSelector1=2021&yearSelector2=2001.

Figure 2. Market Shares of U.S., Russian, and Chinese Nuclear Goods Exports



Source: Observatory of Economic Complexity, https://oec.world/en/profile/hs/nuclear-reactors?yearSelector1=2021&yearSelector2=2001.

In some cases, geopolitical change has benefitted America's nuclear industry. In the wake of Russia's 2014 seizure of Crimea, Westinghouse has won new contracts to supply reactors and/or nuclear fuel to several European countries, including Bulgaria, the Czech Republic, Poland, Slovakia, and Ukraine, and is participating in a consortium to provide nuclear fuel for Soviet- and Russian-built VVER reactors in Europe.[113] Nevertheless, Westinghouse has also lost out to nuclear firms in allied countries; in January, the Czech government decided to move forward with bids from KHNP and Electricite de France for one to four new reactors at Dukovany. Czech officials dropped Westinghouse from the competition.[114]

Russia reportedly has orders for thirty-four nuclear reactors in eleven countries; in January 2023, this represented 70 percent of the global nuclear reactor market.[115] At the end of 2022, Russia's state nuclear company Rosatom held orders worth some $200 billion, a figure that included not only reactors but also enrichment and other fuel-cycle services.[116] Rosatom controlled 46 percent of global enrichment capacity in 2021.[117]

Russia's technology has been successful. Eighty of 439 nuclear reactors operating globally use Russia's technology,[118] as do twenty-one of fifty-two nuclear reactors currently under construction.[119] Rosatom built and is currently operating the world's first commercial floating nuclear power plant, the *Akademik Lomonosov*, which carries two 35 megawatt-capacity small modular reactors.[120] Rosatom has had many competitive advantages in the global nuclear market, including its close cooperation with the Russian government (which allows Rosatom to leverage other areas of Russian policy and offers lower-cost financing) and its ability to provide "one-stop shopping" that incorporates not only reactor design and construction, but fuel services, maintenance, training, and used fuel take-back.[121]

For its part, China is working to leverage its significant, recent domestic reactor construction to build a major role as an exporter. China has fifty-two operating domestic nuclear reactors and another twenty-five under construction, with a further forty-three planned.[122] In 2019, a Chinese official claimed that the country's firms could build thirty reactors overseas by 2030 through its Belt and Road Initiative (BRI),[123] though Beijing has thus far made little progress toward that goal. Though the BRI slowed since the COVID-19 pandemic, China has recently announced new funding for the program.[124] China's large domestic nuclear program may help its firms to win an even greater global market share by gaining experience and visibility while reducing costs.

In the United States, anxiety surrounding U.S. competitiveness in global nuclear markets has contributed to several recent laws intended at least in part to help the industry. These have included the Nuclear Energy Innovation Capabilities Act (2018), the Nuclear Energy Innovation and Modernization Act (2019), the Infrastructure Investment and Jobs Act (2021), the Inflation Reduction Act (2022), and the CHIPS and Science Act (2022). The Biden administration has launched FIRST, Foundational Infrastructure for Responsible Use of SMR Technology, to assist potential SMR partners in capacity-building and other areas.[125] FIRST incorporates Project Phoenix, an effort to promote coal-to-SMR transitions at power plants.

While competition with Russia and China has been the principal axis of geopolitical change for the United States, it has not been the only one. America's relations with its allies are also evolving. To strengthen its leverage in dealing with Beijing and Moscow, the Biden administration has worked assertively to tighten U.S. relationships with allies, especially in Europe and Asia. However, the United States faces some obstacles in doing this in the civil nuclear arena, in that U.S. relations with allies are themselves complex.

The Trump administration's appropriate but clumsy attempts to encourage greater burden-sharing by U.S. allies, particularly in supporting the costs of overseas U.S. military bases and in boosting allies' defense spending, were not always well-received by allied governments. With Donald Trump as the presumptive Republican nominee in America's 2024 presidential elections, and amid fears that regardless of his electoral success, Trump has redefined Republican politics, America's European allies have devoted greater attention to "strategic autonomy," a term that the European Parliament's staff has defined as the EU's capacity "to act autonomously—that is, without being dependent on other countries—in strategically important policy areas."[126]

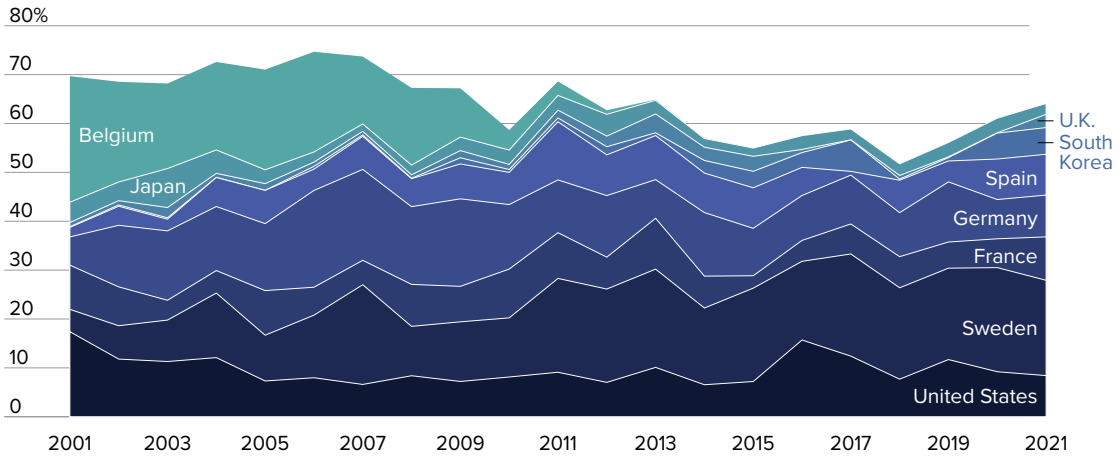
At the same time, U.S. policies to support domestic manufacturing, advanced by both Presidents Trump and Joe Biden, have prompted renewed trade tensions with allies in Europe and Asia. During the Trump administration, competition surrounding potential contracts to build nuclear reactors in Saudi Arabia led to a major dispute between Westinghouse, KEPCO, and KHNP that has moved into arbitration.[127] The Trump administration was highly committed to promoting U.S. nuclear exports; an administration working group developed and released a strategy in 2019–2020.[128] The administration explicitly described this strategy as a component of overall U.S. national security strategy in competing with China and Russia.[129]

While continuing the Trump administration's focus on nuclear energy and nuclear exports, the Biden administration has typically framed its nuclear energy policy as a necessary element in U.S. policies to reduce greenhouse gas emissions domestically and internationally.[130] This is especially important, in that many progressive Democrats have called on the administration to set aside geopolitical competition—especially with China—to allow for cooperation with Beijing in reducing global emissions.[131] The Biden administration has also been more sensitive to tensions surrounding economic competition with U.S. allies, such as in its flexible interpretation of the Inflation Reduction Act to mitigate allies' concerns. The law's electric vehicle tax credits initially drew considerable ire from key U.S. partners, including South Korea.[132]

Several U.S. allies have held significant shares in the global nuclear goods trade over the last two decades. In 2021, the largest exporters were Russia (26.1 percent), Sweden (19.5 percent), France (8.88 percent), Germany (8.55 percent), the United States (8.42 percent), China (7.3 percent), and South Korea (5.46 percent).[133] In that year, the combined Russian and Chinese shares (33.4 percent) were significantly lower than the combined U.S. and allied shares (50.81 percent) even without incorporating smaller exporters like the United Kingdom (2.71 percent) and Japan (2.22 percent).[134]

Figure 3 compares the evolving shares of the United States and selected allies. Perhaps obvious is the decline in the total share of the nine selected countries, from an average of approximately 69 percent in 2001–2011 to an average of about 59 percent in 2012–2021; Figure 2 reveals significant growth in both Russian and Chinese nuclear exports during this period. No less important, however, is the considerable variation over time among Western nations, such as the collapse of Belgium's nuclear exports from a 25.8 percent market share in 2001 to negligible levels by 2012, the considerable growth of Sweden's share during the same period, and the more gradual rise and fall of Germany's share.[135] While on a smaller scale, South Korea's recent export growth—connected overwhelmingly to the Barakah Nuclear Power Plant—is similarly apparent.

Figure 3. Market Shares of U.S. and Allied Nuclear Goods Exports



Source: Observatory of Economic Complexity, https://oec.world/en/profile/hs/nuclear-reactors?yearSelector1=2021&yearSelector2=2001.

Figure 3 illustrates the reality that notwithstanding many shared security and economic goals, the United States and its allies are competitors in trade, investment, and technology. It likewise illustrates that while their combined market share is declining, it totals well over half the global market. Over time, America and its allies have largely—though not entirely—succeeded in structuring their competition within a system of formal and informal rules and understandings. Nevertheless, economic competition among the United States and its allies is also an important driver of geopolitical change—and if Washington is to unite and mobilize U.S. allies to compete with China and Russia on trade, investment, and technology, including in the nuclear sector, U.S. leaders will have to address this problem. Russia and China are, of course, also competing with one another and everyone else; the point is that greater alignment among the United States and its allies could boost their market power, negotiating leverage, and geopolitical positions.

Two dynamics appear likely to influence market shares in the near to medium term. One is the increasing segmentation of some nuclear markets; following Russia's invasion of Ukraine, the United States and its allies are unwinding Russia's post–Cold War integration into Western civil nuclear markets as well as its Cold War–era role in most former Soviet bloc countries. On the one hand, this will put downward pressure on Russia's market share. On the other hand, however, this dynamic will probably intensify competition among the United States and its allies, especially inside developed world markets.

The second dynamic is the rapid growth in projected electricity demand in emerging markets and developing economies, which could account for between two-thirds and four-fifths of the global growth in electricity demand to 2050.[136] As demand growth will probably be considerably slower in Western markets, civil nuclear firms in the United States and its allies will likely see their greatest commercial opportunities here, especially if Washington and other capitals can take steps to improve their competitiveness. Left unmanaged, these competitive pressures will likely also stimulate greater competition among Western companies. Growing U.S. and Western market share in the developing world will also likely require the expansion of programs like FIRST to help customers develop oversight, policy, and technical capacity.

In both Western and emerging/developing markets, U.S. laws and policies that require civil nuclear partners to secure Washington's approval for nuclear exports that incorporate U.S. technology will probably reinforce tendencies toward intra-Western competition by channeling the affected firms toward commercial opportunities in the countries with which the United States has existing 123 agreements (or is negotiating or considering them). Conversely, this can stoke tensions if companies in allied countries that are using U.S. export-controlled technologies pursue nuclear exports and/or technology-sharing with governments lacking a 123 agreement with America.

4. Recommendations

In considering new or modified policies in America's civil nuclear sector, the central task is to assess how well existing policies advance U.S. national interests as well as U.S. priorities. Because civil nuclear technologies are related to weapons technologies, these interests overlap substantially with U.S. national security interests. America's two fundamental national interests in the civil nuclear sector have been largely consistent throughout the nuclear age. They include U.S. broad interests to:

- Prevent the proliferation of nuclear weapons and nuclear weapon technologies to strengthen U.S. national security and to reduce the possibility of any nuclear weapons use anywhere in the world.
- Encourage the responsible development of nuclear energy and other peaceful uses of nuclear technologies to improve the human condition and to provide alternatives to nuclear weapons technologies.

These broad interests in turn subsume many narrower interests, such as U.S. interests to:

- Manage the balance of nuclear weapons among the United States and its allies, rivals, and adversaries while moving (probably extremely gradually) toward disarmament.
- Stop or slow the development of nuclear weapons by states that do not possess them.
- Prevent the development or acquisition of nuclear weapons by non-state actors.
- Sustain and strengthen the global nonproliferation regime.
- Achieve and maintain global leadership in military and peaceful nuclear technologies.
- Improve America's competitive position in the global nuclear market.
- Increase U.S. civil nuclear exports and create and maintain domestic employment opportunities supporting those industries.
- Preserve and protect the U.S. and global natural environment including by reducing greenhouse gas emissions.
- Build and maintain necessary human capital in the military and civil nuclear sectors.
- Use military and civil nuclear cooperation as effective national security and foreign policy tools in dealing with U.S. allies and partners and in building new strategic partnerships.

This list illustrates the breadth and complexity of U.S. interests, as well as their inherent contradictions, such as the tensions between U.S. nonproliferation interests, on the one hand, and U.S. strategic and economic interests, on the other, as well as the tensions between U.S. economic interests and U.S. relations with its allies.

Moreover, U.S. interests and priorities can evolve over time. For example, following the Three Mile Island and Chernobyl nuclear accidents, when the U.S. public increasingly saw nuclear energy as

unsafe, Americans tended to give greater weight to America's environmental interests relative to commercial or other interests in developing nuclear energy domestically. Today, public concern over greenhouse gas emissions and climate change has substantially reframed how Americans define U.S. environmental interests and priorities. This has yielded new public support for nuclear energy as a climate-friendly technology.

Intensifying competition among the United States, China, and Russia similarly shapes the relative priorities of U.S. interests in the civil nuclear sector. From this perspective, civil nuclear cooperation has reemerged as a key element in America's global security, political, and economic strategies; both the Trump and Biden administrations and the Congress have sought to reestablish U.S. leadership in nuclear energy.

Principles

Successfully executing a policy to reestablish U.S. leadership requires adapting to new twenty-first-century realities. First, the United States is far behind Russia in building a leading role in global nuclear energy markets—and catching up will require hard work. Figure 2 showed Russia's dominance in global nuclear markets as well as the rapid (if narrow) growth in China's market share. One of America's principal competitive advantages relative to these two governments is its capacity to innovate both in DOE's National Laboratories and in the private sector. New policies are necessary to supercharge American nuclear innovation and to help translate new technologies into commercial products.

Second, achieving international leadership will require a powerful domestic nuclear industry, including human capital, supply chains, manufacturing, financing, and a supportive policy framework. U.S. companies will be much better placed to succeed in exporting new reactors and associated supplies and services if they can rebuild their lost experience deploying these complex systems at home. A larger domestic market can also improve economies of scale and the financial competitiveness of U.S. nuclear exports.

Third, while a strong nuclear nonproliferation regime is a vital U.S. national interest, the United States' current approach to nonproliferation has undercut its position in markets and thus its day-to-day influence over other governments' nonproliferation choices. The Nuclear Nonproliferation Act's goal of an assured global nuclear fuel supply will very likely remain out of reach in an era of deepening geopolitical competition. Absent this, if the United States does not markedly expand its nuclear fuel production and/or help others to do the same, possibly including enrichment and reprocessing in some cases, America's allies, partners, friends, and many others might pursue acquiring these strategic commodities elsewhere.

Fourth and finally, America is unlikely to succeed if its actions and policies are not closely coordinated with U.S. allies or even undertaken jointly. Joint or cooperative efforts can contribute to U.S. goals in many areas, including developing and testing new technologies, financing a growing domestic nuclear industry and a larger fleet of domestic reactors, and expanding U.S. exports within larger consortia of firms from allied and partner countries, to name only a few examples.

Yet, even as the United States works to cooperate with U.S. allies, it will also compete with them. In pursuing government-to-government cooperation and improving frameworks for collaboration among U.S. and appropriate foreign companies, America cannot and should not sacrifice U.S. jobs or commercial opportunities. Washington's goal should be to leverage cooperation where it advances U.S. interests, not to pursue cooperation for its own sake or at any cost.

The policy recommendations in this report draw upon four key principles.

- **Innovate.** As a foundation for leadership in the security, economic, and geopolitical aspects of nuclear energy and other civil nuclear technologies, the United States must *innovate*. This requires greater federal funding and other support for research, development, demonstration, and the deployment of key technologies.
- **Accelerate.** To build an industry capable of competing internationally, and to reduce greenhouse gas emissions more rapidly, the United States must adopt policies to *accelerate* domestic deployment of nuclear energy, including reactor and fuel supply chains to support domestic deployment and exports.
- **Facilitate.** To boost U.S. civil nuclear exports, the United States must *facilitate* international engagement by streamlining its bureaucratic procedures, providing greater support for exporters, and, where possible, aligning safety and licensing regulations with allies and partners.
- **Cooperate.** Because America is unlikely to win back its past dominance of global civil nuclear markets, the United States must *cooperate* with allies and partners as it pursues policies to *innovate*, *accelerate*, and *facilitate*. In addition, the United States must cooperate to manage inevitable tensions among allies and, where appropriate, provide jointly structured alternatives to Russian and Chinese companies for emerging and developing economies seeking to develop new nuclear energy projects. The United States should more assertively pursue new civil nuclear relationships.

Policies

The following illustrative policy recommendations are intended to articulate and operationalize the four principles: **innovate**, **accelerate**, **facilitate**, and **cooperate**.

Innovate	Continue the Advanced Reactor Demonstration Program and support appropriate next steps, including possible support for one micro-reactor design
	Increase funding for domestic research on used fuel reprocessing and related technologies, e.g., ARPA-E's CURIE program
	Expand bilateral and multilateral research programs with U.S. allies through U.S. National Laboratories
	Explore options to fully fund the Versatile Test Reactor, including through cooperation with interested allied governments
Accelerate	Assist U.S. and selected foreign (allied) companies working to rebuild the domestic nuclear supply chain; seek new roles for U.S. firms in strengthening allied supply chains
	Support Defense Department procurement of SMRs and micro-reactors for critical defense infrastructure, especially in remote or isolated areas
	Amend the Atomic Energy Act to permit partial foreign (allied) ownership of reactor licenses and enrichment facilities to increase investment in America's civil nuclear sector
	Provide additional financing to assist in the commercial deployment of new reactor and fuel technologies
	Review U.S. domestic laws, regulations, and policies on reprocessing to facilitate meeting advanced nuclear reactors' fuel demands, better manage used fuel, and enable future fuel takeback

Facilitate	Establish a single point of contact within the White House for U.S. companies seeking nuclear-related export opportunities and for foreign companies seeking U.S. partners; integrate existing export control information programs (e.g., DOE's Nuclear Nexus, Commerce BIS informational programs, NRC informational programs) into this entity to create unified guidance; harmonize department/agency approaches to avoid discouraging commercial reprocessing
	Increase Export-Import Bank and Development Finance Corporation resources and staff capacity for nuclear-related exports and assistance and press for World Bank finance for nuclear reactor projects (but not nuclear fuel projects)
	Expand the FIRST program to assist governments considering new nuclear energy programs in developing the necessary capacity
	Improve liability protections for the Export-Import Bank, for example, as proposed in the Civil Nuclear Export Act of 2023
	Explore bilateral and multilateral agreements for mutual recognition of civil nuclear safety and licensing standards among allies and civil nuclear partners
	Consider encouraging U.S. partners to review OECD nuclear subsidy rules with a view to improving competitiveness vis-à-vis Russia and China
Cooperate	Develop mechanisms for joint marketing of nuclear reactors, components, and services with interested U.S. allies when this can assist U.S. firms in competing with Russian and Chinese entities
	Develop mechanisms for joint financing of reactor construction with U.S. allies, especially in emerging markets and developing countries
	Reassess laws and policies addressing enrichment and reprocessing in allied states while maintaining strict nonproliferation controls
	Create and provide initial support to a quasi-governmental organization to link U.S. and allied companies in the civil nuclear sector

These recommendations are ambitious in their totality. Some will be more controversial or difficult to implement than others. However, if the United States does not act to bring its civil nuclear policies into greater alignment with global realities, America will likely face significant costs. Some will be economic—lost tax revenue for federal state and local governments, lost jobs for nuclear sector specialists and workers, and lost domestic or export revenue for companies. Others will be strategic, including lost opportunities to secure deep new partnerships as geopolitical competition intensifies as well as ceding those partnerships to U.S. rivals. Still others will be in national security, as the global nonproliferation regime increasingly frays under strategic and technological pressure. It is for U.S. leaders, and Americans generally, to decide whether they are prepared to accept the consequences of failure at this critical time.

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