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REDUCING RUSSIAN INVOLVEMENT IN WESTERN NUCLEAR POWER MARKETS

BY DR. MATT BOWEN AND THE HONORABLE PAUL DABBAR
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The Russian invasion of Ukraine has led to considerable sanctions being levied against Russia.[1] The nation is a major energy supplier to the world—including of oil, gas, coal, and nuclear fuel and reactors—and its energy sector is one area that has already been targeted. Since the war began, some members of the US Congress have called for banning imports of enriched uranium from Russia as soon as 2022 or as late as 2026.[2] This commentary discusses Russian involvement in the Western[3] nuclear power supply chain, particularly in the United States, as well as policy options to reduce—or end—that involvement.

International Nuclear Fuel Dependencies on Russia

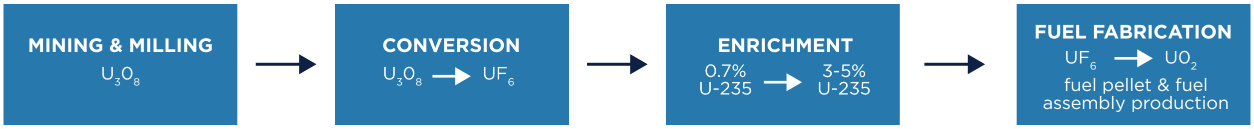
Russia has exported more reactors in recent decades than any other major supplier. In 2021, there were 439 total nuclear power reactors in operation: 38 of them resided in Russia and 42 of them in operation in other countries were of the Russian VVER type (15 of which were in Ukraine). At the end of 2021, 15 Russian-designed reactors were under construction in other nations.

Even for countries that do not host VVERs—including the United States—Russia is a major supplier of several services involved with the manufacturing of nuclear fuel (illustrated in Figure 1). In brief, to make nuclear fuel, raw uranium must be mined out of the ground and milled into uranium-oxide (U_3O_8) before being shipped to facilities that convert it into uranium-hexafluoride (UF_6), which is suitable for enrichment.

Gas centrifuge plants are the type of enrichment facility in use today, where a single centrifuge will take an input stream of UF_6 and produce two output streams: one with a higher percentage of the isotope U-235 than the input stream, and a second with a lower percentage of U-235. Enrichment plants can have thousands of centrifuges, and those centrifuges are connected to one another in different ways depending on the company's goals. Ultimately, an enrichment plant will produce a stream of uranium that is enriched to the desired level (e.g., U-235 content enriched to between 3 percent and 5 percent for use in nuclear power plants) as well as other streams at lower enrichment levels.

In the final step of nuclear fuel making for US power plants, the enriched UF_6 is sent to fuel fabrication facilities where it is converted into UO_2 and fabricated into fuel pellets. Those pellets are stacked inside metal fuel rods that are connected to each other as part of a fuel assembly, and power reactor cores have many fuel assemblies inside of them.

Figure 1: Creating nuclear fuel for reactors



Russia is not one of the leading miners of raw uranium, as shown in Table 1, though it has substantial involvement in the uranium mining operations of some other countries that have greater production. There are multiple allied nations, such as Canada and Australia, who could increase their uranium mining production, if necessary, to make up for any shortfall that might result from cutting off Russian uranium.

Table 1: Global production of uranium from mines and identified recoverable resources

Country	2020 production from mines (metric tons U)	2019 identified recoverable uranium resources (metric tons)
Kazakhstan	19,477	907,000
Australia	6,203	1,693,000
Namibia	5,413	448,000
Canada	3,885	565,000
Uzbekistan (est.)	3,500	132,000
Niger	2,991	276,000
Russia	2,846	486,000
China (est.)	1,885	249,000
US	6	48,000
All other	1,525	1,344,000

Source: World Nuclear Association, "World Uranium Mining Production," accessed March 30, 2022, https://world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/world-uranium-mining-production.aspx.

Note: US production has declined greatly from 1,919 metric tons in 2014, though could be increased again.

The next two steps in the nuclear fuel making process, however, involve a large Russian presence in international markets. As Table 2 shows, Russia accounted for nearly 40 percent of global conversion services in 2020. It also shows that several of the existing Western conversion facilities are operating at low utilization rates, which could be ramped up if there was a need. The ConverDyn conversion facility in the United States, for example, closed in 2017 due in part to challenging market conditions (e.g., decreases in demand from Japan and Germany following the Fukushima accident), but the company announced in 2021 plans to restart operations at the plant in 2023.[4] ConverDyn has also stated that it could potentially reinstate a capacity of 15,000 tons of uranium per year should there be a market signal to do so.[5]

Table 2: Global uranium conversion capacity and utilization in 2020

Country	Nameplate capacity (metric tons U)	Capacity utilization (metric tons U)
France	15,000	2,600
China	15,000	8,000
Canada	12,500	9,000
Russia	12,500	12,000
United States	7,000	0

Source: World Nuclear Association, "Conversion and Deconversion," citing the association's Nuclear Fuel Report (2021 edition), accessed March 30, 2022, https://world-nuclear.org/information-library/nuclear-fuel-cycle/conversion-enrichment-and-fabrication/conversion-and-deconversion.aspx.

Note: The US conversion facility plans to return to operations in 2023.

Similarly, Russia has a large presence in the international enrichment market. As Table 3 shows, Russia had around a 46 percent share of global enrichment capacity in 2018. The Russian enrichment entity Tenex provided 30 percent of enrichment services to European Union utilities in 2019.[6] South Korea's Korea Hydro & Nuclear Power (KHNP) recently signed a contract with Tenex to supply enrichment services out to 2030, reportedly bringing the total value of Tenex's contracts with KHNP to $2 billion.[7]

Table 3: Global uranium enrichment capacity in 2018 by operator

Operator	(thousands of separative work units/year)
Rosatom (Russia)	28,215
Urenco (UK, Netherlands, Germany, USA)	18,600
Orano (France)	7,500
CNNC (China)	6,750
Other	46

Source: World Nuclear Association, "Uranium Enrichment," citing the association's Nuclear Fuel Report 2019, accessed March 30, 2022, https://world-nuclear.org/information-library/nuclear-fuel-cycle/conversion-enrichment-and-fabrication/uranium-enrichment.aspx.

The price of enrichment services (described as "separative work units" or "SWUs") has been depressed for years.[8] The low price has led to existing enrichment facilities resorting to a practice known as "underfeeding": having less natural uranium shipped to them and devoting a greater amount of their capability toward enriching the material that has been produced with lower enrichment levels. In other words, the lower price for enrichment services in recent years has meant that the market is using less uranium mining and conversion services in order to produce the needed amount of low-enriched uranium (LEU) for Western power reactors.

However, if there is a policy in place to reduce or eliminate Russian involvement in Western nuclear fuel markets, this would almost certainly lead to a realignment in the supply chain. In the near-term, the market would likely shift to mining more natural uranium (from non-Russian sources) and raising the low utilization rate of existing Western conversion facilities to closer to their nameplate capacities. This would lead to more expensive fuel for operating reactors and thus will not happen without clear policy direction. (There are no legal or regulatory rules preventing this, and thus if this were the cheaper approach, the market would have already done it.)

No Russian fuel fabrication facilities are involved in the final step of making fuel for US nuclear power plants, but this is not the case for many of the countries hosting Russian VVERs. There is, however, some Western capability to fabricate fuel for those VVER reactors to supplant Russian involvement, if countries so chose. Westinghouse, for example, has the capability to make fuel for Russian VVER-1000s,[9] and could develop the capability to make fuel for other VVER models.

"Megatons to Megawatts" and the Russian Suspension Agreement

The high level of Russian enriched uranium in US nuclear fuel has a unique history and factors into how the United States got to where it is today in terms of diminished domestic capabilities. In 1993, the Russian Federation and the United States signed an agreement to eliminate excess highly enriched uranium (HEU) from dismantled Russian nuclear weapons.[10] From 1993 to 2013, downblended Russian HEU provided about half of the enriched uranium used in US power reactors, as part of the "Megatons to Megawatts" program.

Separate from the Megatons to Megawatts program, exports of Russian uranium products into the US fuel market have been limited for decades by what is colloquially referred to as "the Russian suspension agreement." The original agreement was signed on October 16, 1992, when the US Department of Commerce suspended an anti-dumping duty investigation on uranium from the Russian Federation (hence, "suspension agreement").[11] The agreement restricted the amount of Russian uranium products that could enter the US market, and it has been amended several times since it was first signed. It had previously been scheduled to expire at the end of 2020, but the amendment signed that year extended the agreement to 2040.

In the most recent amendment, the US Department of Commerce and the Russian state nuclear corporation Rosatom agreed to lower the amount of Russian uranium products allowed for export into the US market, and to limit the percentage of US enrichment demand met by Russia to 15 percent starting in 2028. In other words, even before the war in Ukraine began, the US government had been taking steps to reduce Russian involvement in US nuclear fuel markets, both for strategic and commercial reasons.[12] Some of the limits in the suspension agreement are reproduced in Table 4, though only out to 2030.

Table 4: Partially reproduced suspension agreement with limits on Russian exports

Export limit year	Percentage of US enrichment demand	Total export limit in kilograms U as LEU (A)	Total export limit in kilograms U-235 content (B)	USEC export limit allocation in kilograms U-235 (E) (Subset of B)
2021	24%	596,682	26,254	7,780
2022	20%	489,617	21,543	7,430
2023	24%	578,877	25,471	10,700
2024	20%	476,536	20,968	10,300
2025	20%	470,376	20,697	10,300
2026	20%	464,183	20,424	10,700
2027	20%	459,083	20,200	10,600
2028	15%	344,312	15,150	4,100
2029	15%	340,114	14,965	0
2030	15%	332,141	14,614	0

Source: US Department of Commerce, "2020 Amendment to the Agreement Suspending the Antidumping Investigation on Uranium From the Russian Federation," https://www.federalregister.gov/documents/2020/10/09/2020-22431/2020-amendment-to-the-agreement-suspending-the-antidumping-investigation-on-uranium-from-the-russian.

Note: The table does not show two columns in the agreement, "C" and "D": "Cap for LEU exports pursuant to sales of EUP [enriched uranium product] (may include sales of SWU plus conversion) in kilograms U-235" and "Cap for additional LEU exports pursuant to sales of SWU plus conversion Only in kilograms U-235."

As the Table 4 shows, one US company is specifically mentioned in the agreement: USEC,[13] which is today named Centrus. Centrus (located in Ohio) is the sole company with installed enrichment capacity in the United States that is not foreign owned (Urenco, which operates the only commercial-scale enrichment plant in the United States, is owned by the British, Dutch, and German governments). Part of Centrus's current business model is purchasing enrichment services from Tenex in Russia and supplying Russian LEU to US customers, nominally through 2028, and a congressional intervention to block out Russia, such as the bills mentioned earlier would do, would terminate those contracts.[14]

Fuel Supply for Non-Light Water Reactors

Previous to the Ukraine invasion, there was a different potential involvement that Russian enriched uranium might have had with some of the future advanced reactors under development in the United States. In recent decades, a variety of private companies have been founded to pursue commercialization of different advanced reactor designs. Some of these designs use uranium with significantly higher enrichments than light water reactors use: instead of 3–5 percent, the enrichments may be as high as 15–19.75 percent. Currently, the only commercial source of this high-assay low-enriched uranium (HALEU) is Russia.

In 2020, the US Department of Energy (DOE) announced a series of large cost-share awards with some of these private reactor developers.[15] For the biggest demonstrations, DOE would contribute a share of the demonstration costs, as long as private entities more than matched that investment. Given that Russia has been the only commercial source of HALEU, some advanced reactor developers were either planning to obtain—or at least considered obtaining—their first fuel load's worth of HALEU from Russia. In 2018, the Nuclear Energy Institute reported (based on company inputs) that estimated HALEU needs might potentially ramp up from tens of metric tons per year in the mid-2020s to over a 100 metric tons per year in the late 2020s.[16]

Existing enrichment companies, such as Urenco, Orano, GLE, and Centrus, could make HALEU, but these companies would likely be hesitant to invest too much in building HALEU infrastructure and completing NRC licensing without being confident there will in fact be a profitable market for the product. Industry estimates that establishing a commercial-scale production capability would cost more than $500 million.[17] On the reactor developer side, if a single company were to come to an enrichment company and ask to buy only the amount of HALEU they needed—perhaps at the level of tens of metric tons—the price per kilogram of HALEU would be much higher than if the associated development costs could be spread over a large order. Challenges—real and perceived—with HALEU fuel procurement could in turn deter investment in the deployment of some non-light water reactor designs. This is the "chicken and egg" dilemma that the US government is currently grappling with.[18] Buying the first core loads of HALEU from Russia would have enabled reactor developers to easily meet their stated timelines for when they needed fuel. It would also have allowed the federal government to gauge at some level how the construction and operation of the first non-light water reactor projects were executed before committing potentially large amounts of money toward domestic HALEU production.

If the Russian supply option were off the table, however, the United States would need to turn in earnest to remaining possibilities. Congress directed DOE to establish a HALEU availability program in the Energy Act of 2020. At the end of 2021, DOE had already put out a request for information regarding planning for the establishment of a program to support the availability of HALEU for civilian domestic research, development, demonstration, and commercial use,[19] and subsequently received a variety of responses.[20] Multiple bills in the 117th Congress have been introduced that would further authorize and direct DOE to pursue HALEU production programs.[21] Centrus has been working with DOE since 2019 to demonstrate a capability to produce HALEU and obtained NRC approval for HALEU production in 2021.[22]

Exposure of Global Nuclear Power to Russia for Nuclear Components, Services, and New Construction

In addition to a significant exposure to Russia in the uranium fuel chain, the global nuclear market relies on Russia for equipment and construction efforts. Many reactors in operation and under construction around the world are using Russian reactor technology. Given that most of the exported Russian reactors are of the VVER/pressurized water reactor design, we will focus on that technology for this analysis.

Existing/Operating Russian Designed and Built Nuclear Reactors

Operators of existing nuclear reactors can have significant supply chain exposure to original equipment manufacturers (“OEMs”) of their reactor type. Reactors have unique components that their OEM designed and built for their specific reactor type, including (focusing on the pressurized water reactor design):

- Most of the internal components of the reactor vessel, such as the fuel assembly structure, coolant, and flow components; the reactor vessel and head; and the control rod structures
- Components in the rest of the nuclear primary system (i.e., the system immediately connected to the reactor core) are also from the OEM, including the pressurizer, steam generators, and the primary water pumps and related systems

In addition to primary components, in various settings around the globe, many different parts of VVER power plant secondary reactor systems could be from Russian origin, including:

- Control room and reactor control systems
- Secondary pumps and their control systems
- Turbine generators and their control systems

Examples of services and components provided to global nuclear customers listed by Rosatom, the state nuclear power company of Russia and the OEM of the VVER reactors, include: assessing and developing key nuclear infrastructure components, large life extension projects, regular supply of spare parts and equipment, and power capacity expansion uprates.[23] In 2019 (the last year Rosatom published an annual report), Rosatom overseas revenues for nuclear fuel assemblies (excluding the uranium supply chain), reactor components, and services was $1.9 billion.[24]

While there is little data on annual maintenance and capital costs for Russian VVER reactors, public data from US nuclear reactors show that annual capital costs for nuclear power plants are $5.35/megawatt-hour (MWh), and annual maintenance costs are $18.27/MWh,[25] of which about a quarter are for physical supplies that have to be purchased.

The list of VVER reactors operating globally (excluding Russia, Belarus, Iran, and China, since those countries are likely to continue using Russian supplies) are listed in Table 5.

Table 5: Global operating VVER reactors in 2021, excluding those in Russia, Belarus, Iran, and China

Country	Reactor name	Model	Megawatt electrical net
Armenia	Armenian-2	VVER V-270	415
Bulgaria	Kozloduy-5	VVER V-320	1,003
Bulgaria	Kozloduy-6	VVER V-320	1,003
Czech Republic	Temelin-1	VVER V-320	1,027
Czech Republic	Temelin-2	VVER V-320	1,029
Czech Republic	Dukovany-1	VVER V-213	468
Czech Republic	Dukovany-2	VVER V-213	471
Czech Republic	Dukovany-3	VVER V-213	468
Czech Republic	Dukovany-4	VVER V-213	471
Finland	Loviisa-1	VVER V-213	507
Finland	Loviisa-2	VVER V-213	507
Hungary	Paks-1	VVER V-213	479
Hungary	Paks-2	VVER V-213	477
Hungary	Paks-3	VVER V-213	473
Hungary	Paks-4	VVER V-213	473
India	Kudankulam-1	VVER V-412	932
India	Kudankulam-2	VVER V-412	932
Slovakia	Bohunice-3	VVER V-213	466
Slovakia	Bohunice-4	VVER V-213	466
Slovakia	Mochovce-1	VVER V-213	436
Slovakia	Mochovce-2	VVER V-213	469
Ukraine	Zaporozhye-5	VVER V-320	950
Ukraine	Zaporozhye-6	VVER V-320	950
Ukraine	Rovno-1	VVER V-213	381
Ukraine	Rovno-2	VVER V-213	376
Ukraine	Rovno-3	VVER V-320	950
Ukraine	Khmelnitski-1	VVER V-320	950
Ukraine	Khmelnitski-2	VVER V-320	950
Ukraine	South Ukraine -1	VVER V-320	950
Ukraine	South Ukraine -2	VVER V-338	950

continued on next page

Country	Reactor name	Model	Megawatt electrical net
Ukraine	South Ukraine -3	VVER V-320	950
Ukraine	Zaporozhye-1	VVER V-320	950
Ukraine	Zaporozhye-2	VVER V-320	950
Ukraine	Rovno-4	VVER V-320	950
Ukraine	Zaporozhye-3	VVER V-320	950
Ukraine	Zaporozhye-4	VVER V-320	950
Ukraine	Zaporozhye-3	VVER V-320	950
Ukraine	Zaporozhye-4	VVER V-320	950

Source: International Atomic Energy Agency, "Power Reactor Information System," https://pris.iaea.org/pris/."

Exposure of existing nuclear operators to these OEM replacement components is more acute than for typical energy infrastructure for a couple reasons. First, the design requirements for nuclear systems are significantly more stringent than for typical power systems, given failure events are potentially much more acute. As a result, maintenance and procurement teams at existing operators typically return to the OEM for many critical system efforts, and alternative supply chains for replacement nuclear components don't tend to be well developed. Additionally, nuclear operators culturally tend to be very conservative on procurement of maintenance and upgraded equipment, and tend to default to purchasing from the plant OEM.

There is little public data on maintenance and capital expenditure purchase costs for operating VVER reactors. However, VVER reactors in general are of similar designs, sizes, and capacity factors to US light water reactors, so using the robust US data available is a reasonable surrogate for VVER operating costs. Assuming an 80 percent capacity factor for operating reactors, US data would suggest purchases of capital supplies required to run the existing global fleet is $4.3 billion annually.

While some of the countries listed in Table 5 are less likely to embargo Russian businesses as a result of the Ukraine war, the countries in Europe such as in Bulgaria, Czech Republic, Finland, Hungary, and Slovakia could face important impacts on their abilities to continue to operate their facilities due to parts and services needed from their VVER OEM. The VVERs in Ukraine are in a uniquely challenging position. Some non-Russian engineering and construction companies have built capabilities to replicate Rosatom VVER components, but replicating OEM designs and manufacturing can be a challenge for nuclear power plants.

New Nuclear Power Plant Construction

In addition, Russia, through Rosatom, has been a major potential provider of new nuclear power plants globally. Many plants around the world have been conducting multiyear design and site preparation efforts for the construction of VVER reactors, and many are already in construction. A work stoppage or abandonment of these projects would provide significant financial and energy supply impacts to those countries.

VVER reactors globally under construction or publicly identified as planned to be constructed (excluding those in Russia, Belarus, Iran, and China) are listed in Table 6.

Table 6: Global VVER reactors under construction or in planning in 2021, excluding those in Russia, Belarus, Iran, and China

Country	Reactor name	Model	Megawatt electrical net
Bangladesh	Rooppur-1	VVER V-523	1,080
Bangladesh	Rooppur-2	VVER V-523	1,080
Finland	Hanhikivi-1	VVER V-522	1,200
Hungary	Paks-5	VVER V-527	1,185
Hungary	Paks-6	VVER V-527	1,185
India	Kudankulam-3	VVER V-412	917
India	Kudankulam-4	VVER V-412	917
Slovakia	Mochovce-3	VVER V-213	440
Slovakia	Mochovce-4	VVER V-213	440
Turkey	Ankkuyu-1	VVER V-509	1,114
Turkey	Ankkuyu-2	VVER V-509	1,114
Turkey	Ankkuyu-3	VVER V-509	1,114
Turkey	Ankkuyu-4	VVER V-509	1,114

Source: International Atomic Energy Agency, "Power Reactor Information System," https://pris.iaea.org/pris/.

Note: The IAEA lists two VVERs as having been under construction at the Khmelnitski site in Ukraine since 1986/1987, but they have not actually been under construction for many years.

While some of the above are less likely to halt new Russian designed VVER reactor projects as a result of the Ukraine war, ones in Europe such as Finland, Hungary, Slovakia, and possibly Turkey may reconsider development of those plants. Finland already seems to have decided against building a Russian VVER since the Ukraine invasion.[26] As a result, they might have to consider other reactor vendors or look at non-nuclear technologies to fulfill their power needs. Given that power plant development cycles take many years, this could have significant negative impacts on their energy supply and policies.

Policy Options to Move Away from Russian Nuclear Energy Supply Chains

Countries considering new reactors can simply choose other vendors if they don't want to be dependent on Russia for fuel, equipment, and services. The US, France, Republic of Korea, and China are all viable reactor suppliers.

Countries that currently host Russian VVERs have a more complicated set of choices to make. They are likely dependent on Russia not just for fuel but for reactor equipment and services. There are some alternatives at least for replacing Russian fuel. Westinghouse, as mentioned, is able to make fuel assemblies for VVER-1000s, and it is possible the company will be able to manufacture fuel for other VVER designs in the near-term.[27] Westinghouse is also able to supply some services to VVERs.[28]

For all other countries with non-VVER power reactors, Russian-mined uranium is not the challenge in extricating themselves from involvement with Russia in procuring their fuel. As shown in Table 1, Russia only mines approximately 6 percent of the uranium produced each year, and other countries can expand production if necessary. Fuel fabrication is also not the challenge.

Instead, policy options to replace Russia's large presence in global conversion and enrichment services would be where the United States and its allies would need to focus their attention. The conversion and enrichment capacities in Canada, France, Germany, the Netherlands, the United Kingdom, and the United States are enough to replace at least some of the Russian fuel services involved in fueling Western nuclear power plants with greater uranium mining. More investment in mining, conversion, and enrichment facilities may be necessary to fully extricate Western nuclear fuel chains from Russian involvement. However, adding sufficient new conversion capacity and enrichment capacity will take years to accomplish.

In any case, mining, conversion, and enrichment suppliers in the West will be looking to national governments to provide clear policies before they invest money in new facilities and capabilities. Their worry will be that in a year or two, perhaps less, Russian uranium products will be allowed back into national markets and will undercut them, causing them to lose out on their investments. National laws that impose a date for ceasing supplies from Russia—such as the bills cited earlier—would send a clear signal to private markets in the United States and elsewhere so they can adjust efficiently.

International meetings with Western governments could be held to discuss how best to coordinate a reduction or elimination of Russian involvement in their nuclear fuel supply chains. The natural uranium, conversion, and enrichment markets are internationally linked, and national decisions in one country will have impacts on other programs. It will be important for these governments to communicate to the public that all policy options to remove dependency on Russian supply chains are likely to raise costs for operating plants.

The recently created Civil Nuclear Credit Program, established by the 2021 Bipartisan Infrastructure Law,[29] may be able to assist in limiting these impacts, as could the material in DOE's American Assured Fuel Supply.[30]

The optimal timing of full extrication—for either all Western nations or the United States alone—is beyond the scope of this paper but would certainly be an issue DOE would need to study immediately if it intends to act. The total impacts of a shutoff of Russian uranium products in 2022 are unknown to the authors; the relevant information may exist outside the public realm, though congressional hearings could uncover some of these details. Given the long lead times for ordering nuclear fuel assemblies, the authors do not believe it likely that such a decision would result in outages due to lack of fuel at US power reactors this year, but it is harder to assess impacts in 2023. Other Western governments may also want to use the same non-Russian mining, conversion, and enrichment facilities as part of a similar strategy to reduce Russian involvement in their power markets, raising the prospect of competition for services. The only US conversion facility is still on standby and will not return to producing 7,000 tons of uranium per year until 2023; increasing that capacity to 15,000 tons per year will take longer.

Given these factors and the unique historical context for large amounts of Russian material in US commercial reactors (i.e., the Megatons to Megawatts program), the authors reason that ramping down Russian supplies would happen more smoothly over a period of years not months. This is more consistent with the types of lead times that reactor owners employ for contracts involving different stages of the nuclear fuel cycle.[31] The US government could simultaneously facilitate meetings with Western governments that have mining, conversion, and enrichment facilities to discuss policy options to hasten a greater capability to supplant Russian conversion and enrichment services. Such efforts to strengthen capability may involve a move away from underfeeding existing Western enrichment capacity using increased uranium mining and greater utilization of conversion services. The US government could also consider supporting the construction of a national security compliant fuel chain, given the lack of one using only US-origin technology, equipment, and materials—a national security concern noted by external reports.[32]

It is possible that a nearer-term or even immediate suspension of Russian imports could produce disruptions to the US market that are acceptably small. If this were the case and would not cause existing plants to shut down or experience extended outages, an earlier cutoff is preferable to a later one to minimize dollars sent to Russia as well as US exposure to Russian supply.

Finally, with regard to HALEU production, a logical next step that DOE could pursue is to issue a request for proposals on how best to establish a HALEU production line and see what the private sector proposes. Reports have suggested a combination of government cost-sharing and off-take agreements could form a viable strategy.[33]

Notes

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2. For example, Senator Barrasso introduced legislation with several cosponsors to ban Russian uranium imports 45 days after enactment: https://www.barrasso.senate.gov/public/index.cfm/2022/3/barrasso-leads-bill-to-ban-russian-uranium-imports; Senator Manchin and Senator Risch introduced legislation that would not allow Russian LEU imports as of 2026: https://www.congress.gov/bill/117th-congress/senate-bill/4064.
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About the Authors

Dr. Matt Bowen is a Research Scholar at the Center on Global Energy Policy at Columbia University SIPA, focusing on nuclear energy, waste, and nonproliferation. He was formerly a Nuclear Policy Fellow at Clean Air Task Force and a Senior Policy Fellow at the Nuclear Innovation Alliance.

Dr. Bowen has written reports on federal and state policies to encourage advanced reactor development, and has also published papers on reforming U.S. nuclear export controls. During the Obama Administration, he was an Associate Deputy Assistant Secretary in the Office of Nuclear Energy and a Senior Advisor in the Office of Nonproliferation and Arms Control at the U.S. Department of Energy (DOE). Previous to working at DOE, he was an AAAS/APS Science Fellow for Senate Majority Leader Harry Reid. Dr. Bowen received a Bachelor of Science degree in physics from Brown University and a Ph.D. in theoretical physics from the University of Washington, Seattle. He has held positions at the National Academies with the Board on Physics and Astronomy, the Board on Energy and Environmental Studies, and the Division on Engineering and Physical Sciences.

The Honorable Paul M. Dabbar is a Distinguished Visiting Fellow at the Center on Global Energy Policy at Columbia University SIPA. He is also CEO and Co-founder of Bohr Quantum Technology, developing and deploying technologies for the emerging quantum internet.

Prior to that in 2017, the U.S. Senate unanimously confirmed Mr. Dabbar to serve as the

Department of Energy's fourth Under Secretary for Science, where he served from 2017-2021. He managed several areas of the Department, as well as serving as the Department's principal advisor on fundamental energy research, energy technologies, science, and commercialization of technologies. He managed over 60,000 people with a budget of $15 billion p.a. at over 100 sites, including managing the majority of the U.S. National Laboratories.

Areas of research he managed included basic energy sciences, nuclear and high energy physics, advanced computing, fusion, and biological & environmental research. He also led the largest environmental remediation program in the U.S., addressing the operations of nuclear weapons and commercial power production, completing several multi-billion dollar construction projects. He also led various new efforts to commercialize innovations arising from the National Labs. He co-led several new energy innovation efforts, including the Energy Storage Grand Challenge, as well as the passage and implementation of the National Quantum Initiative Act.

Mr. Dabbar was awarded in 2021 the Secretary of Energy's senior DOE award, the James R. Schlesinger Medal, for leadership on developing energy technologies, discovery science, environmental management, and the National Quantum Initiative.

During his time in government service, Mr. Dabbar traveled to both the geographic North and South Poles. He traveled to the North Pole by submarine to conduct environmental research while in the Navy, and to the South Pole in support of high energy physics astronomy missions of DOE at South Pole Station.

Prior to confirmation as Under Secretary, Mr. Dabbar worked in operations, finance, and strategy roles in the energy sector. As a Managing Director at J.P. Morgan, he had over $400 billion in transaction experience across all energy sectors. In addition, he had a senior leadership role for the company's commodity trading business, including energy. Before joining J.P. Morgan, Mr. Dabbar served as a nuclear submarine officer. He has been a lecturer at the U.S. Naval Academy, and conducted research at the Johns Hopkins University Applied Physics Laboratory. Mr. Dabbar is a member of the Council on Foreign Relations.

Mr. Dabbar has a bachelors from the U.S. Naval Academy, is a graduate of the U.S. Navy's nuclear power and nuclear engineer programs, and a masters from Columbia University.

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