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Special Report

Power Plays
Developments in Russian Enriched Uranium Trade

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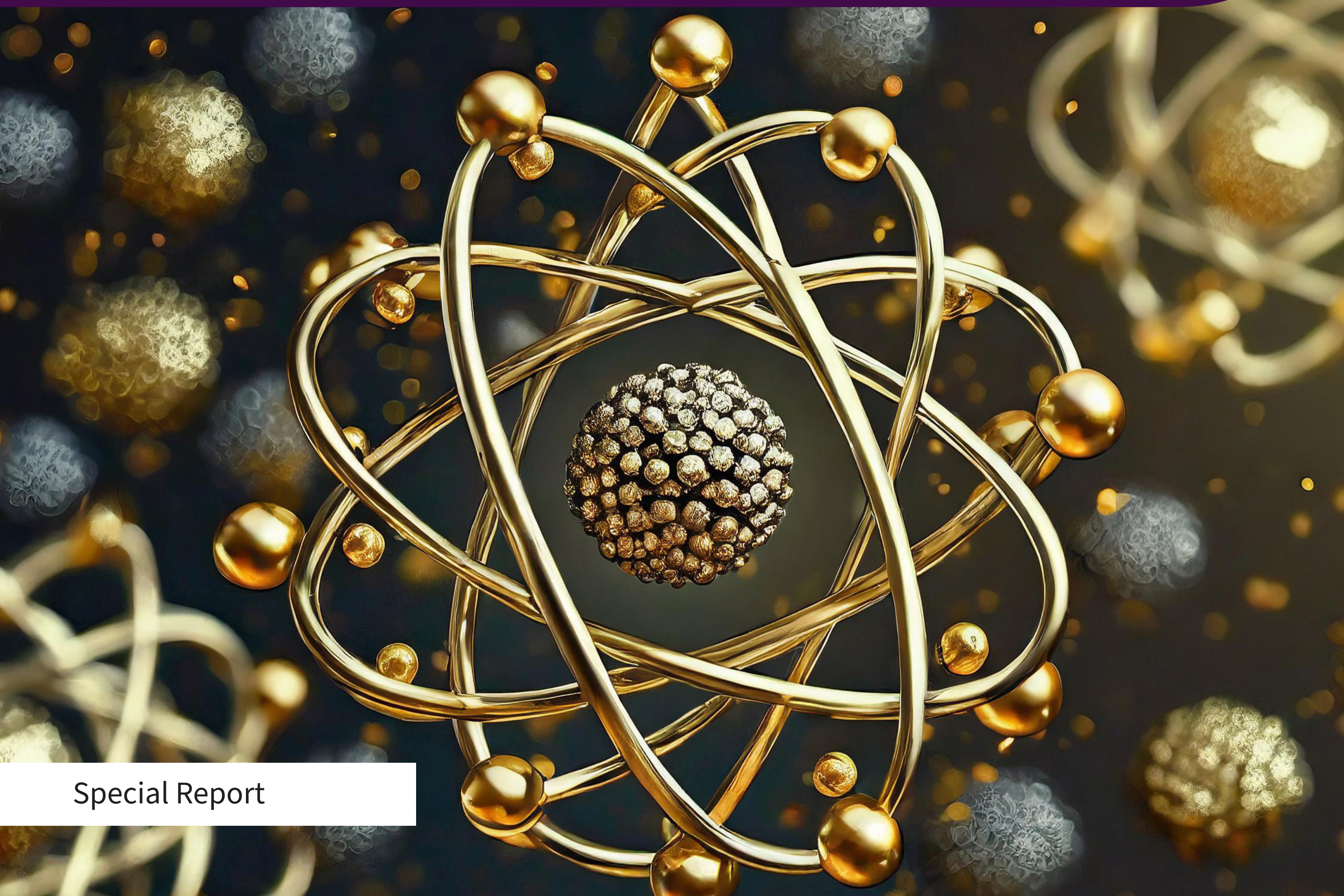

Special Report

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Introduction and Report Overview

On 17 February 2024, almost two years since Russia's full-scale invasion of Ukraine, President Volodymyr Zelenksy addressed the Munich Security Conference, pleading for unity against the aggression perpetuated by Russian President Vladimir Putin and for continued support for Ukraine in its fight.[1] Among his calls to action, Zelensky stressed the need to close 'all loopholes in the sanctions against Russia', singling out Russia's nuclear industry in particular. 'There should be no sectors of the Russian economy involved in its aggression that are still free from sanctions', he said. 'This particularly relates to the nuclear sector'.[2]

Russia's Rosatom State Atomic Energy Corporation (Rosatom)[3] is an important player in the international nuclear energy industry, with a major presence across various stages of the nuclear fuel cycle. The company, through its subsidiaries JSC TVEL[4] and Techsnabexport LLC (better known as TENEX),[5] is the biggest supplier of uranium enrichment to the global market,[6] and has continued to export significant volumes of enriched uranium product since Russia's full-scale invasion of Ukraine in February 2022. In 2022, Russia accounted for 30% of the separative work units (SWU, the unit of measurement for uranium enrichment

1. President of Ukraine Volodymyr Zelenskyy, 'Do not ask Ukraine when the war will end. Ask yourself – why Putin is still able to continue it – speech by President Volodymyr Zelenskyy at the Munich Security Conference', 17 February 2024, <https://www.president.gov.ua/en/news/ne-pitajte-ukrayinu-koli-zakinchitsya-vijna-pitajte-v-sebe-c-89021>, accessed 18 February 2024.
2. *Ibid.*
3. Государственная корпорация по атомной энергии «Росатом» [State Atomic Energy Corporation 'Rosatom'], INN: 7706413348 (company data sourced from Sayari Analytics).
4. Акционерное общество «ТВЕЛ» [Joint Stock Company 'TVEL'], INN: 7706123550 (company data sourced from Sayari Analytics).
5. Акционерное общество «Техснабэкспорт» [Joint Stock Company 'Tekhsnabexport'], INN: 7706039242 (company data sourced from Sayari Analytics).
6. Rosatom, 'Performance of State Atomic Energy Corporation Rosatom in 2022', p. 11, <https://www.report.rosatom.ru/en>, accessed 7 December 2023. The global uranium enrichment market is highly concentrated, with a limited number of companies providing commercial uranium enrichment services. These are Techsnabexport (Russia), Urenco (Germany, the Netherlands and the UK, with enrichment facilities also in the US), Orano (France) and China National Nuclear Corporation (CNNC). See World Nuclear Association, 'Uranium Enrichment', updated October 2022, <https://world-nuclear.org/information-library/nuclear-fuel-cycle/conversion-enrichment-and-fabrication/uranium-enrichment.aspx>, accessed 15 February 2024.

services[7]) delivered to EU utilities[8] and for 44% of global enrichment capacity.[9] In the US, 24% of SWU purchased by US utilities in 2022 came from Russia.[10]

This report examines the extent of Western (European and US) dependencies on Russian enriched uranium and identifies ways in which Rosatom may be continuing to access global, including Western, nuclear fuel supply chains, despite some efforts in the US and Europe to diversify away from Russian supply. The report studies changes in Russian enriched uranium trade patterns since the start of 2022 to identify possible indicators of efforts to adapt to restrictions on Russian uranium supply that have been or may be introduced by governments and companies.

The report examines four main case studies. In the first case study, the report outlines possible Chinese displacement activity using Russian material, identifying trade patterns that suggest that increased imports of Russian enriched uranium into China may be facilitating greater exports of Chinese enriched uranium supply, including to the US. The second case study addresses well-documented increases in enriched uranium imports from Russia to France and considers a range of possible explanations for this growth. While the precise flow and use of the additional Russian material that is being imported into France is difficult to ascertain definitively, it appears that France may be offering an outlet for Russian enriched uranium that is no longer welcome in other countries. This may be facilitating the reallocation of Russian supplies across European utilities' supply chains, allowing Russia to continue accessing the European nuclear fuel market even as some countries seek to diversify away from Russian supply. The third case study examines reported deliveries through France and possibly the Netherlands of Russian enriched uranium to a French-owned fuel fabrication facility in Germany. The trade data reviewed for this report could not confirm the extent of deliveries to Germany of Russian material through third countries, or whether there have been shifts in such activity since the start of 2022; however, any such deliveries to Germany may be providing an additional option for Russian enriched uranium imports no longer welcome in other countries and may potentially be used in the future fabrication of VVER assemblies in Germany. The fourth case study touches on US dependencies on Russian enriched uranium

7. Separative work units (SWU) measure the amount of effort required to separate U-238 and U-235 isotopes. See Eurostat, 'Glossary: Separative Work Unit', <https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Separative_work_unit_(SWU)>, accessed 15 February 2024.
8. Euratom Supply Agency, 'Annual Report 2022', 13 October 2023, p. 19, <https://euratom-supply.ec.europa.eu/system/files/2023-10/ESA%20Annual%20Report%202022%20-%20Final%20%28website%29_2.pdf>, accessed 11 December 2023.
9. World Nuclear Association, *The Nuclear Fuel Report: Global Scenarios for Demand and Supply Availability 2023-2040* (London: World Nuclear Association, 2023), p. 185.
10. US Energy Information Administration, '2022 Uranium Marketing Annual Report', p. 45, June 2023, <https://www.eia.gov/uranium/marketing/pdf/2022%20UMAR.pdf>, accessed 1 November 2023.

and the likely limits of a proposed US ban on imports of Russian uranium in limiting Russia's role in global nuclear fuel supply chains and Rosatom revenues.

Ultimately, the report demonstrates how Russia may be able to take advantage of incongruencies in sanctions or other restrictions, as well as persistent contractual dependencies and supply challenges, to maintain access to Western nuclear fuel supply chains and continue generating revenue through its enriched uranium exports. To improve effectiveness, any future sanctions or other bans aimed at limiting Russia's presence in global nuclear fuel supply chains must be multilateral and accompanied by a concerted effort to increase Western and partner capacity across the supply chain, to successfully undercut dependence on Russian supply.

It is worth noting that most of the activities described in this report are entirely legal and likely represent logical efforts by companies to adapt to the changing trade and geopolitical landscape while continuing to meet whatever contractual obligations they may have for continued purchase and import of Russian material. As such, the report does not imply any violations of the laws of any relevant jurisdiction, or any international laws or sanctions. As described in more detail in Chapter II, the delivery to the US of enriched uranium that has been displaced by Russian supply, as may be the case with Chinese enriched uranium trade, may be in contravention of US regulation, unless assurances have been given to US authorities that such displacement is not taking place.

The practices described in this report raise questions over the extent of Western dependencies on Russian enriched uranium supply, the implications for Western energy security, the imbalance of vulnerability this may create between some Western governments and Moscow, and the effectiveness of efforts to cut Russia out of global, or even Western, nuclear supply chains. While the nuclear sector holds strategic significance for Moscow, it is not a major revenue source for Russia when compared to Russian trade in other commodities, such as oil and gas. However, as outlined in this report, Western reliance on Russian enriched uranium supply is proving challenging to shake, at least in the short term, and may create some difficulties for Western generation of nuclear energy, although experts disagree on the urgency and extent of potential challenges. The willingness, or necessity, of some Western countries to overlook Russian adaptations following efforts by other countries to limit Russian presence in Western nuclear fuel supply chains also points to a political and moral dissonance with stated US and European commitments to support Ukraine in its fight against Russian aggression.

Data and Research Methodology

The data for this report was collected from a range of publicly accessible sources. These include: the UN Comtrade Database; the Eurostat database; trade data made available by national governments; trade data sourced from third-party trade data providers; corporate reporting documents and other publicly available corporate information; analysis published by think tanks, academic institutions, consultancies, industry associations and interest groups; and media reporting. Some of the data was sourced from non-English-language sources. Data from Russian-, Ukrainian-, French- and Spanish-language sources was viewed in its original language. Data from other language sources was viewed using digital translation. Urenco, the project funder, provided additional data and feedback throughout the research process. Any data that was subsequently included in the report or informed the analysis was independently verified through publicly available (or publicly accessible) sources. The report was subsequently subject to several internal and external peer reviews.

Fourteen unstructured anonymous interviews with a range of experts were also conducted to test some of the assumptions and hypotheses being drawn from the data, to identify possible alternative explanations for some of the trade patterns observed, and to capture any necessary nuance or overlooked data. To ensure the highest quality insights, interview questions were tailored to each expert's distinct area of expertise, because, given the commercial sensitivity of nuclear fuel contracts and the intricate nature of global nuclear supply chains, not all experts consulted were necessarily familiar with all the dynamics being examined in this report. This approach facilitated a more nuanced understanding of the subject matter, reinforcing the robustness of the methodology employed in this report. While conducting this research, input was sought from key industry stakeholders and relevant organisations. To ensure comprehensive coverage and balanced perspective, outreach was extended to several entities mentioned in the report. Unfortunately, not all entities that were approached responded.

As with any large data set, the trade data accessed for this report may include some inconsistencies, omissions or duplicates. Misreporting in customs data is also possible. Efforts have been made to clean the datasets (by removing apparent duplicate entries from transaction-level datasets or disregarding datasets that were clearly incorrect) and to validate trends in data across multiple datasets, but it is possible that some inaccuracies remain.

Because Russia does not release data on its enriched uranium exports, values for trade with Russia were sourced from parallel import data of importing countries. Russia is not the only country that does not make information on its enriched uranium exports publicly available. For instance, the UK also does not publicly report its trade in enriched uranium. This limited the analysis that could be conducted for this report to those countries whose data could be accessed through publicly accessible sources. Any reference to exports from a given country indicates values sourced from the export data of that country; any reference to imports into a given country indicates values sourced from the import data of that country. In many instances, the import and export data of two trading partners differed somewhat; this may be due to differences in customs reporting between the two countries or delays between the export of material from one country and its arrival in the other. Such discrepancies have been noted throughout the report and given due attention in instances where they were particularly significant.

It is worth noting that the prices of natural uranium and enrichment services – which are included in the value of enriched uranium product – fluctuate. The spot price (the price of uranium purchased outside existing contracts) of natural (unenriched) uranium has risen significantly in the past three years.[11] To avoid conflating increases in the values and volumes of trade in enriched uranium, data on both the monetary values and the net weight of enriched uranium (in the form of uranium hexafluoride) and nuclear fuel being traded has been included in the report, where available. However, data on the weight of material traded can also vary between datasets. While the data largely captures net weight, in some instances, data may also be capturing gross weight. As such, both the value and volume of goods should be reviewed together when analysing the data. The two largely bear out similar patterns. Where there are notable discrepancies, this has been highlighted.

When querying trade data for enriched uranium, where possible, searches were conducted for HS code 28442035, the commodity code for uranium enriched in U-235 and its compounds.[12] Some databases only allow for searches of six-digit HS codes; in these instances, HS code 284420 was queried instead, which includes the following commodities: uranium enriched in U-235 and its compounds; plutonium and its compounds; alloys; dispersions (including metal-ceramics); ceramic products and mixtures containing uranium enriched in U-235; plutonium or compounds of these products.[13] As such, data queried using the six-digit code may also include some materials besides enriched uranium. However, data for HS code 284420 is normally overwhelmingly made up of enriched uranium, with any other materials appearing in relatively small quantities. Variations of HS

11. Y Charts, 'Uranium Spot Price (I:USPNM)', <https://ycharts.com/indicators/uranium_spot_price>, accessed 18 February 2024.
12. European Customs Portal, 'HS Code 28442035' – Uranium, Enriched, Compounds', <https://www.tariffnumber.com/2024/28442035>, accessed 18 February 2024.
13. UN Statistics Division, 'HS, 2017 - Code 284420', <https://unstats.un.org/unsd/classifications/Econ/Detail/EN/2089/284420>, accessed 18 February 2024.

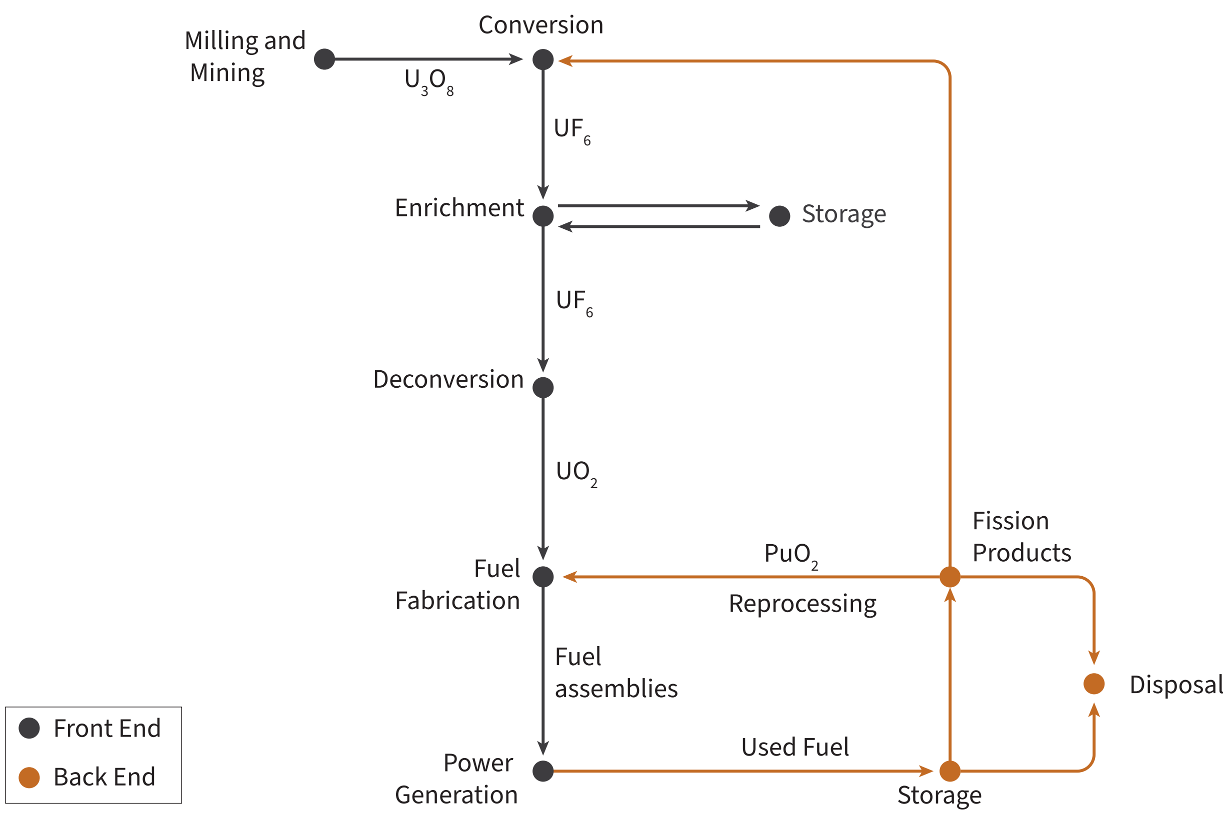
code 284420 were used in some instances – HS code 28442000 to query Chinese data (similar considerations relating to queries using HS code 284420 apply) and HS code 2844200020 to query US data (which captures uranium fluoride enriched in U-235) to access information on the weight of traded material, not just value.

I. Nuclear Fuel Supply Chains and Russia's Role

Before examining Russia's enriched uranium trade, it is worth understanding the nature of global nuclear fuel supply chains. Figure 1 includes a simplified overview of the nuclear fuel cycle. This report is only concerned with the front end of the cycle, and more specifically the enrichment stage.

Overview of Market Dynamics in the Front End of the Nuclear Fuel Cycle

Figure 1: Overview of the Nuclear Fuel Cycle



Source: Data from World Nuclear Association, 'Nuclear Fuel Cycle Overview', updated April 2021, <https://world-nuclear.org/information-library/nuclear-fuel-cycle/introduction/nuclear-fuel-cycle-overview.aspx>, accessed 15 February 2024.

The generation of energy from nuclear fuel depends on the splitting of atoms of the uranium isotope U-235 inside a nuclear reactor (nuclear fission). Mined uranium ore is made up of about 0.7% of U-235, with the remainder consisting of U-238. To make the fissile U-235 isotope suitable for nuclear energy generation in light water reactors its concentration must be increased before the uranium can be used to produce nuclear fuel assemblies (for most contemporary nuclear reactors, the concentration is about 3–5% U-235, which is classified as low enriched uranium (LEU)). This is done through the uranium enrichment process, using one of several possible methods. Globally, there is a limited number of companies that offer enrichment services, with almost all commercial enrichment conducted by one of four companies: Rosatom; China National Nuclear Corporation; Orano; and Urenco.[14] Enrichment capacity is measured in SWU, which represent the effort required to separate isotopes of U-235 and U-238.[15]

Nuclear fuel fabrication is also limited to a relatively small number of manufacturers.[16] Once manufactured, nuclear fuel assemblies may be used in the country of fabrication or shipped for loading into reactors in other countries. Due to the challenges associated with transporting radioactive material, nuclear fuel is usually fabricated broadly in the same region of the world where it will be used.

The ultimate consumers of uranium in the civil nuclear fuel cycle are energy utilities, which generate electricity through the operation of nuclear reactors and sell it to consumers. Most often, the utility purchases the uranium it needs directly from uranium mine operators and owns the uranium throughout the rest of the front end of the nuclear fuel cycle.[17] The utility then purchases the services necessary to turn mined uranium into usable nuclear reactor fuel (that is, conversion, enrichment, deconversion and fuel fabrication) from relevant service providers; however, the utility normally remains the sole owner of the material throughout the process.

The various service providers may be – and often are – located in countries other than the one where the material will eventually be used in reactors for energy generation. As a hypothetical example, uranium ore mined in Kazakhstan may be purchased by a Swiss utility, sent to Russia to be converted and enriched by Russian companies, then transported to a French-owned nuclear fuel fabrication

14. World Nuclear Association, 'Uranium Enrichment'.
15. Eurostat, 'Glossary: Separative Work Unit'.
16. For a list of nuclear fuel manufacturers, see World Nuclear Association, 'Nuclear Fuel and its Fabrication', updated October 2021, <https://world-nuclear.org/information-library/nuclear-fuel-cycle/conversion-enrichment-and-fabrication/fuel-fabrication.aspx>, accessed 15 February 2024.
17. Sfen, 'Le nucléaire français n'est pas sous emprise russe – fact checking du rapport Greenpeace' ['French Nuclear Power is not Under Russian Influence – Fact Checking of Greenpeace Report'], 17 March 2023, <https://www.sfen.org/rgn/le-nucleaire-francais-nest-pas-sous-emprise-russe-fact-checking-du-rapport-greenpeace/>, accessed 15 February 2024.

plant in Germany to be made into nuclear fuel assemblies, before finally being delivered to Switzerland for use in Swiss nuclear reactors. Throughout this process, the Swiss utility would maintain ownership of the uranium material.

An alternative supply model involves the purchase and sale of uranium at various stages of the nuclear fuel cycle by brokers and traders, who have themselves purchased the uranium or services in question from providers and sell these on to utilities.

Russian Presence Across the Global Nuclear Fuel Supply Chain

While Russian companies offer services across the nuclear fuel cycle, this report focuses on the provision of Russian enrichment services, as enrichment and conversion are the parts of the global nuclear supply chain where there are the greatest dependencies on Russia. Russia and, more specifically, the Rosatom subsidiaries TVEL and TENEX, is the greatest supplier of enrichment services to the global market.[18] In 2022, Rosatom provided 35% of uranium enrichment services globally, according to the company's 2022 annual report,[19] and, according to the World Nuclear Association (WNA), provided 44% of global enrichment capacity in 2022.[20]

The precise value of Russian enriched uranium exports over the past two years is difficult to ascertain as Russia does not make data on its enriched uranium trade publicly available. Some estimates are possible using import data from Russian customer countries reported through publicly accessible sources such as UN Comtrade, Eurostat, individual government reporting and third-party trade data providers. However, as noted earlier, some countries, for example, the UK, do not report their enriched uranium imports. Furthermore, at least in the case of the US, the import values of Russian enriched uranium include 'returned feed', that is, unenriched uranium the equivalent of which is returned to Russia, as required under US regulation (for more details, see Chapter V).[21] As such, estimates of Russian enriched uranium exports are likely to be inexact and are not necessarily representative of the revenue that Rosatom generates from this trade. UN Comtrade data shows $2.03 billion in global imports from

18. World Nuclear Association, 'Uranium Enrichment'.
19. Rosatom, 'Performance of State Atomic Energy Corporation Rosatom in 2022', p. 45.
20. World Nuclear Association, *The Nuclear Fuel Report*, p. 185.
21. Rowen Price, Ryan Norman and Alan Ahn, 'Western Reliance on Russian Fuel: A Dangerous Game', *Third Way*, 20 September 2023, <https://www.thirdway.org/memo/western-reliance-on-russian-fuel-a-dangerous-game>, accessed 18 February 2024.

Russia under HS code 284420 in 2022, up from $1.29 billion in 2021.[22] Data compiled from a range of sources shows $2.7 billion of enriched uranium imports from Russia in 2023.[23]

Several Western and partner governments have taken some limited measures to sanction Rosatom or to make trade with Russia in nuclear materials more challenging or unattractive. The UK,[24] the US[25] and others[26] have sanctioned parts of the Rosatom leadership and/or a small number of the company's subsidiaries. In July 2022, the UK also introduced a new 35% tariff on imports of radioactive

22. UN Comtrade Database, <https://comtradeplus.un.org/>, accessed 29 January 2024. For more information on sources and analysis of trade data in this report, see 'Data and Research Methodology'.
23. Data on the value of imports of Russian enriched uranium for 2023 was sourced from a number of sources, including: UN Comtrade (using HS code 284420, accessed 4 February 2024); a third-party trade data provider (using HS codes 284420 and 28442035, accessed 4 February 2024); US customs data sourced from the United States Census Bureau (using HS code 284420) (United States Census Bureau, 'USA Trade Online', <https://usatrade.census.gov/index.php>, accessed 15 February 2024); Chinese customs data sourced from the General Administration of Customs of the People's Republic of China (using HS code 28442000) (General Administration of Customs of the People's Republic of China, 'Customs Statistics', <http://stats.customs.gov.cn/indexEn>, accessed 29 January 2024); the Korea International Trade Association (using HS Code 284420) (Korea International Trade Association (KITA), 'k-Statistics', <https://kita.org/kStatistics/overview/balanceOfTrade/balanceOfTradeList.do>, accessed 15 February 2024). EU countries' trade data sourced from Eurostat (using HS code 28442035, and using EUR to USD conversion rate of 1.0824) (Eurostat, 'EU Trade since 1988 by HS2-4-6 and CN8', accessed 24 February 2024). Kazakhstan trade data sourced from the Development Bank of Kazakhstan (using HS code 284420) (Development Bank of Kazakhstan, 'Analytical Portal on the RK Foreign Trade', <https://www.kdb.kz/en/analytics/analytical-portal-foreign-trade-of-the-RK/>, accessed 8 March 2024). Countries whose import data was queried for 2023 were selected based on the countries for which UN Comtrade showed historical imports of Russian enriched uranium since 2019. For more information on sources and analysis of trade data, see 'Data and Research Methodology'.
24. Foreign, Commonwealth and Development Office (FCDO), 'UK Sanctions Target Russia's Theft of Ukrainian Grain, Advanced Military Technology, and Remaining Revenue Sources', press release, 19 May 2023, <https://www.gov.uk/government/news/uk-sanctions-target-russias-theft-of-ukrainian-grain-advanced-military-technology-and-remaining-revenue-sources>, accessed 14 November 2023; FCDO and Department for Business and Trade, 'New Sanctions Ban Every Item Russia is Using on Battlefield', press release, 24 February 2023, <https://www.gov.uk/government/news/new-sanctions-ban-every-item-russia-is-using-on-the-battlefield>, accessed 14 November 2023.
25. US Department of State, 'The United States Takes Sweeping Actions on the One Year Anniversary of Russia's War Against Ukraine', fact sheet, 24 February 2023, <https://www.state.gov/the-united-states-takes-sweeping-actions-on-the-one-year-anniversary-of-russias-war-against-ukraine/>, accessed 14 November 2023; US Department of the Treasury, 'Treasury Targets Russian Financial Facilitators and Sanctions Evaders Around the World', 12 April 2023, <https://home.treasury.gov/news/press-releases/jy1402>, accessed 15 February 2024; US Department of State, 'United States Imposes Additional Sanctions and Export Controls on Russia in Coordination with International Partners', fact sheet, 19 May 2023, <https://www.state.gov/united-states-imposes-additional-sanctions-and-export-controls-on-russia/>, accessed 14 November 2023; US Department of State, 'Imposing Additional Sanctions on Those Supporting Russia's War Against Ukraine', fact sheet, 20 July 2023, <https://www.state.gov/imposing-additional-sanctions-on-those-supporting-russias-war-against-ukraine/>, accessed 14 November 2023.
26. Government of Canada, 'Canada Announces Additional Sanctions Against Russia's Military and Nuclear Sectors', 23 August 2023, <https://www.canada.ca/en/global-affairs/news/2023/08/canada-announces-additional-sanctions-against-russias-military-and-nuclear-sectors.html>, accessed 18 February 2024; Australian Minister for Foreign Affairs, 'Australia Stands With Ukraine and the G7 Against Russia's Invasion', 19 May 2023, <https://www.foreignminister.gov.au/minister/penny-wong/media-release/australia-stands-ukraine-and-g7-against-russias-invasion>, accessed 18 February 2024.

chemical elements and isotopes from Russia, which includes enriched uranium.[27] While the EU has not introduced sanctions on Russia's nuclear sector, some European countries and companies have undertaken efforts to diversify away from Russian imports, turning to alternative suppliers of nuclear reactor technology[28] and nuclear fuel.[29] A bill that would restrict the import of Russian enriched uranium into the US was also passed in the US House of Representatives in December 2023 and, at the time of writing, was awaiting debate by the US Senate.[30]

While analysts disagree on precisely how much the termination of Russian enriched uranium deliveries would impact Western utilities, there seems to be broad agreement that, in the absence of additional Western capacity coming online, such an embargo, whether introduced by Western governments or by Russia, as Moscow has previously threatened,[31] would create at least some challenges for Western utilities.[32] Several experts interviewed for this research expressed concerns that some US utilities may struggle to keep nuclear power plants operating should Russian enriched uranium supply be cut off;[33] one interviewee noted that the concern is probably over longer-term supply and that utilities likely have sufficient stockpiles to carry them over in the short term.[34] Furthermore, as time passes, governments and utilities may become increasingly better prepared to deal with disruptions in Russian enriched uranium supply. (For a further discussion on potential supply challenges, see Chapter V.)

27. Department for Business and Trade, 'Additional Duties on Goods Originating in Russia and Belarus', last updated 30 November 2023, <https://www.gov.uk/guidance/additional-duties-on-goods-originating-in-russia-and-belarus>, accessed 18 February 2024.
28. Karel Janicek, '3 Energy Companies Compete to Build a New Nuclear Reactor in the Czech Republic', *AP News,* 31 October 2023; *World Nuclear News*, 'Bulgaria to Push Ahead with Two New Units at Kozloduy', 25 October 2023, <https://www.world-nuclear-news.org/Articles/Bulgaria-to-push-ahead-with-two-new-units-at-Kozlo>, accessed 15 January 2024.
29. Westinghouse Electric Company, 'Westinghouse Advances Energy Security in Czech Republic', 28 June 2022, <https://info.westinghousenuclear.com/news/westinghouse-advances-energy-security-in-cz>, accessed 14 November 2023; Westinghouse Electric Company, 'Westinghouse's VVER-1000 Nuclear Fuel Fabrication Agreement Helps Cement Bulgaria's Energy Security', 22 December 2022, <https://info.westinghousenuclear.com/news/westinghouse-vver-1000-nuclear-fuel-fabrication-agreement-helps-cement-bulgarias-energy>, accessed 14 November 2023; *World Nuclear News*, 'Westinghouse VVER-440 Fuel Loaded into Reactor', 11 September 2023, <https://world-nuclear-news.org/Articles/Westinghouse-VVER-440-fuel-loaded-into-reactor>, accessed 14 November 2023.
30. US Congress, 'H.R.1042 – Prohibiting Russian Uranium Imports Act', 118th Congress (2023–24), <https://www.congress.gov/bill/118th-congress/house-bill/1042>, accessed 16 February 2024.
31. Ari Natter, 'Russia Uranium Supplier Warns US Clients to Brace for Export Ban', *BNN Bloomberg*, 14 December 2023, <https://www.bnnbloomberg.ca/russia-uranium-supplier-warns-us-clients-to-brace-for-export-ban-1.2011820>, accessed 18 February 2024.
32. Price, Norman and Ahn, 'Western Reliance on Russian Fuel'; Matt Wald, 'On the Verge of a Crisis: The U.S. Nuclear Fuel Gordian Knot', *Nuclear Newswire*, 14 April 2023, <https://www.ans.org/news/article-4909/on-the-verge-of-a-crisis-the-us-nuclear-fuel-gordian-knot/>, accessed 2 March 2024.
33. Interviews with N and F.
34. Interview with H.

Alternative enrichment capacity exists in Europe and the US – a combined 25,400 tonnes of SWU as of 2022, according to the WNA.[35] In its latest report on global nuclear fuel markets, the WNA concludes that there is currently an oversupply of global enrichment capacity when compared to demand;[36] however, Russia accounts for nearly half of current global SWU capacity.[37] Additional Western capacity is being added through the expansion of Urenco's enrichment plant in Eunice, New Mexico (an additional 700 tonnes of SWU per year, with the first cascades expected to become operational in 2025),[38] Urenco's Dutch facility at Almelo (an additional 750 tonnes of SWU per year, with the first cascades expected to become operational in 2027),[39] Urenco's enrichment plant in Gronau, Germany,[40] and Orano's Georges Besse II plant in southern France (an additional 2,500 tonnes of SWU per year, with additional capacity starting to become operational in 2028).[41] Increased uranium enrichment in the US and Europe will also depend on the availability of the stage in the nuclear fuel cycle that precedes enrichment – conversion, where Russia also dominates the market. There are also enriched uranium inventories in the US and Europe, which stood at 3,963 tonnes of uranium in Europe and 2,670 tonnes of uranium in the US at the end of 2021[42] and which may help alleviate (at least partially) shortages caused by a termination of Russian supply. However, inventories vary between countries and utilities.

Russia is also a major supplier of nuclear reactor technology and nuclear reactor fuel, although the dependencies in this context have historically been in Eastern Europe and are now increasing in the Global South.[43] Western suppliers have begun successfully replacing Russia's supply of reactor and fuel technology to

35. World Nuclear Association, *The Nuclear Fuel Report*, p. 185.
36. *Ibid.*
37. *Ibid*, p. 188.
38. *Nuclear Engineering International*, 'Urenco Plans to Expand US Enrichment Plant', 12 July 2023, <https://www.neimagazine.com/news/newsurenco-plans-to-expand-us-enrichment-plant-11000632>, accessed 18 February 2024.
39. Urenco, 'Urenco Announces Major Netherlands Expansion to Strengthen Energy Security', 14 December 2023, <https://www.urenco.com/news/global/2023/urenco-announces-major-expansion-in-the-netherlands-to-strengthen-energy-security>, accessed 18 February 2024.
40. Jessica Sondgeroth, 'Nuclear Fuel Market: Urenco Plans Slight Capacity Increase at Gronau', *Energy Intelligence*, 5 May 2023, <https://www.energyintel.com/00000187-ec47-d9d3-a7b7-eccff4c80000>, accessed 18 February 2024.
41. Orano, 'Board of Directors of Orano Approves Project to Extend the Enrichment Capacity of the Georges Besse 2 Plant', 19 October 2023, <https://www.orano.group/en/news/news-group/2023/october/board-of-directors-of-orano-approves-project-to-extend-the-enrichment-capacity-of-the-georges-besse-2-plant>, accessed 18 February 2024.
42. International Atomic Energy Agency (IAEA), 'Global Inventories of Secondary Uranium Supplies', IAEA-TECDOC-2030, 2023, <https://www-pub.iaea.org/MTCD/publications/PDF/TE-2030web.pdf>, accessed 16 February 2024.
43. Darya Dolzikova, 'Atoms for Sale: Developments in Russian Nuclear Energy Exports', RUSI, 14 February 2023; Jonathan Tirone, 'Russia's Grip on Nuclear-Power Trade is Only Getting Stronger', *Bloomberg*, 14 February 2023.

certain markets.[44] Russia is also an important supplier in the back end of the nuclear fuel cycle, taking deliveries of spent nuclear fuel (which has already been irradiated in a nuclear reactor) for long-term storage or for reprocessing (the extraction of uranium from used reactor fuel, which can then be enriched and reused in the production of new nuclear fuel).[45] France has historically sent reprocessed uranium from its reactors to Russia for re-enrichment.[46] In 2018, Urenco concluded a contract with French utility EDF to enrich uranium recovered from reprocessed fuel from French reactors;[47] the reprocessed fuel will be converted in Russia and delivered to Urenco's facility in Almelo (the Netherlands) for enrichment, before being sent to a fuel fabrication plant at Romans-sur-Isère (France) for the fabrication of nuclear fuel assemblies for French reactors.[48] The UK's nuclear reactor at the Sizewell-B nuclear power plant has also previously used Framatome-manufactured nuclear fuel containing enriched reprocessed uranium (ERU) which was enriched in Russia.[49] Sizewell-B has now switched to using natural (non-reprocessed) uranium enriched by Orano.[50]

As this report focuses on Russian enrichment services, Russian presence across the rest of the fuel cycle, including in uranium conversion and reprocessing services, is not discussed at length. However, it is worth noting that weaning utilities in Western and partner countries off dependencies on Russian enriched uranium will only tackle one piece of the puzzle. Curtailing dependencies on Russia in Western countries' nuclear energy supply chains will require investment in non-Russian capacity in other parts of the nuclear fuel cycle, too, with conversion services being a particular chokepoint.[51]

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44. Westinghouse, 'VVER', <https://www.westinghousenuclear.com/nuclear-fuel/vver>, accessed 18 February 2024.
45. World Nuclear Association, 'Processing of Used Nuclear Fuel', updated December 2020, <https://world-nuclear.org/information-library/nuclear-fuel-cycle/fuel-recycling/processing-of-used-nuclear-fuel.aspx>, accessed 18 February 2024.
46. Greenpeace, 'French Nuclear Waste: A One-Way Ticket to Siberia', October 2021, <https://cdn.greenpeace.fr/site/uploads/2021/10/French-nuclear-waste-_-a-one-way-ticket-to-Siberia-_-Briefing-Greenpeace-France-Embargo-12-10-2021.pdf>, accessed 18 February 2024.
47. *World Nuclear News*, 'Urenco to Enrich Reprocessed Uranium', 5 July 2018, <https://www.world-nuclear-news.org/Articles/Urenco-to-enrich-reprocessed-uranium>, accessed 18 February 2024.
48. *World Nuclear News*, 'Framatome to Supply EDF with Reprocessed Uranium Fuel', 25 May 2018, <https://www.world-nuclear-news.org/Articles/Framatome-to-supply-EDF-with-reprocessed-uranium-f>, accessed 18 February 2024.
49. Framatome, 'Enriched Reprocessed Uranium: Operational Feedback', <https://www.framatome.com/solutions-portfolio/docs/default-source/default-document-library/product-sheets/a0511-z-ge-g-en-poster-eru-v7.pdf?Status=Master&sfvrsn=294d57c3_2>, accessed 18 February 2024.
50. Orano, 'Orano in United Kingdom', <https://www.orano.group/en/orano-across-the-world/united-kingdom>, accessed 18 February 2024.
51. Matt Bowen and Paul Dabbar, 'Reducing Russian Involvement in Western Nuclear Power Markets', Columbia Center on Global Energy Policy, May 2022, <https://www.energypolicy.columbia.edu/wp-content/uploads/2022/05/RussiaNuclearMarkets_CGEP_Commentary_051822-2.pdf>, accessed 18 February 2024.

Rosatom and the War in Ukraine

Rosatom, Russia's nuclear state enterprise, is responsible – through its many subsidiaries – for the development and export of Russian nuclear energy-related technology, services and materials. However, the company has also been reported as being connected with Russia's war effort in Ukraine,[52] and is headed up by some of the most senior people in Russia's political and security circles.[53] The company's supervisory board is chaired by Sergey Kirienko, former prime minister of Russia and currently first deputy chief of staff of the Presidential Administration of Russia. Kirienko has admitted to orchestrating Russia's annexation of Ukraine's occupied territories.[54] According to Rosatom's webpage, its board also includes: Rosatom Director General Alexey Likhachev; Assistant to the President of Russia Larissa Brychyova; Deputy Prime Minister and Minister of Trade and Industry Denis Manturov; First Deputy Director of the Federal Security Service (FSB) Sergey Korolev; Deputy Prime Minister (and former Minister of Energy) Alexander Novak; Deputy Prime Minister Yuri Trutnev; Assistant to the President Maxim Oreshkin; and former Russian Ambassador to the US and currently Advisor to the President Yuri Ushakov.[55] All members of the Rosatom supervisory board, with the exception of Ushakov, have been sanctioned by either the UK, the US or both.[56] At the time of writing, there are no sanctions on Rosatom nor its leadership from the EU.[57]

The company has reportedly offered to provide technology for the Russian military,[58] and Rosatom staff were allegedly present at the Chornobyl Exclusion Zone following the Russian occupation of the site in February 2022.[59] The company has also been reported as playing an important role in Russia's occupation of

52. Charles Digges, 'Rosatom's Role in the War in Ukraine', Bellona, 29 June 2023, <https://bellona.org/publication/rosatoms-role-in-the-war-in-ukraine>, accessed 1 October 2023.
53. Rosatom, 'Supervisory Board', <https://rosatom.ru/en/about-us/governance/supervisory-board/>, accessed 10 December 2023.
54. *New Voice*, 'Vozmozhnij Preiemnik Putina rasskazal kak Kreml' planirujet aniksirovat' zakhvachennie ukrainskie teritorii i priznal, chto rukovodit protsessom' ['Putin's Possible Successor Said the Kremlin Plans to Annex the Captured Ukrainian Territories and Admitted He Leads the Process'], 12 June 2022, <https://nv.ua/world/geopolitics/vozmozhnyy-preemnik-putina-skazal-chto-kreml-planiruet-dlya-ukrainskih-territoriy-poslednie-novosti-50249320.html>, accessed 11 December 2023.
55. Rosatom, 'Supervisory Board'.
56. Andrea Stricker and Anthony Ruggiero, 'Radioactive: Executives from Russia's Rosatom May Qualify for U.S. Sanctions', Foundation for Defense of Democracies, 6 December 2023, <Radioactive: Executives from Russia's Rosatom Corporation May Qualify for U.S. Sanctions (fdd.org)>, accessed 11 December 2023.
57. In February 2023, the EU sanctioned Atomflot, a Rosatom subsidiary, which operates Russia's nuclear icebreaker fleet. See Council of the European Union, 'Council Implementing Regulation (EU) 2023/429 of 25 February 2023', *Official Journal of the European Union* (L 59 I/278, 25 February 2023).
58. Catherine Belton, 'Russia's State Nuclear Company Aids War Effort, Leading to Calls for Sanctions', *Washington Post,* 20 January 2023; FCDO, 'UK Sanctions Target Russia's Theft of Ukrainian Grain, Advanced Military Technology, and Remaining Revenue Sources'.
59. Yogita Limaye, 'Inside Chernobyl: We Stole Russian Fuel to Prevent Catastrophe', *BBC,* 9 April 2022.

the Zaporizhzhia Nuclear Power Plant (ZNPP), the largest nuclear power plant (NPP) in Europe, which was attacked and occupied by the Russian military on 4 March 2022. Following the occupation, Rosatom was reported as having taken over management of the plant.[60] In October 2022, the Joint Stock Company Operating Organisation of the Zaporozhye Nuclear Power Plant (JSC ZNPP OO)[61] was established[62] and currently operates the ZNPP.[63] Kirienko has also repeatedly visited the ZNPP since its occupation.[64]

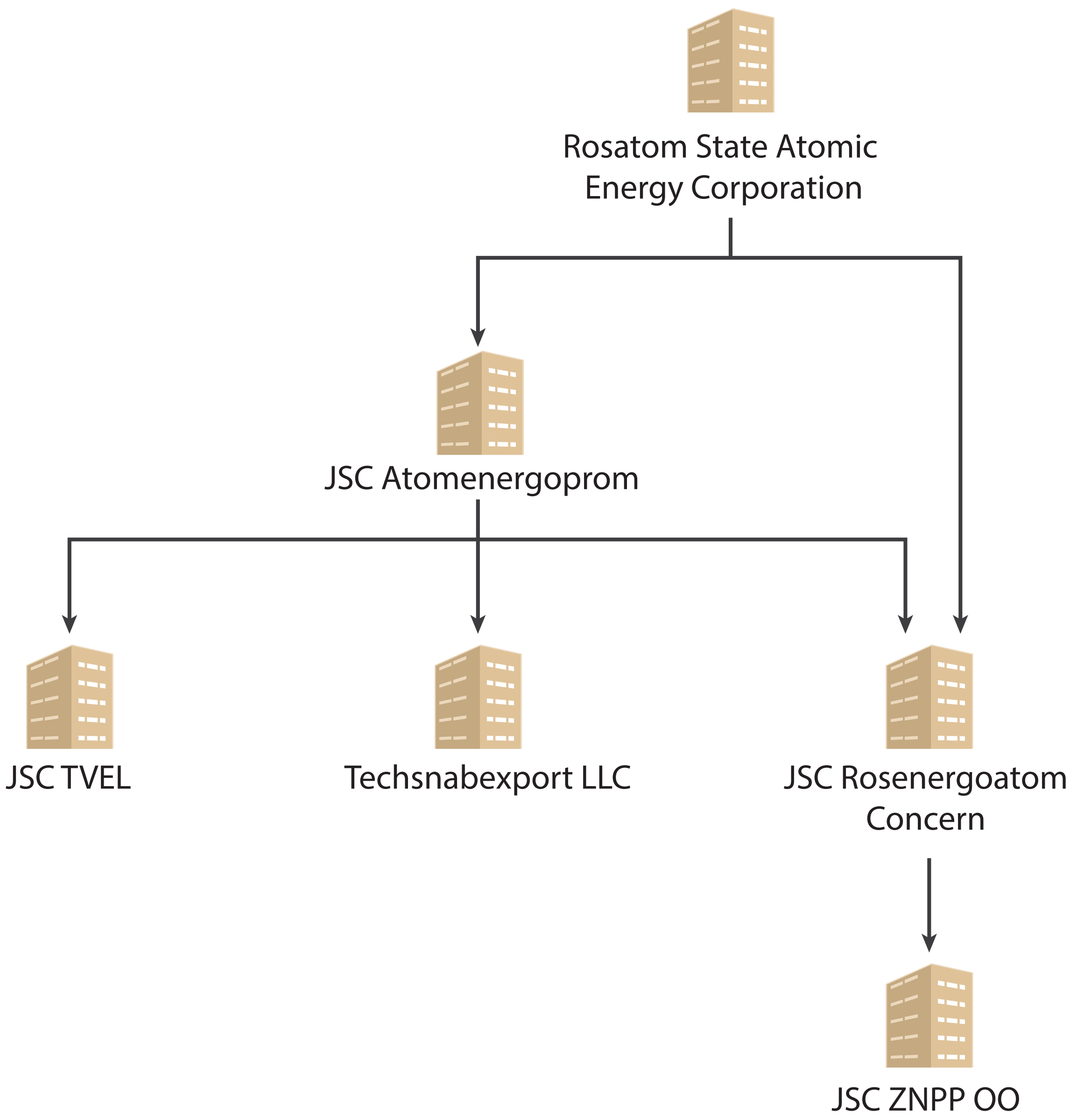
There have been media reports of torture and harassment of the ZNPP's Ukrainian staff since the invasion.[65] Staff that had not fled the fighting around the plant were reportedly forced to sign contracts with Rosatom.[66] The International Atomic Energy Agency (IAEA) has repeatedly raised concerns over the safety and security of the ZNPP and the wellbeing of its staff, while US and European governments have condemned Russian behaviour at the plant.[67] An apparent interest by Rosatom in the ZNPP's Western-supplied fuel and related technology has also raised concerns of industrial espionage and the security of the nuclear material at the facility.[68]

60. *Reuters*, 'Russia Wants Full Operational Control of Zaporizhzhia Nuclear Plant – Energoatom Chief', 11 March 2022.
61. Акционерное общество «Эксплуатирующая организация Запорожской АЭС» ['Joint Stock Company 'Zaporozhye NPP Operating Organization'], INN: 9721179921 (company data sourced from Sayari Analytics).
62. Company data sourced from Sayari Analytics; Запорожская АЭС [Zaporizhzhia NPP], О Запорожской АЭС ['About the Zaporizhzhia NPP'], <https://znpp.ru/o-zaporozhskoy-aes/>, accessed 17 February 2024.
63. Запорожская АЭС [Zaporizhzhia NPP], «О Запорожской АЭС» ['About the Zaporizhzhia NPP'], <https://znpp.ru/o-zaporozhskoy-aes/NPP>, accessed 17 February 2024.
64. *Reuters*, 'Top Putin Aide Visits Ukraine's Russian-Held Zaporizhzhia Nuclear Plant', 28 December 2022. For more on the role of Rosatom and related individuals in Russia's invasion of Ukraine, see Bellona, 'Rosatom During the War in Ukraine: How Militarization of the Russian Nuclear Giant Took Place', 7 December 2023, <https://bellona.org/news/nuclear-issues/2023-12-bellona-publishes-new-report-on-rosatoms-role-in-the-ukraine-invasion>, accessed 11 December 2023; Jack Watling, Oleksandr V Danylyuk and Nick Reynolds, 'Preliminary Lessons from Russia's Unconventional Operations During the Russo-Ukrainian War, February 2022–February 2023', RUSI, 29 March 2023, pp. 6–7.
65. Marc Santora, 'Torture and Turmoil at Ukrainian Nuclear Plant: An Insider's Account', *New York Times*, 28 March 2023.
66. *Reuters*, 'Workers Who Won't Sign Russian Contracts Banned From Nuclear Plant – Ukraine', 28 November 2022; *New Voice of Ukraine*, 'Workers at ZNPP Forced to Sign Contracts with Rosatom Under Duress, Ukraine Says', 30 May 2023, <https://english.nv.ua/nation/workers-at-znpp-forced-to-sign-contracts-with-rosatom-under-duress-ukraine-says-50328376.html>, accessed 18 February 2024.
67. UN Security Council, 'Briefing Security Council, International Atomic Energy Agency Director Outlines Five Principles to Prevent Nuclear Accident at Zaporizhzhia Power Plant in Ukraine', Meetings Coverage, 30 May 2023, SC/15300, <https://press.un.org/en/2023/sc15300.doc.htm>, accessed 8 March 2024; Press and Information Team of the Delegation to UN and OSCE in Vienna, 'Ukraine-joint Statement on the Situation at the Zaporizhzhia Nuclear Power Plant', European Union External Action, 14 August 2022, <https://www.eeas.europa.eu/delegations/vienna-international-organisations/ukraine-joint-statement-situation-zaporizhzhia-nuclear-power-plant_en>, accessed 8 March 2024.
68. Andrian Prokip, 'Why the Zaporizhzhia Nuclear Power Plant Matters … for the Whole World', Wilson Center, 19 September 2022, <https://www.wilsoncenter.org/blog-post/why-zaporizhzhia-nuclear-power-plant-mattersfor-whole-world>, accessed 18 February 2024.

TVEL, which operates Russia's uranium enrichment plants,[69] and TENEX, which supplies Russian enriched uranium abroad,[70] are important members of the Rosatom family of companies. They are also closely related to JSC ZNPP OO, which is owned by JSC Rosenergoatom Concern (Rosenergoatom),[71] the state enterprise responsible for the operation of Russia's NPPs.[72] TVEL, TENEX and Rosenergoatom are in turn owned by JSC Atomenergoprom (Atomenergoprom),[73] the Russian state enterprise established 'to consolidate the assets of the civilian part of the Russian nuclear industry'[74] and which is a direct subsidiary of Rosatom.[75] Figure 2 shows these relationships.

69. Rosatom, 'Fuel and Enrichment', <https://rosatom-centralasia.com/en/rosatom-group/fuel-and-enrichmen/>, accessed 16 February 2024; World Nuclear Association, 'Russia's Nuclear Fuel Cycle', updated December 2021, <https://world-nuclear.org/information-library/country-profiles/countries-o-s/russia-nuclear-fuel-cycle.aspx>, accessed 18 February 2024.
70. TENEX, <https://www.tenex.ru/en/#start>, accessed 14 February 2024.
71. Акционерное Общество «Российский Концерн по Производству Электрической и Тепловой Энергии на Атомных Станциях» [Joint Stock Company 'Russian Concern for the Production of Electric and Heat Energy at Nuclear Plants'], INN: 7721632827 (company data sourced from Sayari Analytics). Russian Federal Tax Register, document dated 9 November 2023 from Sayari Analytics, <https://sayari.com/>, accessed 8 March 2024.
72. Rosenergoatom, 'About us', <https://www.rosenergoatom.ru/en/about-us/>, accessed 14 February 2024.
73. Акционерное общество «Атомный энергопромышленный комплекс» [Joint Stock Company 'Atomic Energy Complex'], INN: 7706664260 (company data sourced from Sayari Analytics). Rosenergoatom, 'About Us', <https://www.rosenergoatom.ru/en/about-us/>, accessed 14 February 2024; Atomenergoprom, <https://atomenergoprom.ru/en/>, accessed 14 February 2024; <https://www.tenex.ru/download/330/articles_of_association_of_tenex__joint_stock_company__revision_dated_march_27__2020_.pdf>, accessed 8 March 2024; Russian Federal Tax Register, document dated 1 November 2023 from Sayari Analytics, <https://sayari.com/>, accessed 8 March 2024.
74. Atomenergoprom, <https://atomenergoprom.ru/en/>, accessed 14 February 2024.
75. *Ibid.*

Figure 2: Ownership Structures of Rosatom Subsidiaries



Source: Rosenergoatom, 'About Us', <https://www.rosenergoatom.ru/en/about-us/>, accessed 14 February 2024; Atomenergoprom, <https://atomenergoprom.ru/en/>, accessed 14 February 2024; <https://www.tenex.ru/download/330/articles_of_association_of_tenex__joint_stock_company__revision_dated_march_27__2020_.pdf>, accessed 8 March 2024; Russian Federal Tax Register documents sourced through Sayari Analytics, <https://sayari.com/>; IBR EU Power Technologies LLC, Department of Nuclear Power Engineering and Nuclear Fuel Cycle, 'Russian Uranium Enrichment Industry State and Prospects of Development', 2023, pp. 22–24.

Pursuit for Continued Market Access

Since Russia's full-scale invasion of Ukraine in February 2022, Rosatom and its subsidiaries have continued to do business with customers around the world, including the sale of enriched uranium to Europe, the US and globally. Rosatom's 2022 annual report noted a 14.9% increase from the previous year (2021) in revenue for the company's fuel division, which includes enrichment services (but also encompasses conversion services and production of nuclear fuel for reactors).[76] Rosatom has also made no revisions to its business strategy up to 2030, which was last revised in 2020 and expects to see an increase in Rosatom's revenue to 4 trillion RUB.[77] This suggests a certain level of confidence (or at least an effort to portray confidence) in continued demand, despite clearly countervailing winds in trade with Russia among Western countries.

One likely reason for this apparent confidence is Rosatom's determined pursuit of the development and sale of new products, as well as expansion into new markets, particularly as it relates to the construction of NPPs abroad.[78] Yet, Rosatom's continued engagement with some of its traditional customers may also offer the company alternative or indirect access into markets that may otherwise be trying to diversify away from Russian supplies. One strategy that Rosatom may be trying to employ in its enriched uranium business is displacement, increasing its deliveries of enriched uranium to countries that are still willing – or contractually obligated – to accept them and which may then be able to increase exports of their own enriched uranium to global markets. This has been suggested in a report by nuclear industry consultancy IBR EU Power Technologies LLC.[79] The company was established in 1991 'by a group of researchers and engineers who had previously worked at the research centers of the Soviet Ministry of Atomic Energy and Industry and the Ministry's headquarters'.[80] The company's latest report on the state and development of the Russian nuclear enrichment industry, published in October 2023, notes that, in examining data on enriched uranium exports from Russia in 2022, the report's authors were able to draw 'preliminary conclusions' about Rosatom's introduction of a new strategy in response to decreased purchases of Russian enriched

76. Rosatom, 'Performance of State Atomic Energy Corporation Rosatom in 2022', p. 115.
77. *Ibid*, p. 26.
78. *Ibid*, pp. 195–210. For more on Rosatom's strategy of technological diversification, see Bellona, 'Rosatom During the War in Ukraine', p. 8. For more on Rosatom's pursuit of new customers, see Dolzikova, 'Atoms for Sale'; Tirone, 'Russia's Grip on Nuclear-Power Trade is Only Getting Stronger'.
79. IBR EU Power Technologies LLC, Department of Nuclear Power Engineering and Nuclear Fuel Cycle, 'Russian Uranium Enrichment Industry State and Prospects of Development', 2023, p. 30.
80. IBR EU Power Technologies, <http://ibr.ru/>, accessed 14 February 2024. The company's website says that it has relocated to Hungary and operates in the country under the name IBR EU Power Technologies Kft. (EU tax number: HU27844504).

uranium by some foreign customers, as a result of the war in Ukraine.[81] The report notes:

> The essence of this element can be formulated as follows – to increase the supply of EUP [enriched uranium product] to countries that have a fleet of their own nuclear power plants and a uranium enrichment industry, with the aim of using this EUP at local nuclear power plants, which will partially free up local uranium enrichment capacities from the production of EUP for local nuclear power plants and use freed-up capacity for the production of EUP for export.[82]

The report singles out France and China in its analysis of a potential Russian displacement strategy, noting the significant increase of enriched uranium imports by these two countries in 2022, as compared to 2021, driven primarily by imports from Russia. The report's authors point to a planned increase in enriched uranium exports from France to the US, as well as a 2026–31 contract for the provision of SWU by the China Nuclear Energy Industry Corporation (CNEIC) to South Korea's KHNP (Korea Hydro & Nuclear Power), as potential vehicles for this strategy.[83]

The data presented and analysed later in this report tries, in part, to test this displacement hypothesis. While this report is unable to definitively confirm using publicly available sources that displacement activity is occurring, at least in China's case, shifts in trade patterns appear to be consistent with what one would expect to see if a displacement strategy was being introduced. Testing the possibility of displacement through France is even more challenging, considering the complexities of European nuclear fuel supply chains and the central role that France plays therein. Changes to French trade in enriched uranium could technically point to displacement, but – as in the case of China – there are other possible explanations for the shifts in trade patterns.

The nuclear sector is not the only instance where Russia has been accused of resorting to a displacement strategy to compensate for the loss of certain markets in the wake of its invasion of Ukraine. A similar tactic has been reported in relation to the oil sector. Media reporting has detailed increases in German imports of refined oil products from India in 2023 as compared to 2022, at the same time as India became a leading importer of Russian crude in 2022, thus apparently providing what has been called a 'backdoor route' for Russian oil into

81. IBR EU Power Technologies LLC, Department of Nuclear Power Engineering and Nuclear Fuel Cycle, 'Russian Uranium Enrichment Industry State and Prospects of Development', p. 30.
82. IBR EU Power Technologies LLC, Department of Nuclear Power Engineering & Nuclear Fuel Cycle, 'Russian Uranium Enrichment Industry State & Prospects of Development', p. 30.
83. *Ibid*.

European markets.[84] Some have even suggested that some of the oil products shipped from India to European countries may include Russian material.[85] If such activity is taking place to circumvent sanctions on Russian oil trade, it would not be inconceivable that a similar strategy may be applied in the nuclear sector, which has yet to be sanctioned to the same extent as the Russian petroleum sector.

The following sections of this report examine whether and how similar displacement, and other possible adaptation methods, may be playing out (or may play out in future) in Russian trade in enriched uranium and enrichment services. They also offer and test possible alternative explanations for the observed shifts in Russian enriched uranium trade patterns.

84. *Energyworld.com*, 'Germany Snapping up Indian Fuels Amid Russia Sanctions: Data', 12 September 2023, <https://energy.economictimes.indiatimes.com/news/oil-and-gas/germany-snapping-up-indian-fuels-amid-russia-sanctions-data/103608066>, accessed 18 February 2024.
85. Sophie Landrin, 'India is Acting as a Hub for Russian Oil', *Le Monde*, 6 May 2023, <https://www.lemonde.fr/en/international/article/2023/05/06/india-is-acting-as-a-hub-for-russian-oil_6025598_4.html>, accessed 18 February 2024.

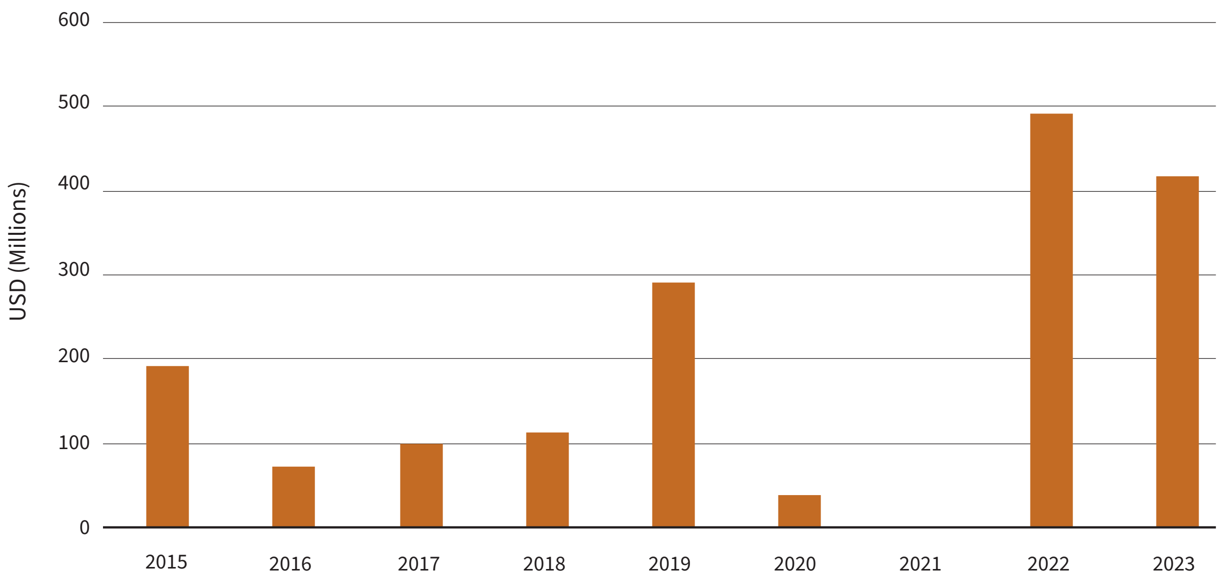
II. Case Study: China

Russia has been a long-time partner of the Chinese nuclear energy industry, having built numerous nuclear reactors in China,[86] contributed to the development of China's domestic enrichment capabilities,[87] and served as a long-time supplier of enriched uranium and nuclear fuel to the country.[88] Trade data made available by the Chinese government reveals a number of shifts in China's enriched uranium trade patterns since 2022, including with regard to its imports of Russian material and exports to the US. While the trade data alone cannot definitively confirm the hypothesis put forward by IBR EU Power Technologies that displacement of enriched uranium is taking place through China backed by greater Chinese imports of Russian enriched uranium, it does point to the possibility of such activity. As China may be seeking to carve out a greater role for itself in world enriched uranium markets, increased imports of Russian enriched uranium may facilitate the pursuit of Beijing's ambitions.

Figures 3 and 4 show the value and weight of enriched uranium imports from Russia into China since 2015, respectively. After importing no enriched uranium from Russia in 2021 and 44 tonnes in 2020, Chinese enriched uranium imports from Russia rose to 685 tonnes ($492.6 million) in 2022.[89] This was the highest level since 2011 (when Chinese imports of Russian enriched uranium stood at 779 tonnes [$544 million]),[90] as well as a 36% increase in volume from the next-highest yearly value – observed in 2019 (504 tonnes [$292 million]).[91] The 2023 value of Russian imports of enriched uranium into China reached 467 tonnes ($418 million), a slight decrease from 2022 but still much higher than in many previous years.[92]

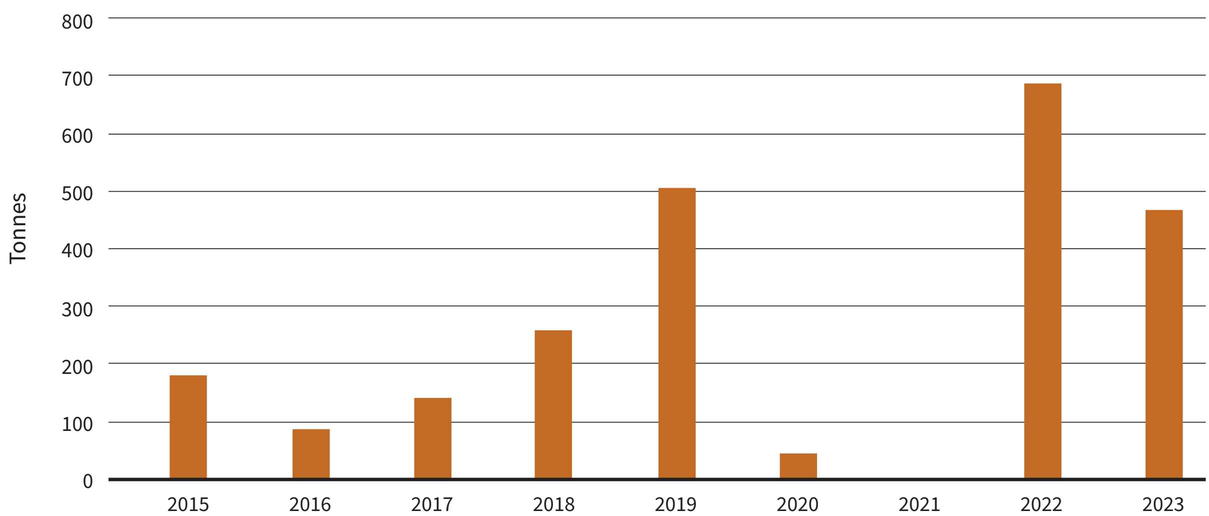
86. Dan Yurman, 'China's Ambitious Nuclear Energy Program', *Nuclear Newswire*, 2 December 2010, <https://www.ans.org/news/article-587/chinas-ambitious-nuclear-energy-program/>, accessed 18 February 2024.
87. *World Nuclear News*, 'Russia and China Sign Enrichment Plant Agreement', 27 May 2008, <https://www.world-nuclear-news.org/Articles/Russia-and-China-sign-enrichment-plant-agreement>, accessed 18 February 2024.
88. IAEA, 'Global Inventories of Secondary Uranium Supplies', p. 65.
89. Data sourced from the General Administration of Customs of the People's Republic of China (HS code 28442000, accessed 29 January 2024).
90. UN Comtrade (HS code 284420), accessed 4 March 2024.
91. Data sourced from the General Administration of Customs of the People's Republic of China (HS code 28442000), accessed 29 January 2024.
92. *Ibid*.

Figure 3: Chinese Imports from Russia under HS Code 28442000, 2015–23 (USD)



Source: Data sourced from the General Administration of Customs of the People's Republic of China (HS code 28442000), accessed 29 January 2024.

Figure 4: Chinese Imports from Russia under HS Code 28442000, 2015–23 (Tonnes)



Source: Data sourced from the General Administration of Customs of the People's Republic of China (HS code 28442000), accessed 29 January 2024.

Possible Stockpiling and Domestic Demand

The relatively high volumes of Chinese imports of enriched uranium from Russia in the last two years could potentially be attributed to Chinese stockpiling efforts to meet nuclear fuel needs for its domestic fleet of reactors. This was the conclusion of a number of the experts interviewed for this report when shown trade data indicating an increase in the value of Chinese imports of Russian enriched uranium.[93] Indeed, in 2021, the chairperson of a China Nuclear Energy Industrial Corporation (CNEIC) subsidiary and a member of the National People's Congress said that China should prioritise the expansion of the domestic strategic enriched uranium stockpile to limit the impact of enriched uranium price fluctuations, possible supply chain risks and other potential challenges.[94]

China is a major nuclear energy power. As of December 2023, it was operating 55 nuclear reactors, with a further 22 under construction.[95] Chinese SWU requirements are expected to rise significantly over the next decade. Chinese enrichment capacity is not reported publicly, but expert estimates seem to expect that China will increase its enrichment capacity to meet domestic demand.[96] As these are simply estimates they may be subject to developments in opportunities to increase supply and inventories through additional imports. In its 2023 report 'Global Inventories of Secondary Uranium Supplies' the IAEA estimates that China has also maintained a strategic enriched uranium stockpile since before 2010, which it believes may have increased by as much as 910 tonnes of enriched uranium product (tEUP) since then (the IAEA does not provide estimates of material stockpiled before 2010).[97] The IAEA has observed that the strategic stockpile is intended for domestic consumption but notes that it may also be used to meet export demand, should China choose to increase its presence on international markets.

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93. Interviews with B and G.
94. 中国原子能工业公司 [China Nuclear Energy Industry Corporation], '全国人大代表，四川红华实业有限公司董事长朱纪：建立我国低浓铀储备体系迫在眉睫【两会声音】' ['Representative to the National People's Congress and Chairperson of Sichuan Honghua Industry Co, Zhu Ji at the "Two Sessions": It is Urgent to Establish a Reserve System for Low-Enriched Uranium'], 国际电力网 [*Power.IN-EN.com*], 10 March 2021, <https://power.in-en.com/html/power-2384665.shtml>, accessed 14 February 2024.
95. IAEA Power Reactor Information System, 'China, People's Republic of', <https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=CN>, accessed 14 February 2024.
96. Hui Zhang, 'The Development Status of China's Uranium Enrichment', Project on Managing the Atom, Kennedy School of Government, Harvard University, nd, <https://www.belfercenter.org/sites/default/files/files/publication/The%20Development%20Status%20of%20China%27s%20Uranium%20Enrichment.pdf>, accessed 29 February 2024; World Nuclear Association, *The Nuclear Fuel Report,* p. 185.
97. IAEA, 'Global Inventories of Secondary Uranium Supplies', p. 65.

Chinese Exports of Enriched Uranium

Historically, China has been a net importer of enriched uranium, exporting material only to Kazakhstan, the US, South Korea (until recently), and a small annual value ($100) to Austria, as well as nuclear fuel assemblies to Pakistan.[98] However, it appears that China may be interested in becoming a greater supplier of enriched uranium to global markets.[99] In October 2023, China reportedly completed its first export since 2014 of enriched uranium using imported feed material.[100] In other words, for the first time in nearly a decade, China has provided enrichment services for a customer that had sourced the feed material elsewhere. Reports on this development noted that the resumption of trade in enrichment services (and the efforts that had gone into ensuring that the necessary regulatory and licensing frameworks are in place to allow this trade) are part of a CNEIC strategic policy of 'going out, grabbing orders, and stabilizing growth' in the nuclear fuel trade, in light of the 'historical window period' since the start of the 'conflict between Russia and Ukraine' and its impact on international nuclear fuel demand and prices.[101]

The introduction of this option for enrichment-service-only trade, combined with the articulated policy to capture more of the global nuclear fuel market, supports assessments that China may be looking to play an increasingly larger role as a supplier of enriched uranium and enrichment services. Increased imports of Russian material could help China meet the expanded demand that will result from a combination of the expected growth in its domestic enriched uranium needs and any expected increase in exports. In 2022, China announced a number of long-term nuclear fuel contracts with US and EU utilities, although it is unclear what those contracts involved specifically, whether they include deliveries of Chinese enriched uranium and, if so, when these would commence.[102]

98. *Ibid.*, pp. 64, 65 and 69; data sourced from the General Administration of Customs of the People's Republic of China (HS codes 28442000 and 840130, accessed 29 January 2024).
99. Interview with O; Grace Symes, 'China: CNNC Increases SWU Capacity, International Sales', Energy Intelligence, 26 January 2024, <https://www.energyintel.com/0000018d-417a-d5fe-a1dd-657e6daa0000>, accessed 8 March 2024.
100. The news piece that announced this shipment referred to 'imported feed' but does not specify what state the uranium was in. As such, 'feed' in this instance could be referring to mined uranium or natural (unenriched) uranium hexafluoride.
101. 中国原子能工业公司 [China Nuclear Energy Industry Corporation], '中国原子能重启进料加工贸易 助推核燃料产业体系升级发展' ['CNEIC Restarts Feed Processing Trade to Promote the Upgrading and Development of the Nuclear Fuel Industry System'], 中国和电网 [*China National Nuclear Power Net*], 8 November 2023, <https://www.cnnpn.cn/article/39637.html>, accessed 14 February 2024.
102. 中国原子能工业公司 [China Nuclear Energy Industry Corporation], '中国原子能荣获中核集团2021-2022年市场开发（国际化经营）先进集体和先进个人' ['CNEIC Recognised by China National Nuclear Corporation for 2021–2022 Market Development (International Operations) Advanced Collectives and Advanced Individuals'], *WeChat*, 16 January 2023, <https://mp.weixin.qq.com/s?src=11&timestamp=1708089092&ver=5084&signature=jnnuHGzBPsbII*k*p4oeWfksSolGvBeKgQ

The IBR EU Power Technologies report pointed to a 2026–31 CNEIC contract with KHNP as a potential vehicle for enriched uranium displacement through China.[103]

Should China be engaging in the displacement of enriched uranium, facilitated by the observed increases in imports of Russian material, one would expect to see an increase in Chinese exports of enriched uranium since 2022, as Russian supply freed up domestic capacity for export. While the 2022 value and volume of Chinese exports of enriched uranium (97 tonnes [$65 million]) remained more or less on a par with 2021 figures (95 tonnes [$64 million]) and well below the values and volumes of exports in previous years, the volume of Chinese exports in 2023 (368 tonnes [$445 million]) increased by 288% from 2021.[104] The increase is less dramatic when compared to previous years but is still noteworthy. The increase in exports in 2023 was in large part due to a spike in Chinese exports of enriched uranium to the US, which amounted to 175 tonnes ($316 million) in 2023, following three years (2019–21) of no Chinese exports to the US appearing in Chinese or US government trade data, and 5% higher than the volume of all Chinese exports of enriched uranium to the US from 2015 to 2022 combined (see Figure 5).[105] Trade data made available by the US government confirms the Chinese-reported export values, although US import data shows much higher volumes of material delivered in 2023 (293 tonnes) than those reported in Chinese export data (the reason for this discrepancy is not clear).[106] Besides the US, China also exported enriched uranium to Kazakhstan in 2023, with the value of these exports also increasing significantly, nearly doubling from 2022 (97 tonnes [$65 million]) to 2023 (193 tonnes [$130 million]).[107] The additional exports under HS code 284420 from China to Kazakhstan could be related to the fabrication of nuclear fuel for Chinese reactors at a nuclear fabrication facility in Kazakhstan. The plant is operated by a Kazakh-Chinese joint venture and made its first delivery of fuel assemblies to China in early 2023.[108]

amWXeuwt1W23nzh87jgyV2H2J3Df86L-evN9x028LOEzt7vgyEX1TbynT6FubHRBwhk9Kg3Ky42pKRMsxB31SQhLQnsNKv&new=1>, accessed 14 February 2024.

103. IBR EU Power Technologies LLC, Department of Nuclear Power Engineering and Nuclear Fuel Cycle, ‘Russian Uranium Enrichment Industry State and Prospects of Development’, 2023, p. 30.
104. Chinese customs data made available by the General Administration of Customs of the People’s Republic of China (HS code 28442000, accessed 3 March 2024).
105. Chinese customs data made available by the General Administration of Customs of the People’s Republic of China (HS code 28442000, accessed 28 February 2024).
106. Data sourced from the United States Census Bureau (HS code 284420300, accessed 15 February 2024). There are other discrepancies between US import data and Chinese export data, with Chinese export data reporting an overall 9.9% higher value of enriched uranium exports between 2015 and 2022 and 13.2% lower volume of imports from the US across the same time period, with a particularly significant discrepancy in 2017. Nevertheless, the general trends are comparable across the two datasets.
107. Data sourced from the General Administration of Customs of the People’s Republic of China (HS code 28442000), accessed 29 January 2024. Chinese customs data also shows yearly exports under HS code 284420 of $100 to Austria.
108. *Nuclear Engineering International*, ‘Kazatomprom Delivers First Batch of Fuel Assemblies to China’, 24 March 2023, <https://www.neimagazine.com/news/newskazatomprom-delivers-first-batch-of-fuel-

An increase in Chinese exports of enriched uranium, even if coupled with an increase in enriched uranium imports from Russia, is not in itself sufficient to prove that displacement is occurring, as increased exports may also be the result of expanded domestic enrichment activity. The cyclical nature of trade in the nuclear energy sector and long contracting lead times for supply of enriched uranium for fuel manufacturing also mean that one cannot read too closely into variations in enriched uranium trade values. Furthermore, the volume of Chinese imports of Russian enriched uranium in 2022 and 2023 is significantly greater than the volume of 2023 Chinese exports to the US. This suggests that at least some of the material may be being used for the manufacturing of nuclear fuel inside China or being stockpiled – either to meet Chinese domestic demand or perhaps to support a future expansion of Chinese exports. In the absence of data on Chinese enriched uranium stockpiles, this is difficult to assess. Nevertheless, the scale of the increase in the volume and value of Chinese deliveries to the US in 2023 is noteworthy.

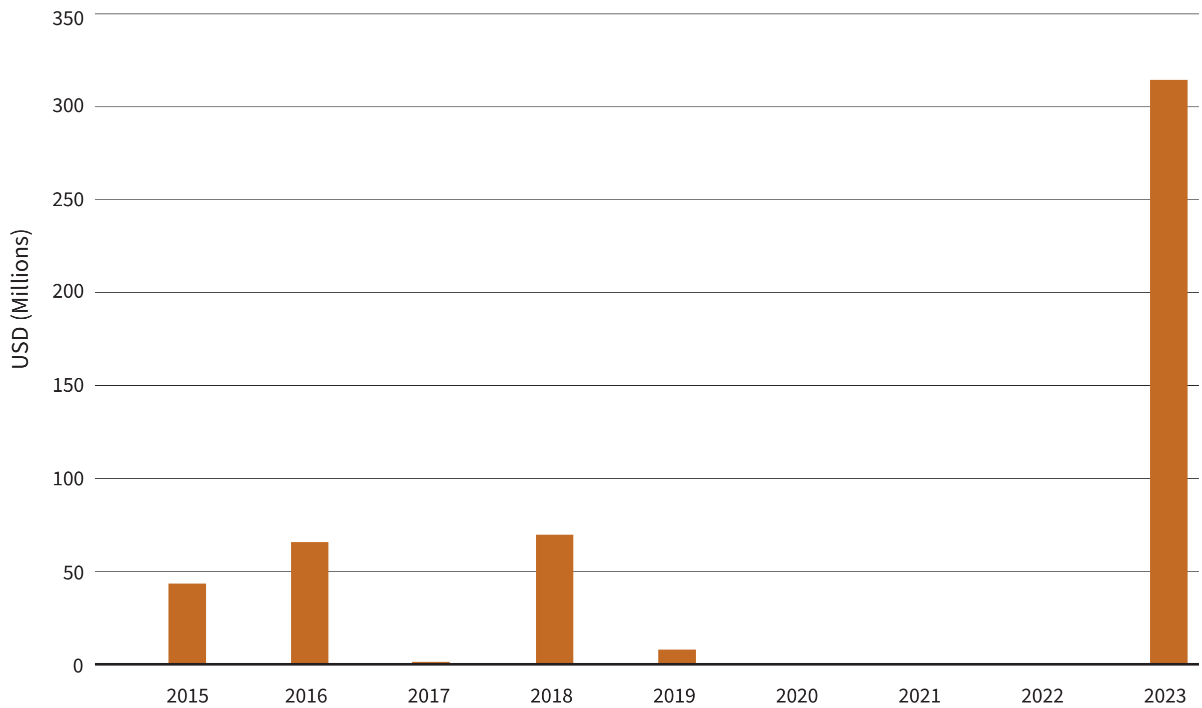
The reason for these increases is not clear. However, trade records for 2023 Chinese deliveries of enriched uranium to the US sourced through corporate and trade data provider Sayari Analytics indicate that Global Nuclear Fuel Americas LLC and Westinghouse Electric Company, both manufacturers of nuclear fuel, received shipments of uranium hexafluoride from China in 2023.[109] It is unclear whether the enriched uranium was ultimately used for the manufacture of nuclear fuel in the US, or who the ultimate recipient of any manufactured nuclear fuel may have been, including whether customers are domestic or foreign utilities. For instance, when asked about likely drivers for increased Chinese enriched uranium imports into the US, one expert interviewed for this report suggested that the increased imports of Chinese material into the US may be meant for the fabrication of nuclear fuel assemblies for Chinese reactors and therefore may be re-exported back to China.[110]

assemblies-to-china-10701431>, accessed 8 March 2024.

109. Bill of lading data sourced through Sayari Analytics, <https://sayari.com/>, accessed 3 March 2024.

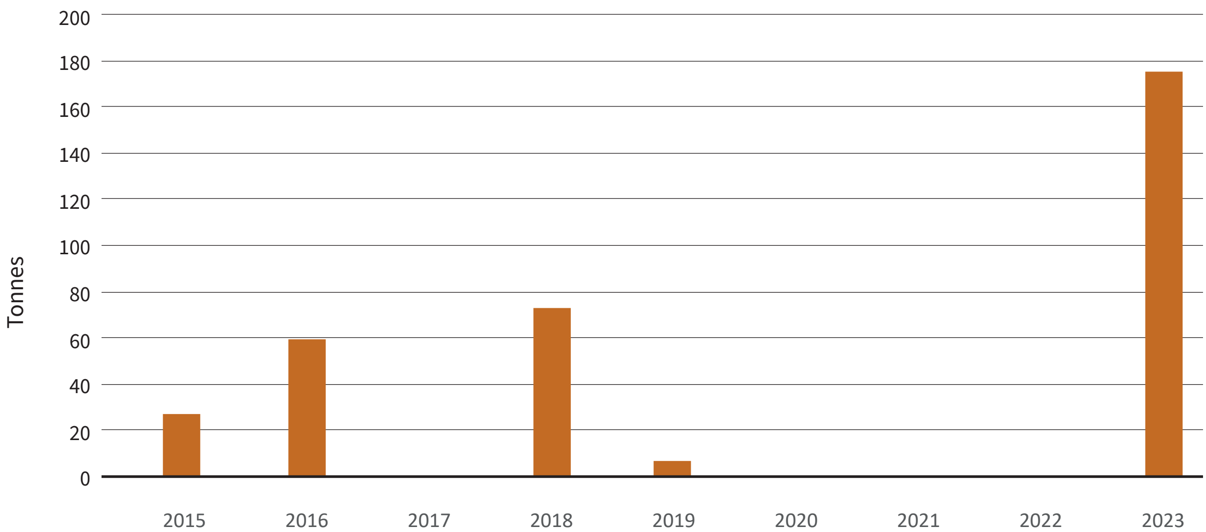
110. Interview with E.

Figure 5: Chinese Exports to the US under HS Code 28442000, 2015–23 (USD)



Source: Data sourced from the General Administration of Customs of the People's Republic of China (HS code 28442000), accessed 23 February 2024.

Figure 6: Chinese Exports to the US under HS Code 28442000, 2015–23 (Tonnes)



Source: Chinese customs data made available by the General Administration of Customs of the People's Republic of China (HS code 28442000), accessed 23 February 2024.

Implications

The limited publicly available information on domestic Chinese enrichment activity and the opacity of China's internal nuclear fuel supply chains make it challenging to ascertain whether the increase in the value of exports of enriched uranium to the US in 2023 has been backed by increases in enrichment activity at domestic Chinese facilities or is the result of displacement facilitated by increased imports of Russian material into China. However, the data reviewed here points to the possibility that displacement may be taking place.

As the US seeks to diversify away from Russian uranium supply and curtail Rosatom revenues, to what extent might any such efforts be undermined by increased Russian access to the Chinese market and subsequent increases in deliveries of Chinese material to the US? Under US regulation that limits the amount of enriched uranium that can be imported into the country from Russia ('The Russian Suspension Agreement' [1992], discussed in greater detail in Chapter V), imports of enriched uranium 'which can be shown to have resulted in the ultimate delivery or sale into the United States of displaced uranium products of any type, regardless of the sequence of the transactions' are considered a circumvention tactic.[111] Importers of enriched uranium into the US are required to 'submit at the time of entry a written statement certifying that the uranium being imported was not obtained under any arrangement, swap, or other exchange designed to circumvent the export limits for uranium of Russian Federation origin established by this Agreement'.[112] A bill passed in the US House of Representatives in December 2023, which would prohibit the import of Russian enriched uranium into the US (but which has not yet passed the Senate or received presidential approval at the time of drafting), contains a similar anti-circumvention provision, prohibiting the import of 'unirradiated low-enriched uranium that is determined to have been exchanged with, swapped for, or otherwise obtained in lieu of unirradiated low-enriched uranium [produced in the Russian Federation or by a Russian entity] in a manner designed to circumvent the restrictions under this section'.[113]

It is not clear whether imports of enriched uranium from China into the US were accompanied by any such certification. Such a declaration would likely have been subject to processes governed by contractual confidentiality. Considering the complexity and commercial sensitivity inherent to nuclear fuel supply chains, definitively proving that any given import of enriched uranium into a given country is not the product of displacement using Russian enriched uranium is likely to be

111. US Department of Commerce, 'Russia Uranium Antidumping Investigation Suspension Agreement', 30 October 1992, <https://tcc.export.gov/Trade_Agreements/All_Trade_Agreements/exp_005378_v1.asp>, accessed 18 February 2024.
112. *Ibid*.
113. US Congress, 'H.R.1042 – Prohibiting Russian Uranium Imports Act', sec. 2, para. 1B.

challenging.[114] However, should such displacement be occurring, it would undermine US efforts to diversify away from Russian supply. While imports of enriched uranium from China into the US remain a minor share of all US imports of enriched uranium, the stark increase in the value of deliveries in 2023 should be examined more closely. US utilities and government would also do well to consider the risks of swapping dependencies on Russia for dependencies on China in its enriched uranium supply. China's apparent interest in taking advantage of the shifts occurring in global nuclear supply chains suggests that China may be actively angling to replace Russia in the US's nuclear energy supply chain, potentially using increased imports of Russian material.

114. Interview with N.

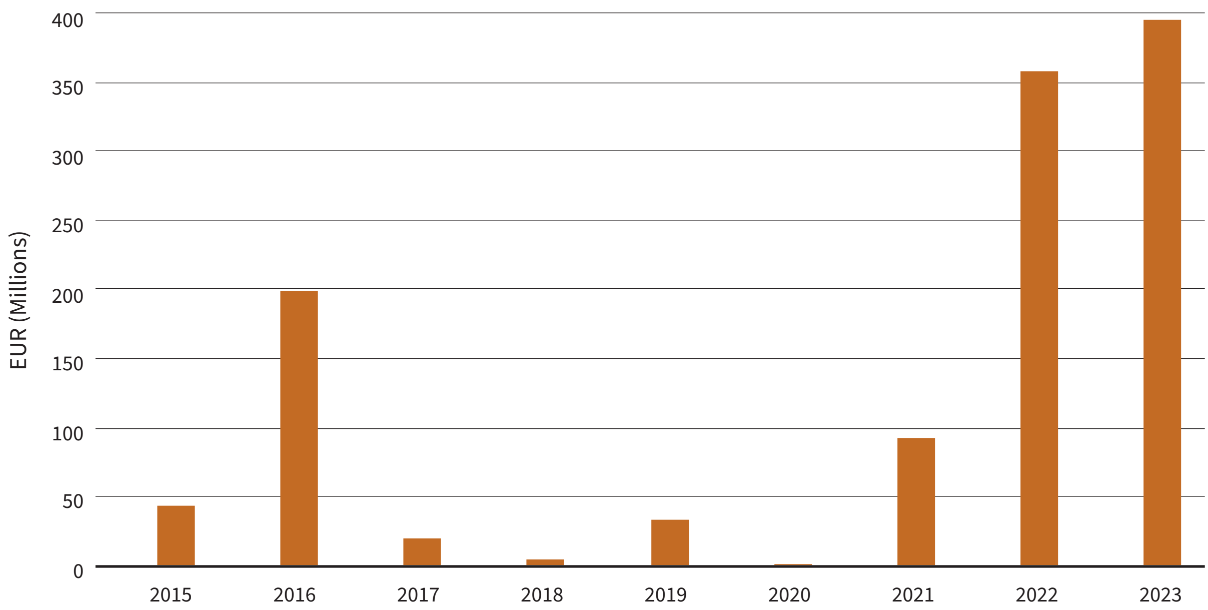
III. Case Study: France

France is regularly mentioned in media coverage and expert discussion of continued Western reliance on Russian enriched uranium. The French nuclear sector has a long history of partnership with Russia, with Rosatom entering the French market in the 1970s.[115] The value and volume of French imports of enriched uranium from Russia rose notably in 2022 and has remained high in 2023, relative to pre-2022 levels. According to Eurostat data, in 2021, France imported 110 tonnes (€93 million) from Russia under HS code 28442035. In 2022, the volume of imports rose to 312 tonnes (€359 million), an increase of 184% from 2021.[116] Eurostat data shows 223 tonnes in imports of enriched uranium from Russia in 2023, a 103% increase in volume from 2021 but a decrease of 29% from 2022 imports.[117] Comparable levels of imports from Russia into France were last seen in 2014, when France imported 399 tonnes (€398 million) of enriched uranium from Russia.[118] It is worth noting that the value of French imports of enriched uranium from Russia in 2023 actually increased from 2022, to €396 million, pointing to a discrepancy between changes in the value and weight of imports from Russia in 2023. The reason for this discrepancy was not clear. Figures 7 and 8 show the value and weight, respectively, of French imports of enriched uranium from Russia from 2015 to 2023.

Several explanations for the increase in French imports of Russian material are possible and are explored in this chapter. Based on a review of trade data, publicly available information on nuclear fuel supply chains in Europe and other public reporting, one likely explanation (although difficult to prove with certainty) is that the increased imports of enriched uranium from Russia in 2022 and continued relatively high levels in 2023 may be the result of the redistribution of Russian enriched uranium by some utilities across their supply chains – delivering more of their Russian-sourced material for fuel fabrication in France instead of to fabrication facilities in other countries that may be less willing to accept Russian supply. If true, this would mean that efforts to move away from Russian enriched uranium supply by some companies and governments may be being offset – at least in part – by greater imports of Russian enriched uranium into France. This chapter outlines these developments and tests a number of other possible explanations for the observed increases in French imports of Russian enriched uranium since 2022.

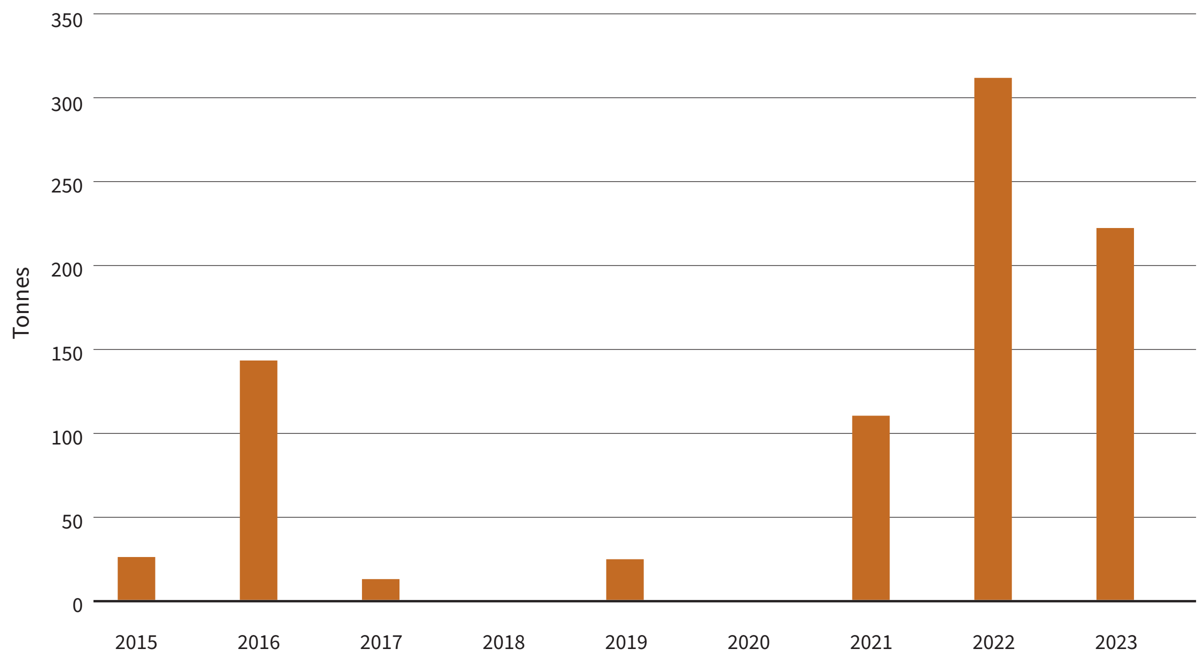
115. Rosatom, 'History of Cooperation', <https://rosatom-europe.com/rosatom-in-country/history-of-cooperation/>, accessed 14 February 2024.
116. Eurostat, 'EU Trade Since 1988 by HS2-4-6 and CN8' (HS code 28442035), accessed 4 March 2024.
117. *Ibid.*
118. *Ibid.*

Figure 7: French Imports from Russia under HS Code 28442035, 2015–23 (EUR)



Source: Data sourced from Eurostat, 'EU Trade Since 1988 by HS2-4-6 and CN8' (HS code 28442035), accessed 4 March 2024.

Figure 8: French Imports from Russia under HS Code 28442035, 2015–23 (Tonnes)



Source: Data sourced from Eurostat, 'EU Trade Since 1988 by HS2-4-6 and CN8' (HS code 28442035), accessed 4 March 2024.

Overview of the French Nuclear Energy Sector

France plays a significant role in European and global nuclear fuel supply chains. The country is not only a major producer and consumer of nuclear energy, but it also hosts conversion, enrichment, fuel fabrication and fuel reprocessing facilities. At the time of writing, France hosted 56 operational reactors with a total net electrical capacity of 61.37 GW(e), second only to the US on both metrics.[119] Another reactor is expected to be connected to the grid in mid-2024.[120] France's nuclear reactor fleet is operated by Électricité de France SA (EDF), which is fully owned by the French state.[121] France also performs uranium conversion at the Philippe Coste plant (an Orano facility),[122] uranium enrichment at the Georges Besse II plant (also an Orano facility)[123] and nuclear fuel fabrication at the Romans-sur-Isère plant (a Framatome facility).[124] According to its webpage, Framatome is owned by EDF (80.5%) and Mitsubishi Heavy Industries (19.5%).[125] Through its subsidiary companies, Framatome also operates nuclear fuel fabrication plants at Lingen, Germany (Advanced Nuclear Fuels GmbH)[126] and in Richland, Washington (Framatome, Inc.).[127] Fuel manufactured at Framatome's Romans-sur-Isère facility serves both the French domestic fleet of reactors and nuclear utilities and research reactors abroad. French reactors are also loaded with fuel manufactured at the fuel fabrication plant at Västerås, Sweden (owned by a subsidiary of US company Westinghouse Electric),[128] at a plant in Juzbado, Spain (owned by Spanish company Enusa; Westinghouse manufactures EDF fuel at the facility),[129] and at the

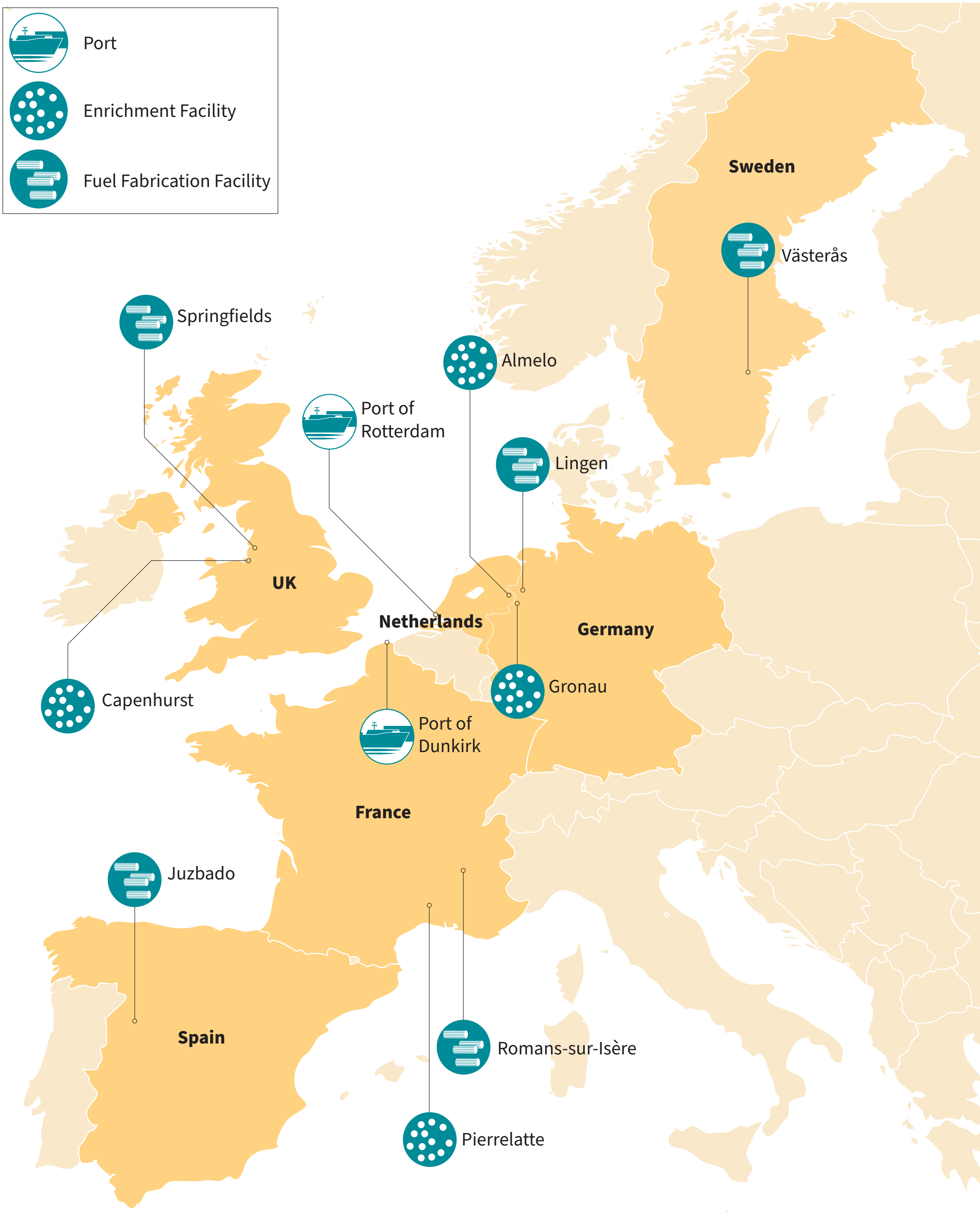
119. IAEA Power Reactor Information System, 'France', <https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=FR>, accessed 16 February 2024.
120. *Reuters*, 'EDF Eyes Flamanville EPR Nuclear Reactor Fuel Loading in March', 21 December 2023.
121. Autorité de sûreté nucléaire (ASN), 'ASN Report on the State of Nuclear Safety and Radiation Protection in France in 2022', 3 August 2023, <https://www.french-nuclear-safety.fr/asn-informs/publications/asn-s-annual-reports/asn-report-on-the-state-of-nuclear-safety-and-radiation-protection-in-france-in-20222>, p. 286, accessed 16 February 2024; EDF, 'Capital Structure', <https://www.edf.fr/en/the-edf-group/dedicated-sections/investors/capital-structure>, accessed 16 February 2024.
122. Orano, 'Tricastin', <https://www.orano.group/en/nuclear-expertise/orano-s-sites-around-the-world/uranium-transformation/tricastin/expertise>, accessed 16 February 2024.
123. Orano, 'Tricastin'.
124. Framatome, 'Romans', <https://www.framatome.com/en/implantations/romans/>, accessed 16 February 2024.
125. Framatome, 'Governance', <https://www.framatome.com/en/about/governance/>, accessed 16 February 2024.
126. Framatome, 'Fertigung Brennelemente Lingen ANF', <https://www.framatome.com/de/implantations/lingen/>, accessed 16 February 2024.
127. Framatome, 'Richland, Washington', <https://www.framatome.com/en/implantations/richland/>, accessed 16 February 2024.
128. Westinghouse, 'Om Oss' ['About Us'], <https://www.westinghousenuclear.com/sweden/om-oss>, accessed 16 February 2024.
129. *World Nuclear News*, 'Westinghouse and EDF Sign Long-Term Fuel Contract', 18 December 2014, <https://www.world-nuclear-news.org/ENF-Westinghouse-and-EDF-sign-long-term-fuel-contract-18121401.html>,

Westinghouse-operated facility at Springfields, UK.[130] Components of fuel assemblies destined for French reactors may also be manufactured at Framatome's facility in Lingen.[131] Figure 9 shows a simplified summary of the locations of uranium enrichment and nuclear fuel fabrication facilities in Europe and the UK.

accessed 16 February 2024.

130. *Nuclear Engineering International*, 'Spotlight on Springfields', 9 July 2015, <https://www.neimagazine.com/features/featurespotlight-on-springfields-4618537/>, accessed 16 February 2024; EDF, 'Document d'enregistrement universel 2022' ['Universal Registration Document'], p. 29, <https://www.edf.fr/sites/groupe/files/2023-03/edf-urd-rapport-financier-annuel-2022-fr.pdf>, accessed 16 February 2024. The report states that fuel is fabricated for EDF either in France by Framatome or abroad by Westinghouse. Westinghouse – through its subsidiaries – operates fuel fabrication facilities in Richmond, Washington (US), Västerås (Sweden) and Springfields (UK).
131. Sylvie Corbet, 'Russia's Nuclear Trade with Europe Flows Despite Ukraine War', *AP News*, 29 September 2022.

Figure 9: Locations of European and UK Uranium Enrichment and Nuclear Fuel Fabrication Facilities



Source: Generated based on data from various sources.

As such, enriched uranium may theoretically be imported into France for the following purposes:

- Production of nuclear fuel in France (at the Romans-sur-Isère facility) for the French reactor fleet.
- Production of nuclear fuel in France (at the Romans-sur-Isère facility) for export to utilities abroad.
- Further shipment of the enriched uranium from France to Germany, Sweden, the UK or Spain (via other countries for deconversion) to be used in the production of nuclear fuel for the French reactor fleet.
- Further shipment of the enriched uranium from France to Germany, Sweden, the UK or Spain (via other countries for deconversion) to be used in the production of nuclear fuel for export to utilities abroad.

An increase in French imports of Russian enriched uranium could therefore be explained by an increase in demand for enriched uranium generally, or for Russian material specifically, for one or several of these purposes.

Possible Stockpiling in France

One possible explanation for the increased French imports of Russian enriched uranium, and the initial suspicion of a number of the experts consulted for this report, is that French utilities and fuel manufacturing facilities have been in a rush to stockpile Russian material for future use, in advance of possible future bans on enriched uranium imports from Russia.[132] Such stockpiling would help to ensure that sufficient inventories are in place to meet long-term domestic French needs as well as future demand of foreign customers.

To test this hypothesis, an assessment of changes in French enriched uranium stockpiles is needed. Information on France's annual national inventories of enriched uranium is made available in reports by France's national agency for radioactive waste management (Agence nationale pour la gestion des déchets radioactifs, ANDRA).[133] At the time of writing, ANDRA has not made available information on 2022 or 2023 stockpiles. Its estimates of French enriched uranium stocks up to 2040 predict relatively consistent inventory levels over this time period, although it notes that the estimates are based on historical trends and

132. Interviews with B, N, D, F, G and H.
133. Agence nationale pour la gestion des déchets radioactifs [National Agency for Radioactive Waste Management], 'National Inventory of Radioactive Materials and Waste', 2023, <https://inventaire.andra.fr/sites/default/files/pdf/20230316_-_andra_-_inventaire_national_-_essentiel_-en.pdf>, accessed February 2024.

do not represent (or reflect) an industrial strategy.[134] The financial reports of EDF[135] and Framatome[136] indicate a drop in the monetary value of their holdings of nuclear fuel between 2021 and 2022, while Orano reported a slight increase in the value of its ‘inventories and in-process’ material from 2021 to 2022 (of €15 million).[137] However, these figures are not an ideal point of analysis, as they include materials other than enriched uranium and are expressed in terms of monetary value (which can fluctuate) instead of volume. The data also does not offer any insights on where any enriched uranium in the inventories may have come from.

In comments made to the press in response to questions about the increase of imports into France of Russian enriched uranium, an EDF representative noted that the company has not increased its dependence on Russian enriched uranium and is purchasing as per ‘the contractual minimums with its Russian partners’.[138] This suggests that the French utility is not maxing out its contractual options in an effort to import as much Russian material as possible in advance of a potential ban. In the case of Orano, considering that the company is itself a provider of uranium enrichment services, it is unlikely, although technically possible, that the company is importing and stockpiling large volumes of Russian enriched uranium.[139]

It is worth noting that ANDRA does not capture enriched uranium inventories held in France by non-French utilities. As such, it is possible that some non-French utilities are importing and maintaining stocks of Russian material in France. Swiss utilities, for instance, have been known to hold natural and enriched uranium stocks in Germany, France, Sweden and the UK.[140] Testing this hypothesis would likely require access to commercially sensitive information. One could

134. Agence nationale pour la gestion des déchets radioactifs [National Agency for Radioactive Waste Management], ‘Inventaire national des matières et déchets radioactifs: Catalogue descriptif des matières 2023’ [‘National Inventory of Radioactive Materials and Waste: 2023 Descriptive Materials Catalogue’], <https://inventaire.andra.fr/sites/default/files/pdf/andra_inventairenational_cataloguematieres2023_bat_v2-web_bd-23_12_06-alr.pdf>, p. 11.
135. EDF, ‘Consolidated Financial Statements at 31 December 2022’, p. 71, <https://www.edf.fr/sites/groupe/files/2023-02/annual-results-2021-consolidated-financial-statements-2023-02-17.pdf>, accessed 14 February 2024.
136. Data sourced through a third-party website aggregating French corporate information. See Societé, ‘Framatome’, <https://www.societe.com/bilan/framatome-379041395202212311.html>, accessed 14 February 2024.
137. Orano, ‘2022 Annual Results’, 16 February 2023, p. 32, <https://cdn.orano.group/orano/docs/default-source/orano-doc/finance/publications-financieres-et-reglementees/2022/orano-2022-annual-results.pdf?sfvrsn=2b5e58d3_6>, accessed 14 February 2024.
138. Quang Pham, ‘Nucléaire : la France importe-t-elle de l’uranium de Russie, comme l’affirme Cécile Duflot?’ [‘Nuclear: Does France Import Uranium from Russia, as Cécile Duflot Affirms?’], *France Info*, 7 October 2022, <https://www.francetvinfo.fr/societe/nucleaire/vrai-ou-fake-nucleaire-la-france-importe-t-elle-de-l-uranium-de-russie-comme-l-affirme-cecile-duflot_5398636.html>, accessed 16 February 2024.
139. Interview with F.
140. IAEA, ‘Global Inventories of Secondary Uranium Supplies’, pp. 41–42.

also compare the sum of EDF's imports and Orano-produced enriched uranium against the sum of domestic uranium consumption and total enriched uranium and fabricated fuel exports, to determine the overall stocks of enriched uranium in the country, including any changes in stocks that may belong to foreign utilities. Such an assessment was not undertaken as part of the analysis for this report. Data on uranium inventories across Europe made available by the Euratom Supply Agency (ESA) shows a decrease in overall inventories from 2021 to 2022, however the figure is an aggregate of total stocks across Europe and captures uranium at various stages of the nuclear fuel cycle (not just enriched uranium).[141] As mentioned earlier, the monetary value of nuclear fuel held by Framatome did not increase in 2022, also suggesting that significant stockpiling, even for fabrication of fuel for foreign customers, is likely not happening.

As such, based on publicly available data, there is no obvious indication that significant stockpiling of enriched uranium is taking place in France. However, there is also insufficient data to definitively discount the possibility that the increase in imports of Russian enriched uranium into France is due to a major stockpiling drive. Details on 2022 and 2023 uranium inventories in future ANDRA reporting, or future IAEA reports on French enriched uranium inventories, will provide a clearer picture of how French stocks of enriched uranium may have changed and whether these changes are reflective of the significant increase in imports from Russia.

Possible Shifts in Domestic Demand

An increase in France's domestic demand for enriched uranium to respond to greater domestic nuclear energy production could also technically explain the increase in imports of Russian enriched uranium in 2022 and 2023. However, this explanation does not appear very likely. Based on WNA projections of France's enriched uranium production and needs through 2040, it appears that the country has sufficient domestic uranium enrichment capacity to cover its domestic needs. The WNA estimates that France's enriched uranium needs up to 2040 will not rise significantly, reaching a peak of 6,986 thousand SWU in 2023 and fluctuating below that number in the subsequent 17 years.[142] This indicates about a 4.7% increase from the 2022 demand of 6,639 thousand SWU, hardly justifying the 184% increase in the volume of imports of enriched uranium from Russia in 2022

141. Euratom Supply Agency, 'Euratom Supply Agency Annual Report 2022', 2023, p. 20, <https://euratom-supply.ec.europa.eu/system/files/2023-10/ESA%20Annual%20Report%202022%20-%20Final%20%28website%29_2.pdf>, accessed 16 February 2024.
142. These estimates represent the reference scenario. The upper scenario would see a peak in demand to 7,677 thousand SWU in 2038, representing a 15.6% increase from 2022 demand. The lower scenario expected a peak in demand in 2025 at 6,986 thousand SWU. See World Nuclear Association, *The Nuclear Fuel Report*, pp. 239–41.

and the continued relatively high volume of imports in 2023. Of course, the projections for French demand do not account for the enriched uranium that will be needed by French fuel fabricators to fulfil their contracts with foreign customers, which is likely to be significant.

There are other indicators that French domestic demand for Russian material specifically has not increased. Based on public reporting and statements by French authorities and EDF, it appears that only a limited amount of Russian enriched uranium is actually used in France's energy generation. In its 2022 'Universal Registration Document', EDF notes that it 'has a limited dependence on imports of Russian uranium, considering existing inventories and diversified and long-term supply contracts'.[143] As mentioned earlier, EDF representatives have also stated to the media that the company 'has not increased its share of enrichment of its natural uranium carried out in Russia in 2022 compared to 2021, in accordance with "the contractual minimums with its Russian partners"' and that uranium enriched in Russia 'represents a very small part of its enrichment activities'.[144]

Spikes can also sometimes be seen in trade data for enriched uranium corresponding to reactor refuelling cycles, which usually see a quarter to a third of the assemblies in a reactor core replaced every 12, 18 or 24 months.[145] In other words, deliveries of enriched uranium to fabrication facilities (like the one at Romans-sur-Isère) might spike at predictable intervals (for instance, every other year) to account for the fabrication of new fuel assemblies in advance of a reactor reload. It is technically possible that the refuelling cycles of a number of facilities that use the Romans-sur-Isère plant aligned. However, the increase in imports of Russian enriched uranium to France in 2022, and continued high levels of imports in 2023, do not match any observable pattern of regular increases in preceding years. Furthermore, the high levels of Russian imports into France (relative to pre-2022 values) have persisted for two consecutive years.

Possible Reallocation of Russian Enriched Uranium Across European Supply Chains

An April 2023 news report for *Le Monde* provides additional indication as to possible drivers for the increase in French imports of Russian enriched material in 2022. The article notes:

143. EDF, 'Document d'enregistrement universel 2022', p. 495.
144. Pham, 'Nucléaire'.
145. World Nuclear Association, 'Nuclear Power Reactors', updated May 2023, <https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/nuclear-power-reactors.aspx>, accessed 16 February 2024.

> When questioned, EDF said that its imports of Russian-enriched uranium have remained at the same level between 2021 and 2022. But it added that it has made more use of French factories for the manufacture of fuel assemblies, which would partly explain the difference. In other words, in previous years, some of the enriched uranium imported did not arrive in France but at plants in Sweden or the UK and was therefore not accounted for in the same way by customs.[146]

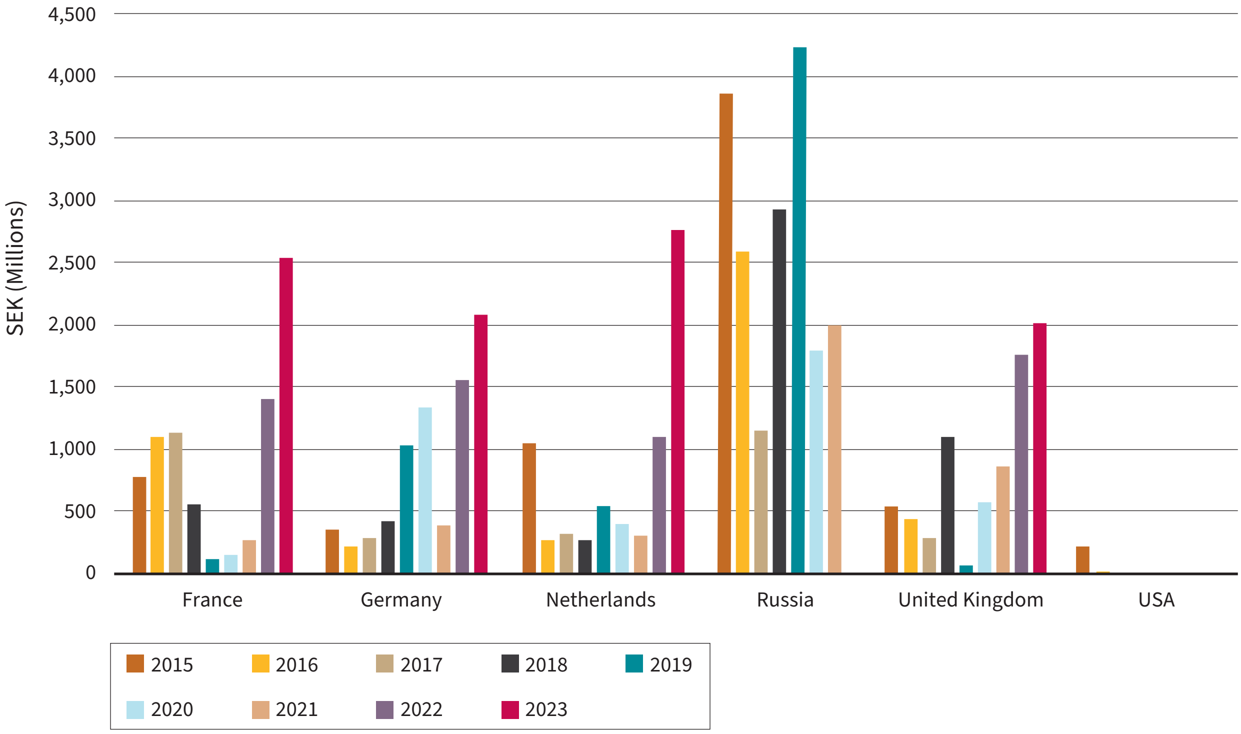
In its 2022 annual report, EDF noted that it sources its enriched uranium from Orano, Urenco and TENEX.[147] Based on the above comments, it appears that EDF may be reallocating its supply of Russian enriched uranium from Sweden (which hosts a fuel fabrication facility at Västerås, operated by Westinghouse Electric Sweden AB)[148] and/or the UK (which hosts a fuel fabrication facility at Springfields, operated by Westinghouse Springfields Fuels Ltd)[149] to France, for fabrication of nuclear fuel at Framatome's Romans-sur-Isère plant. This would mean that, as some European countries are trying to diversify away from Russian enriched uranium, France may be offering an alternative entry point for Rosatom to the European nuclear fuel market.

On the day of Russia's full-scale invasion of Ukraine, Swedish energy giant Vattenfall announced that it would no longer be accepting deliveries of Russian nuclear fuel, until further notice.[150] As it eventually became clear, that would also include all Russian enriched uranium.[151] In April 2022, Sweden's other utility also announced that it was pausing deliveries of enriched uranium from TENEX.[152] While there is currently no ban on imports of Russian material into Sweden at a national level,

146. Perrine Mouterde and Marjorie Cessac, 'French Nuclear Industry Maintains Links with Russian Giant Rosatom', *Le Monde*, 12 March 2023, <https://www.lemonde.fr/en/energies/article/2023/03/12/french-nuclear-industry-maintains-links-with-russian-giant-rosatom_6019019_98.html>, accessed 16 February 2024.
147. EDF, 'Document d'enregistrement universel 2022', p. 29.
148. Westinghouse, 'Kontakta oss' ['Contact Us'], <https://www.westinghousenuclear.com/sweden/kontakt/>, accessed 17 February 2024.
149. Westinghouse, 'The Place to Invest, Innovate and Grow in Nuclear', <https://www.westinghousenuclear.com/uknuclear/springfields>, accessed 17 February 2024.
150. Vattenfall, 'Vattenfall Stops Deliveries of Russian Nuclear Fuel', 24 February 2022, <https://group.vattenfall.com/press-and-media/newsroom/2022/vattenfall-stops-delivieries-of-russian-nuclear-fuel>, accessed 16 February 2024.
151. EPD notes that the utility now sources all of its enriched uranium supply from Orano's Georges Besse II facility in France and Urenco's facility in the UK. See EPD, 'EPD of Electricity from Vattenfall's Nuclear Power Plants', 31 December 2022, p. 13, <https://api.environdec.com/api/v1/EPDLibrary/Files/44e304c6-429b-44a2-f008-08daf7da081a/Data>, accessed 16 February 2024.
152. Energimyndigheten [Swedish Energy Agency], 'Lägesbild över energiförsörjningen med anledning av kriget i Ukraina' ['Situational Picture of the Energy Supply Due to the War in Ukraine'], 17 May 2022, <https://www.energimyndigheten.se/49a85c/globalassets/om-oss/ukraina/lagesbilder/uppdaterad-lagesbild-med-anledning-av-situationen-i-ukraina-220517_.pdf>, accessed 15 February 2024.

trade data made available by the Swedish government shows a complete stop of imports of enriched uranium from Russia into Sweden as of 2022.[153]

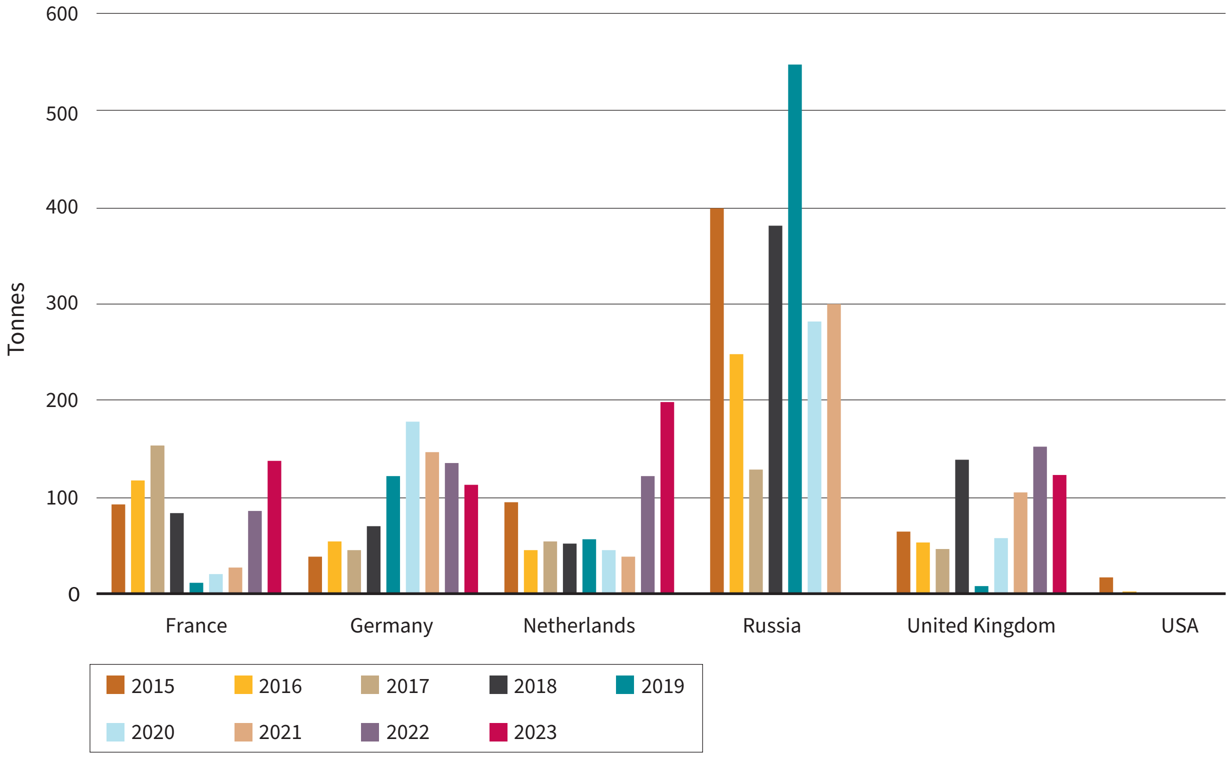
Figure 10: Swedish Imports under HS Code 28442035, 2015–23 (SEK)



Source: Data sourced from Official Statistics of Sweden, 'Imports of Goods from Country of Consignment. Not Adjusted for Non Response, SEK thousand by Commodity Group According to CN, Trading Partner and Year' (HS code 28442035), accessed 29 February 2024.

153. Official Statistics of Sweden, 'Imports of Goods from Country of Consignment. Not Adjusted for Non Response, Metric Ton by Commodity Group According to CN, Trading Partner and Year' (HS code 28442035), accessed 29 February 2024.

Figure 11: Swedish Imports under HS Code 28442035, 2015–23 (Tonnes)



Source: Data sourced from Official Statistics of Sweden, 'Imports of Goods from Country of Consignment. Not Adjusted for Non Response, Metric Ton by Commodity Group According to CN, Trading Partner and Year' (HS code 28442035), accessed 29 February 2024.

This is significant not only for Sweden's own nuclear energy sector but also for nuclear energy production across Europe, as the nuclear fuel production facility at Västerås manufactures fuel for Vattenfall and reactors across Europe.[154] The Västerås facility also has the capability to produce fuel for Soviet and Russian-built VVER-type reactors (водо-водяной энергетический реактор [vodo-vodyanoi enyergeticheskiy reactor]), offering an alternative supply of VVER fuel for countries, mostly in Eastern Europe, which have historically relied on Rosatom subsidiary TVEL for their supply. Västerås-manufactured VVER fuel has already been supplied to Ukrainian reactors and deliveries are planned for reactors in Bulgaria in 2024.[155]

154. EPD, 'EPD of Electricity from Vattenfall's Nuclear Power Plants'; Westinghouse, 'Om Oss' ['About us'].
155. Westinghouse Electric Company, 'Westinghouse Delivers First VVER-440 Fuel Assemblies to Energoatom', Westinghouse, 12 September 2023, <https://info.westinghousenuclear.com/news/westinghouse-delivers-first-vver-440-fuel-assemblies-to-energoatom>, accessed 16 February 2024; *Nuclear Newswire*, 'Westinghouse Continues Dealmaking in Ukraine, Bulgaria', 15 June 2023, <https://www.ans.org/news/article-5091/westinghouse-continues-deal-making-in-ukraine-bulgaria/>, accessed 16 February 2024. Westinghouse has also agreed to supply VVER-440 fuel to reactors in Finland, Czechia and Slovakia, but it is unclear whether the fuel for these countries will be manufactured at the company's facility in Västerås or at Enusa's Juzbado facility. See Jessica Sondgeroth and Grace Symes, 'Westinghouse Locks in Slovak VVER-400 Fuel Contract', *Energy Intelligence*, 25 August 2023, <https://www.energyintel.com/0000018a-2919-d6c1-adae-ab7d84e60000>, accessed 16 February 2024; *Nuclear Engineering International*,

The cessation of imports of enriched uranium from Russia to Sweden after 2022 indicates that all the utilities using the Västerås facility for their fuel manufacturing, and which may have previously relied on Russian enriched uranium supply, have found alternative enriched uranium suppliers for the manufacture of their fuel at Västerås. In 2022 and 2023, the value of imports of enriched uranium into Sweden increased from France, Germany, the Netherlands and the UK, suggesting an uptick in deliveries from Orano (France) and Urenco (the UK, the Netherlands and Germany). The German Federal Office for the Safety of Nuclear Waste Management (Bundesamt für die Sicherheit der nuklearen Entsorgung, BASE) has also issued a permit for the transport to Västerås through German territory of uranium hexafluoride from enrichment facilities in France (Orano), the Netherlands (Urenco) and Germany (Urenco), with regular transport activity recorded throughout 2023.[156] At the time of writing, no such permit has been reported by the German authorities for the transport of enriched uranium to Västerås from TENEX, although it is unclear when the last permit for such transit expired.[157]

Supply of enriched uranium is normally secured by utilities under long-term contracts, meaning that utilities still obligated to source enriched uranium from Russia but suddenly unable to send it to Sweden will have needed to deliver it to fuel fabrication facilities in countries still willing to accept Russian material. According to Eurostat data, since February 2022 France and Germany are the only European countries that have continued to import enriched uranium from Russia, although the latter at much lower volumes than before 2022.[158] Both host nuclear fuel fabrication facilities. At least some imports of Russian-origin material also appear to have been delivered to Spain in 2022; a fuel fabrication facility is located at Juzbado, owned by Enusa.

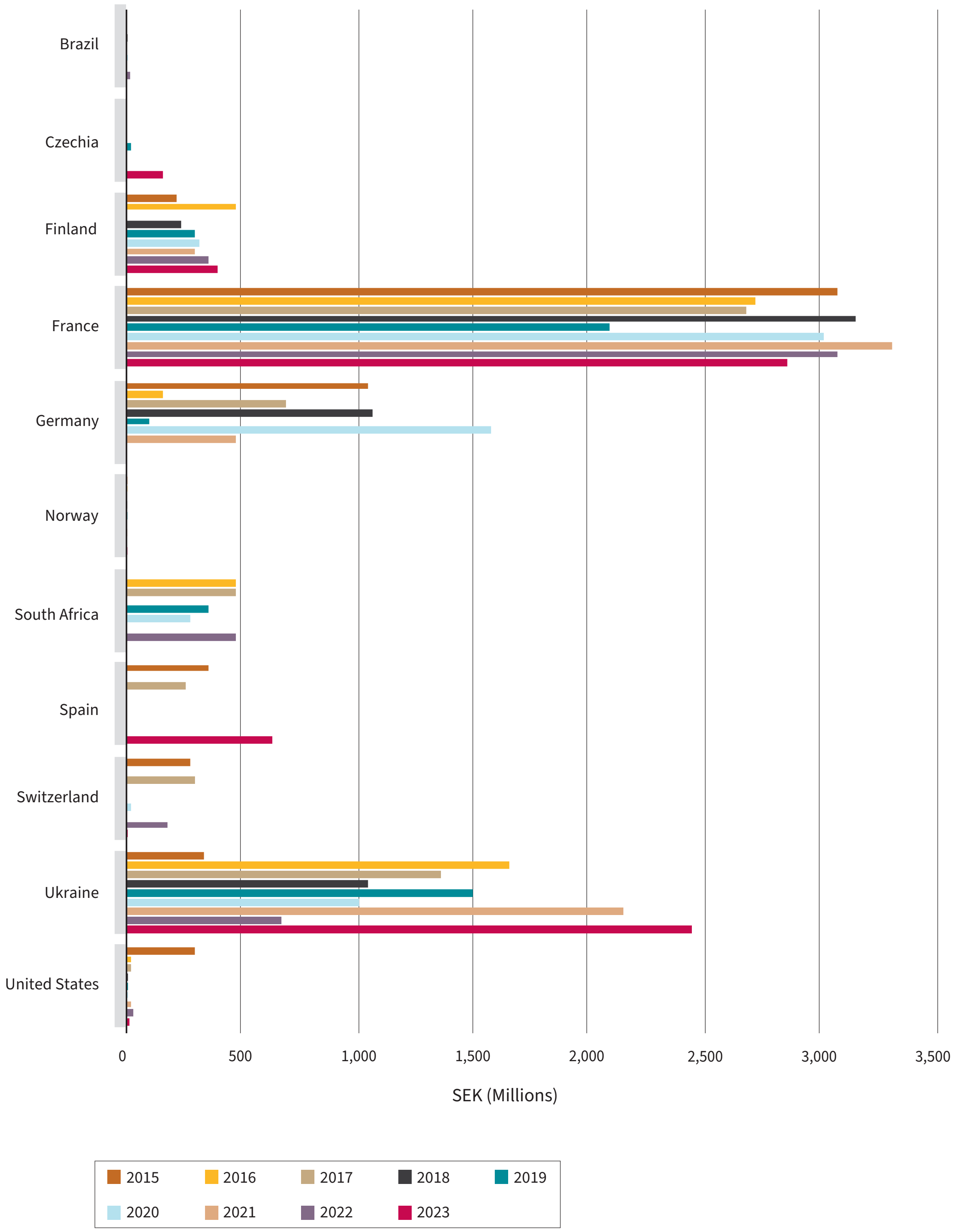
‘Westinghouse to Supply VVER-440 Fuel to Dukovany’, 4 April 2023, <https://www.neimagazine.com/news/newswestinghouse-to-supply-vver-440-fuel-to-dukovany-10731125>, accessed 16 February 2024; Westinghouse, ‘Helping Finland to Secure its Energy Future’, 22 November 2022, <https://info.westinghousenuclear.com/news/helping-finland-secure-energy-future>, accessed 16 February 2024.

156. Bundesamt für die Sicherheit der nuklearen Entsorgung (BASE) [Federal Office for the Safety of Nuclear Waste Management], ‘Gültige Beförderungsgenehmigungen nach § 4 Atomgesetz bzw. §§ 27 und 29 StrlSchG’ [‘Valid Transport Permits in Accordance with Section 4 of the Atomic Energy Act or Sections 27 and 29 of the Radiation Protection Law’], 9 February 2024, <https://www.base.bund.de/SharedDocs/Downloads/BASE/DE/fachinfo/ne/transportgenehmigungen.pdf;jsessionid=F462F51AA9DC4D11ED99E6382654E93A.internet941?__blob=publicationFile&v=154>, accessed 17 February 2024.
157. *Ibid.*
158. Eurostat, ‘EU Trade Since 1988 by HS2-4-6 and CN8’.

At the time of writing, the webpage of the Västerås fabrication plant noted that, alongside Ukraine, France is its biggest customer.[159] This is also borne out in trade data, which shows France as the primary destination for Swedish nuclear fuel exports (See Figure 13).[160] It is unclear from publicly available sources how much, if any, of EDF's TENEX-sourced supply had historically been sent to Sweden, but the complete cessation of Russian enriched uranium imports into Sweden suggests that all of EDF's TENEX-supplied material is now being delivered to one of the other fuel fabrication facilities the company uses. Other utilities that have used the Västerås facility – Swedish, Ukrainian, German and Finnish companies – had also historically relied on the Russian supply of enriched uranium, some of which may have been delivered to Västerås prior to 2022.

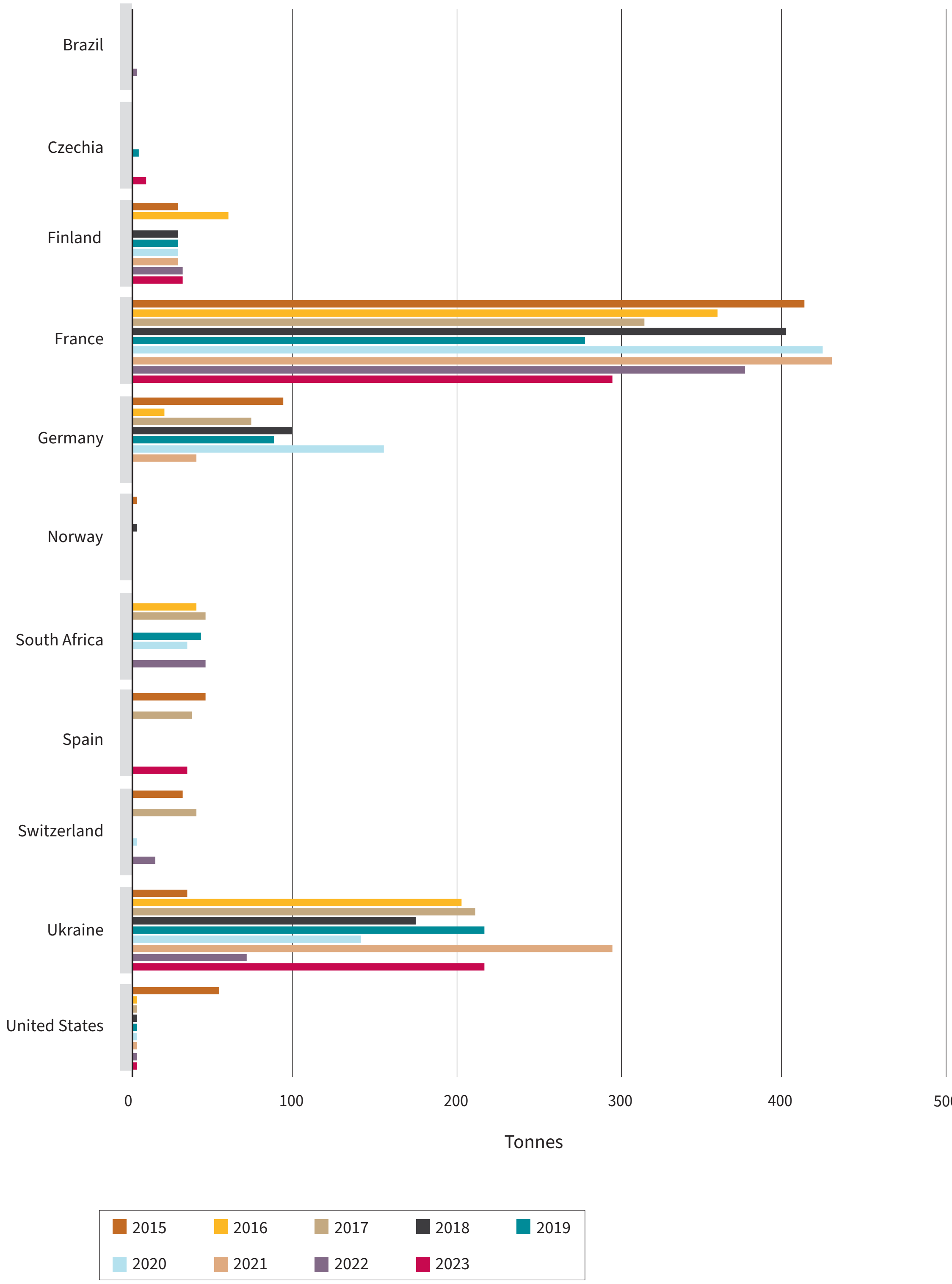
159. Westinghouse, 'Om Oss' ['About us'].
160. Official Statistics of Sweden, 'Exports of Goods to Country of Destination. Not Adjusted for Non Response, Metric Ton by Commodity Group According to CN, Trading Partner and Year' (HS Code 84013000), accessed 23 February 2024.

Figure 12: Swedish Exports under HS Code 84013000, 2015–23 (SEK)



Source: Data sourced from Official Statistics of Sweden, 'Exports of Goods to Country of Destination. Not Adjusted for Non Response, SEK Thousand by Commodity Group According to CN, Trading Partner and Year' (HS Code 84013000), accessed 23 February 2024.

Figure 13: Swedish Exports Under HS Code 84013000, 2015–23 (Tonnes)



Source: Data sourced from Official Statistics of Sweden, 'Exports of Goods to Country of Destination. Not Adjusted for Non Response, Metric Ton by Commodity Group According to CN, Trading Partner and Year' (HS Code 84013000), accessed 23 February 2024.

Fuel for French reactors is also manufactured at the nuclear fuel manufacturing facility at Springfields (UK), operated by a subsidiary of Westinghouse.[161] Eurostat data shows imports under HS code 840130 – which captures nuclear fuel assemblies (but may also include components thereof) – from the UK into France from 2021 onwards, including 49 tonnes of imports in 2022 and 74 tonnes in 2023.[162] It is unclear whether Russian enriched uranium is or has in the past been used for the manufacture of nuclear fuel for French reactors at the facility. As neither Russia nor the UK publicly report their trade in enriched uranium, any deliveries of Russian enriched material to the UK, or changes in any such trade, cannot be tracked through a review of trade data. However, in July 2022, the UK introduced a 35% tariff on goods under HS code 2844 ('Radioactive chemical elements and radioactive isotopes (including the fissile or fertile chemical elements and isotopes) and their compounds; mixtures and residues containing these products')[163] imported into the UK from Russia, which includes enriched uranium. As such, while deliveries of Russian enriched uranium into the UK are still permitted and may therefore be taking place, the introduction of the 35% tariff makes it unlikely that such imports have continued since July 2022. This means that EDF's supply of Russian enriched uranium is now likely being sent to one of two facilities – the Enusa facility in Juzbado (Spain) or the Framatome facility at Romans-sur-Isère (France).

A reallocation of Russian material by EDF from other facilities – Västerås or Springfields – to France would explain, at least in part, the increase in 2022 of imports of Russian enriched uranium into the country. It also aligns with statements by EDF that the company 'has made more use of French factories for the manufacture of fuel assemblies' in 2022 than in past years[164] and that it has not increased its overall reliance on Russian enriched uranium. However, any such reallocation is difficult to confirm from publicly available information, as supply contracts tend to be commercially sensitive.

In its 2022 annual report on the state of nuclear safety and radiation protection in France, the nuclear safety authority (Autorité de sûreté nucléaire, ASN) reported an increase compared with 2021 in the amount of TENEX-supplied enriched uranium processed at the Romans-sur-Isère facility, from 21 to 40 tonnes.[165] However, compared to Orano- and Urenco-supplied product processed

161. Westinghouse, 'Fuel Manufacturing', <https://www.westinghousenuclear.com/uknuclear/springfields>, accessed 4 March 2024.
162. Eurostat, 'EU Trade Since 1988 by HS2-4-6 and CN8'.
163. Department for Business & Trade, 'Additional Duties on Russian and Belarusian Imports: Product Lists', Table 1, <https://assets.publishing.service.gov.uk/media/6568c2935936bb001331682a/uk-product-list-additional-duties-on-products-originating-from-russia-and-belarus.odt>, accessed 17 February 2024.
164. Perrine Mouterde and Marjorie Cessac, 'French Nuclear Industry Maintains Links with Russian Giant Rosatom'.
165. Autorité de sûreté nucléaire (ASN) [Nuclear Security Authority], 'ASN Report on the State of Nuclear Safety and Radiation Protection in France in 2022', 3 August 2023, p. 321, <https://www.french-nuclear-safety.fr/

by the facility in 2022 (564 tonnes and 142 tonnes, respectively), the 19-tonne increase in TENEX-supplied enriched uranium processed at Romans-sur-Isère in 2022 is not significant in terms of volume and certainly does not fully account for the increase of Russian enriched uranium into France. The ANS report refers to enriched uranium 'processed' (not necessarily 'delivered') at the facility in a given year, meaning that it is possible that any additional deliveries of Russian material to the facility made in 2022 may not actually be processed until 2023 or later. Alternatively, the additional TENEX material processed may have been drawn from existing stocks, not new deliveries.

Exports under HS code 840130 from Sweden and the UK to France continued in 2022 and 2023, albeit at lower volumes than pre-2022 in the case of exports from Sweden. If, as per EDF's comments in *Le Monde*,[166] less of the company's Russian supply of enriched uranium is being delivered to fuel fabrication facilities abroad, that material may have been replaced by deliveries to those facilities of non-Russian material from elsewhere in EDF's supply chain. The value of French exports of enriched uranium to Sweden increased from 40 tonnes in 2021 to 120 tonnes in 2022 and to 153 tonnes in 2023.[167] French exports of enriched uranium to the UK have decreased, from 167 tonnes in 2021 to 129 tonnes in 2022 and 90 tonnes in 2023.[168] US imports of enriched uranium from France increased from 121 tonnes in 2021 to 327 tonnes in 2023.[169] However, at least some of the additional exports of enriched uranium from France are very likely the result of deliveries for non-French utilities under new contracts with enrichment services provider Orano as countries seek to diversify away from Rosatom supply. For instance, Sweden's utility Vattenfall, which previously received enriched uranium from Russia, is now sourcing its supply from Orano in France and Urenco in the UK.[170] US-based broker of enrichment services Centrus Energy Corp. (Centrus) also

asn-informs/publications/asn-s-annual-reports/asn-report-on-the-state-of-nuclear-safety-and-radiation-protection-in-france-in-20222>, accessed 16 February 2024; ASN, 'ASN Report on the State of Nuclear Safety and Radiation Protection in France in 2021', 7 July 2022, p. 313, <https://www.french-nuclear-safety.fr/asn-informs/publications/asn-s-annual-reports/asn-report-on-the-state-of-nuclear-safety-and-radiation-protection-in-france-in-2021>, accessed 16 February 2024.

166. Mouterde and Cessac, 'French Nuclear Industry Maintains Links with Russian Giant Rosatom'.
167. Eurostat, 'EU Trade Since 1988 by HS2-4-6 and CN8'. Trade data made available by the Swedish government shows slightly different volumes of imports under HS code 28442035 from France but still captures an increase from 27 tonnes in 2021 to 85 tonnes in 2022 and 137 tonnes in 2023 (data available to November 2023). See Official Statistics of Sweden, 'Imports of Goods from Country of Consignment. Not Adjusted for Non Response, Metric Ton by Commodity Group According to CN, Trading Partner and Year'.
168. Eurostat, 'EU Trade Since 1988 by HS2-4-6 and CN8', accessed 10 March 2024.
169. Data sourced from the US Census Bureau, HS code 2844200020, accessed 26 February 2024. US Census Bureau data shows imports of 212 tonnes of enriched uranium from France in 2022. Eurostat data shows exports under HS code 284420 from France to the US at 186 tonnes in 2021, 181 tonnes in 2022 and 427 tonnes in 2023.
170. EPD, 'EPD of Electricity from Vattenfall's Nuclear Power Plants'.

started taking deliveries of enriched uranium from Orano in 2023 under a contract that was concluded in 2018.[171]

In its comments to *Le Monde*,[172] EDF also highlighted that it is not the only importer of uranium into France, and the news article points out that part of a delivery of Russian enriched uranium to Dunkirk in November 2022 belonged to Framatome, which operates the Romans-sur-Isère facility and manufactures fuel for a number of other European utilities at fabrication facilities in France and Germany. It is unclear whether that particular shipment remained in France or was transported onwards to Germany. As such, the increase of Russian enriched uranium deliveries to the site may be for the fabrication of nuclear fuel for other reactors, not just the French fleet. The 2021 and 2022 ANS reports record deliveries of nuclear fuel assemblies from Romans-sur-Isère to Switzerland, Belgium and China.[173] The plant also produces nuclear fuel assemblies for South Africa.[174] Theoretically, the additional imports into France of Russian enriched uranium could have been for integration into fuel assemblies for some of these customers. As of April 2022, Swiss energy utility Axpo was reported as having considerable dependencies on Russian uranium and stated that it would honour its existing contracts but not sign new ones.[175] It is unclear from the report whether the dependency was in relation to mined or enriched uranium and when the existing contracts expire. China is also a well-established consumer of Russian enriched uranium and, as discussed in Chapter II, ramped up its own imports of enriched uranium from Russia in 2022 and 2023. Synatom, which provides enriched uranium to Belgium's nuclear power plants, was reported in early 2022 to be relying on Russian uranium supply,[176] although the report seems to have been referencing mined uranium and not enrichment services. While Belgium's supply contract with Rosatom is no longer active, it reportedly took its last delivery of enriched uranium from Rosatom in May 2022.[177] It is unclear which fabrication facility took delivery of this material.

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171. US Securities and Exchange Commission, 'Centrus, Form 10-K: Annual Report Pursuant to Section 13 or 15(d) of the Securities Exchange Act of 1934 for the Fiscal Year Ended December 31, 2023', p. 15. <https://investors.centrusenergy.com/static-files/bc06aee7-5726-4f20-9ef7-e177f063625e> accessed 17 February 2024.
172. Mouterde and Cessac, 'French Nuclear Industry Maintains Links with Russian Giant Rosatom'.
173. Autorité de sûreté nucléaire (ASN) [Nuclear Security Authority], 'ASN Report on the State of Nuclear Safety and Radiation Protection in France in 2022'.
174. *World Nuclear News,* '"No Crisis" for Koeberg Fuel Supply as South Africa Continues Load Shedding', 3 February 2023, <https://world-nuclear-news.org/Articles/No-crisis-for-Koeberg-fuel-supply-as-South-Africa>, accessed 19 February 2024.
175. *Swissinfo*, 'Use of Russian Uranium for Swiss Nuclear Power Under Scrutiny', 31 March 2022, <https://www.swissinfo.ch/eng/business/use-of-russian-uranium-for-swiss-nuclear-power-under-scrutiny/47479722>, accessed 16 February 2024.
176. Liv Klingert, 'Russia's Energy Chokehold: 40% of Uranium Used in Belgium Linked to Russia', 5 May 2022, <https://www.brusselstimes.com/222425/russias-energy-chokehold-40-of-uranium-used-in-belgium-linked-to-russia>, accessed 16 February 2024.
177. *Ibid*.

Russian Enriched Uranium Deliveries to Spain

Besides Springfields, Västerås and Romans-sur-Isère, the nuclear fuel fabrication plant at Juzbado in Spain is the other facility that fabricates nuclear fuel for EDF. The facility also produces nuclear fuel for reactors in Spanish, Belgian, Swedish and Finnish reactors[178] and has taken delivery of Russian enriched uranium since February 2022.[179] It is technically possible that Russian enriched material delivered to Juzbado (if such deliveries have continued) may be used for fuel fabrication for a number of European utilities. Swedish and Finnish policies of diversification away from Russian supply mean that any deliveries of Russian enriched uranium to Juzbado would likely only be for the production of fuel for Spanish, Belgian or French reactors.

Tracking shifts in the flow of enriched uranium into Spain is challenging. As Spain does not have a domestic deconversion capacity,[180] enriched uranium destined for Juzbado undergoes deconversion abroad before being delivered to Spain for fuel fabrication.[181] Enusa's contract for the supply of enriched uranium to Spanish reactors from TENEX runs until 2027[182] and the Spanish government has confirmed that Enusa has taken delivery of Russian enriched uranium in the UK and the US (as well as in Germany) since February 2022. Eighteen tonnes of the material were eventually delivered to Spain from the US in March 2023.[183] However, it is unclear when the deliveries were made to the US and the UK or whether the two countries have since taken any other deliveries of Russian enriched uranium for Enusa.

Implications

Due to the commercial sensitivity of uranium supply and fuel manufacturing contracts, limited information on French uranium stocks and any stockpiles

178. Foro Nuclear, 'Juzbado, Fuel Assembly Factory', <https://www.foronuclear.org/en/nuclear-power/nuclear-power-in-spain/juzbado-fuel-assembly-factory/>, accessed 16 February 2024; IAEA, 'Global Inventories of Secondary Uranium Supplies', p. 45.
179. Secretaria de estado de relaciones con las cortes y asuntos constitucionales [Secretary of State for Relations with the Courts and Constitutional Matters] 'Respuesta del gobierno (184/103641)' ['Government Response (184/103641)'], 8 March 2023, <e_0268264_n_000.pdf (congreso.es)>, accessed 16 February 2024.
180. Deconversion is a stage that enriched uranium must pass through before it is manufactured into nuclear fuel assemblies; not to be confused with conversion, a process undertaken prior to enriching the uranium.
181. IAEA, 'Global Inventories of Secondary Uranium Supplies', p. 45.
182. Rosatom, 'TENEX Continues Supplies of Enriched Uranium to Spain', 17 December 2020, <https://rosatom-europe.com/press-centre/news/tenex-continues-supplies-of-enriched-uranium-to-spain/>, accessed 14 February 2024.
183. Secretaria de estado de relaciones con las cortes y asuntos constitucionales [Secretary of State for Relations with the Courts and Constitutional Matters] 'Respuesta del gobierno (184/103641)' ['Government Response (184/103641)'].

held in France by foreign utilities, as well as the difficulties inherent in tracing complex supply chain dynamics, it is challenging to ascertain the precise drivers of increased imports of Russian enriched uranium into France. While at least some reallocation of Russian supplies to France appears to be happening, the degree to which such activity is responsible for the additional import of Russian material into France is difficult to confirm. A range of other explanations for the increased Russian enriched uranium imports into France are also technically possible, some of which have been outlined earlier in this chapter.

In the absence of EU sanctions on Rosatom, there is no legal basis on which to disallow continued imports of Russian enriched uranium into EU countries. Neither is any redistribution of Russian and non-Russian supplies across European nuclear fuel supply chains prohibited in any way. Since the start of the war in Ukraine, there has been no public reporting of new contracts for enriched uranium supply between Rosatom and European utilities; as such, if any reallocation of Russian material into France is taking place, it is likely facilitating the execution of existing contracts by companies still obligated to continue taking Russian enriched uranium, the breach of which may have proven very costly for the companies in question. France's willingness to continue accepting Russian imports of enriched uranium may therefore be granting utilities the flexibility they need in their supply chains to maintain continuity of supply and to avoid breaching existing contracts. Industry will do what it must to adjust to changing market dynamics and can hardly be blamed for doing so, within the parameters permitted by regulation. However, it points to the importance of considering how industry is likely to adapt to the implementation of new restrictions and what measures may be needed to facilitate and incentivise alignment of private sector behaviour with political objectives. The observed increase in imports of Russian material into France, even as other European countries look to move away from Russian supply, also highlights the limited impact of unilateral national or company efforts to cut Russia out of the highly interconnected European nuclear fuel supply chain.

IV. Case Study: Germany

Germany is the other country in Europe which has continued to import enriched uranium from Russia since February 2022, according to Eurostat data.[184] The only nuclear fuel fabrication facility in Germany is the Lingen plant, which is owned by a subsidiary of France's Framatome and has been reported as apparently continuing to accept deliveries of Russian uranium.[185] This raises questions over whether the Lingen plant could be another possible diversion point for Russian material that is no longer wanted in other countries, now or in the future.

Deliveries of Russian Enriched Uranium to Germany

The Lingen plant produces fuel assemblies for customers around the world and supplies 'components and fuel for Framatome's fuel assembly plants in the USA and Europe'.[186] The IAEA's 2023 report 'Global Inventories of Secondary Uranium Supplies' notes that Lingen manufactures fuel for customers in the Netherlands[187] and that Spain has received deliveries of fuel from Germany.[188] UN Comtrade data also shows exports since 2019 from Germany of goods under HS code 840130 to Switzerland, Sweden, Spain, the UK, Belgium, France, Finland, Kazakhstan, the Netherlands, Brazil and a number of other countries;[189] however, while the code captures unirradiated nuclear fuel, it also includes nuclear assembly parts – as such, exports recorded under this code do not necessarily signify the delivery of manufactured fuel assemblies. Russian-origin enriched uranium has also previously been supplied to the UK via Lingen for use in UK reactors operated by EDF's British subsidiary EDF Energy.[190]

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184. Eurostat, 'EU Trade Since 1988 by HS2-4-6 and CN8', accessed 3 March 2024.
185. Frank Jordans, 'Germany: No Option but to Permit Russian Uranium Shipment', *AP News*, 12 September 2022, <https://apnews.com/article/russia-ukraine-germany-global-trade-berlin-912d444b8a2fa2e96fc28aceeaac6e26>, accessed 16 February 2024; Rivasi et al., 'Transparency on Uranium Deliveries'; Vladimir Slivyak and Matthias Eickhoff, 'Rosatom is Putin's Geopolitical Arm', Rosa Luxembourg Stiftung, 12 February 2024, <https://www.rosalux.de/en/news/id/51556/rosatom-is-putins-geopolitical-arm>, accessed 17 February 2024; Bundesamt für die Sicherheit der nuklearen Entsorgung (BASE) [Federal Office for the Safety of Nuclear Waste Management], 'Gültige Beförderungsgenehmigungen nach § 4 Atomgesetz bzw. §§ 27 und 29 StrlSchG' ['Valid Transport Permits in Accordance with Section 4 of the Atomic Energy Act or Sections 27 and 29 of the Radiation Protection Law'].
186. Framatome, 'Fertigung Brennelemente Lingen ANF'.
187. IAEA, 'Global Inventories of Secondary Uranium Supplies', p. 39.
188. *Ibid.*, p. 45.
189. UN Comtrade data (HS code 840130, accessed 29 February 2024).
190. IAEA, 'Global Inventories of Secondary Uranium Supplies', p. 43.

In August 2023, BASE issued a permit to Orano NCS GmbH (a nuclear logistics provider and part of the Orano Group of companies) for the transport of enriched uranium (in the form of uranium hexafluoride) from JSC TENEX to Advanced Nuclear Fuels (ANF) GmbH, the Framatome subsidiary that operates nuclear fuel manufacturing facility at Lingen.[191] The current permit is valid from 7 August 2023 to 31 December 2024; however, as of 29 February 2024, only two transport activities had been recorded under this permit, on 5 September 2023 and 8 February 2024.[192] It is unclear where the transport originated. The cargo vessel *Mikhail Dudin*, which has been known to transport Russian enriched uranium to Europe,[193] made a port call in Rotterdam on 5 September 2023.[194] The cargo vessel *Baltiysky-202*, which had previously been reported unloading Russian enriched uranium in Dunkirk,[195] called at the port of Rotterdam on 8 February 2024 and the port of Dunkirk on 9 February 2024.[196] However, the Netherlands has not reported any imports of enriched uranium from Russia since February 2022.[197] On at least one occasion, Russian enriched uranium being delivered by the *Mikhail Dudin* to Dunkirk was reportedly on its way to Lingen.[198] According to reports by environmental activist groups, the delivery had been due to arrive in Rotterdam but was ultimately delivered to France instead.[199]

Between March 2022 and January 2024, the *Mikhail Dudin* called at the port of Rotterdam at least eight times and at least 12 times at Dunkirk.[200] The vessel has also made four port calls at Vlissingen in the Netherlands and multiple calls at other ports in Europe and the UK.[201] It is unclear what, if anything, was loaded or unloaded during these calls or where the final destination of any deliveries may have been. The *Baltiysky-202* has called at the port of Rotterdam four times since March 2022 and nine times at Dunkirk (as well as one port call at Cherbourg, France).[202]

191. Bundesamt für die Sicherheit der nuklearen Entsorgung (BASE) [Federal Office for the Safety of Nuclear Waste Management], 'Gültige Beförderungsgenehmigungen nach § 4 Atomgesetz bzw. §§ 27 und 29 StrlSchG' ['Valid Transport Permits in Accordance with Section 4 of the Atomic Energy Act or Sections 27 and 29 of the Radiation Protection Law'].
192. *Ibid.*
193. Laka, 'Next Week'; Jordans, 'Germany'.
194. Port call data sourced from S&P Global, accessed 9 January 2024.
195. AFP, 'Russian Uranium Delivery to France "Scandalous" – Greenpeace', *Moscow Times*, 20 March 2023, <https://www.themoscowtimes.com/2023/03/20/russian-uranium-delivery-to-france-scandalous-greenpeace-a80552>, accessed 19 February 2024.
196. Port call data sourced from S&P Global, accessed 19 February 2024.
197. Eurostat, 'EU Trade Since 1988 by HS2-4-6 and CN8'.
198. Jordans, 'Germany'; Rivasi et al., 'Transparency on Uranium Deliveries'; Corbet, 'Russia's Nuclear Trade with Europe Flows Despite Ukraine War'.
199. Violette Bonnebas, 'L'encombante livraison d'uranium russe à l'Europe' ['The Cumbersome Delivery of Russian Uranium to Europe'], *Reporterre*, 14 September 2022, <https://reporterre.net/L-encombrante-livraison-d-uranium-russe-a-l-Europe>, accessed 16 February 2024; Laka, 'Next Week'.
200. Port call data sourced from S&P Global, accessed 19 February 2024.
201. *Ibid.*
202. *Ibid.*

As such, it appears that some of the Russian material entering France, and possibly the Netherlands, may be passing through these countries on its way to Lingen in Germany. However, trade data reviewed for this report does not provide a clear enough picture to confirm how much Russian material is actually arriving at Lingen, whether the value or volume of any such Russian deliveries has changed since the start of 2022, which customers may be benefiting and which routes may be being used.

Unlike in the case of France, the value of Germany's imports of enriched uranium from Russia decreased from 2021 to 2022.[203] One possible explanation may be German reactor closures, at least some of which appear to have used the Lingen facility for the fabrication of their fuel[204] and had historically relied on Russian re-enrichment of reprocessed uranium.[205] In 2022, the value of imports of enriched uranium into Germany increased from the Netherlands and from France; however, imports from these two countries fell to below pre-2022 levels in 2023.[206]

The cause of the increases in 2022 is difficult to ascertain and several explanations are possible. For instance, the increases in import values may be capturing deliveries to the Lingen plant of enriched uranium secured under renewed contracts with or expanded deliveries from Urenco (the Netherlands) or Orano (France) as utilities using the fabrication plant seek alternative, non-Russian, suppliers. Urenco also hosts an enrichment facility at Gronau in Germany; as such, the data may be capturing Urenco's internal company transfers and not material travelling to Lingen for fuel fabrication. Transfers from the Netherlands and France into Germany, including to the Lingen facility, by Orano and Urenco have been recorded in German transport licence documents.[207] As mentioned earlier, Urenco has also concluded an agreement with EDF to enrich reprocessed uranium from French reactors at its Almelo facility, which will first be converted by Rosatom in Russia. As such, from 2024, Dutch trade data is likely to show increased imports of

203. Eurostat, 'EU Trade Since 1988 by HS2-4-6 and CN8'.
204. World Nuclear Association, 'Nuclear Power in Germany', updated April 2023, <https://world-nuclear.org/information-library/country-profiles/countries-g-n/germany.aspx>, accessed 16 February 2024; *Power Engineering*, 'Areva to Supply Fuel Assemblies to Germany Nuclear Power Plant', 15 September 2014, <https://www.power-eng.com/nuclear/areva-to-supply-fuel-assemblies-to-germany-nuclear-power-plant/#gref>, accessed 16 February 2024.
205. IAEA, 'Use of Reprocessed Uranium: Challenges and Options', 2009, pp. 7–8, <https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1411_web.pdf>, accessed 16 February 2024; IAEA, 'Use of Reprocessed Uranium: Proceedings of a Technical Committee Meeting Held in Vienna, August 2007', 2009, <https://www-pub.iaea.org/MTCD/publications/PDF/TE_1630_CD/PDF/IAEA-TECDOC-1630.pdf>, accessed 16 February 2024.
206. Eurostat, 'EU Trade Since 1988 by HS2-4-6 and CN8'. Data for imports from the Netherlands may not be full year data as at the time of writing.
207. Bundesamt für die Sicherheit der nuklearen Entsorgung (BASE) [Federal Office for the Safety of Nuclear Waste Management], 'Gültige Beförderungsgenehmigungen nach § 4 Atomgesetz bzw. §§ 27 und 29 StrlSchG' ['Valid Transport Permits in Accordance with Section 4 of the Atomic Energy Act or Sections 27 and 29 of the Radiation Protection Law'].

reprocessed uranium from Russia (although not enriched uranium), as well as increased exports of enriched uranium from the Netherlands to France for the fabrication of nuclear fuel at Framatome's Romans-sur-Isère facility. The decrease in the value and volume of imports of enriched uranium from France and the Netherlands into Germany in 2023 also raises the possibility that any increase in 2022 deliveries may not be part of a sustained pattern but a one-off.

Furthermore, there are significant discrepancies in Eurostat data between German-reported import data and French- and Dutch-reported data on the export of enriched uranium to Germany, which suggests that the data must be treated with some caution. While data on French exports as well as data on German exports made available through Eurostat both show increases in the value of French exports to Germany (in the case of the German data, French imports into Germany) of enriched uranium in 2022, German import data shows a much lower increase than the French export data. A similar discrepancy can be observed when comparing Eurostat data on German imports with data on Dutch exports, with the former showing markedly lower values of enriched material transferred in 2022 than the latter. Furthermore, in contrast to German import data, Dutch export data shows an overall decrease from 2021 to 2022 in the net weight of enriched uranium exported to Germany. The reason for these discrepancies in the reporting is unclear but may be due to particularities in the recording of transhipment data or delays between the recording of export and import data. Critically, as mentioned earlier, trade data reviewed for this report shows no deliveries of enriched uranium from Russia to the Netherlands since February 2022.[208]

Implications

As with reallocation of Russian supplies across a utility's supply chain, shipment of enriched uranium, Russian or otherwise, through third jurisdictions, if such activity is indeed occurring through France or the Netherlands, is a perfectly permissible activity and does not suggest any wrongdoing. Furthermore, because of the specialised nature of radioactive material transport and the associated logistics and certification required, not all ports are able to receive deliveries of enriched uranium, limiting supply routes. As mentioned above, there is currently also no legal obligation for Germany, France, Spain or any other EU country to terminate existing contracts for Russian supply, prevent the conclusion of new ones, or deny delivery of Russian material to facilities on their territory. As the German government has rightly pointed out in response to questions about deliveries of Russian material to the Lingen facility, there are no legal grounds on which to deny shipments of Russian material to the plant as Russian enriched

208. Eurostat, 'EU Trade Since 1988 by HS2-4-6 and CN8', accessed 10 March 2024.

uranium is not covered by EU sanctions.[209] However, transhipment activity would add further opacity to European nuclear supply chains and may provide additional, less obvious, entry points for Russian material into the European market. It may also allow countries to save face by officially refusing to accept Russian enriched uranium at their ports, all the while continuing to import it through third jurisdictions or accepting non-Russian material from a third country which has been displaced by Russian imports.

Of note is the fact that ANF has applied to German authorities for permission to manufacture VVER fuel assemblies at the Lingen plant.[210] According to reports, fabrication of VVER fuel at the plant may take place in collaboration with Rosatom;[211] however, prospects of German government approval remain unclear.[212] Framatome has signed agreements for VVER fuel supply with Bulgaria[213] and Czechia.[214] It is unclear where fuel assemblies for Bulgarian and Czech VVER reactors will take place and who would be the supplier of enriched uranium for these or any other VVER fuel assemblies. However, should fuel fabrication for VVER reactors take place at the Lingen facility with the use of Rosatom-supplied enriched uranium and in collaboration with Rosatom, this could hardly be considered successful diversification away from Russia for Framatome's VVER fuel customers.

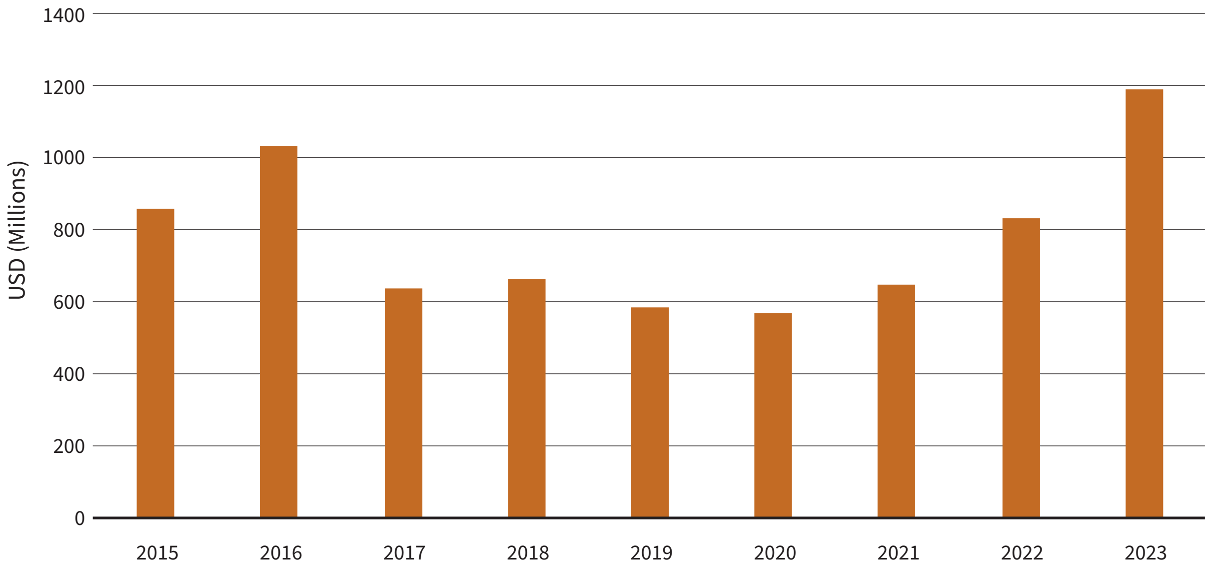
209. Jordans, 'Germany'.
210. Lower Saxony Ministry for the Environment, Energy and Climate Protection, ['Öffentliche Bekanntmachung des Niedersächsischen Ministeriums für Umwelt, Energie und Klimaschutz (MU) Genehmigungsverfahren zur Fertigung hexagonaler Druckwasser-Brennelemente des Typs VVER nach § 7 Atomgesetz (AtG) in der Brennelement-Fertigungsanlage Lingen (BFL) '] ['Public Notice of the Lower Saxony Ministry for the Environment, Energy and Climate Protection (MU)Approval Process for the Production of Hexagonal Pressurized Water Fuel Elements of the VVER Type in Accordance with Section 7 of the Atomic Energy Act (AtG) in the Lingen Fuel Assembly Plant (BFL)'], Ref42-40311/06/12/23/40-0003-006, 20 December 2023, <https://www.umwelt.niedersachsen.de/download/203712>, accessed 17 February 2024.
211. Julia Borutta, 'Frankreich Fördert Indirect Russlands Strategie' ['France is Indirectly Promoting Russia's Strategy'], *tagesschau*, 26 April 2024, <https://www.tagesschau.de/ausland/europa/frankreich-atomkraft-uran-russland-100.html>, accessed 17 February 2024; Alfie Shaw, 'The Future of Nuclear: France's Nuclear Dreams or Nightmares?', *Power Technology*, 5 February 2024, <https://www.power-technology.com/news/france-has-laid-out-ambitious-nuclear-plans-but-challenges-remain/>, accessed 17 February 2024; *Süddeutsche*, 'Warnung vor russischem Einstieg in Brennelementefabrik' ['Warning Over Russian Entry into Fuel Element Facility'], 16 February 2024, <https://www.sueddeutsche.de/wissen/atom-lingen-ems-warnung-vor-russischem-einstieg-in-brennelementefabrik-dpa.urn-newsml-dpa-com-20090101-240216-99-14595>, accessed 17 February 2024; Claus von Hecking, 'Macht sich Putins Atomkonzern im Emsland breit?' ['Is Putin's Nuclear Company Spreading in Emsland?'], *Der Spiegel*, 13 February 2024, <https://www.spiegel.de/wissenschaft/lingen-in-niedersachsen-macht-sich-wladimir-putins-atomkonzern-im-emsland-breit-a-94efc445-ca9f-4f2d-82cf-10fc51f64249>, accessed 17 February 2024.
212. Hecking, 'Macht sich Putins Atomkonzern im Emsland breit?' ['Is Putin's Nuclear Company Spreading in Emsland?'].
213. *World Nuclear News*, 'Kozloduy and Framatome Sign Nuclear Fuel Agreement', 4 January 2023, <https://world-nuclear-news.org/Articles/Kozloduy-and-Framatome-sign-nuclear-fuel-agreement>, accessed 16 February 2024; *Nuclear Engineering International*, 'Bulgaria signs nuclear fuel deal with Framatome', 3 January 2023, <https://www.neimagazine.com/news/newsbulgaria-signs-nuclear-fuel-deal-with-framatome-10486195>, accessed 16 February 2024.
214. *Nuclear Engineering International*, 'ČEZ Selects Westinghouse and Framatome to Supply Fuel to Temelin', 14 April 2022, <https://www.neimagazine.com/news/newsez-selects-westinghouse-and-framatome-to-supply-fuel-to-temelin-9627715>, accessed 16 February 2024.

V. Case Study: US

In the trade data reviewed for this report, the US stands out conspicuously as the largest importer of Russian material, both prior to Moscow's invasion of Ukraine and since. Figure 14 shows the value of US imports of enriched uranium from Russia since 2015; Figure 15 shows the weight of imports in tonnes. As mentioned earlier, data on US imports of Russian enriched uranium requires caveating. Some US customers purchase only SWU from Russia, meaning that some natural (unenriched) uranium is returned to Russia as 'returned feed', while other customers purchase both the feed and the services from Russia. As such, the values (and volume) of US imports of enriched uranium are not necessarily representative of the values (or volume) of Russian materials and services that are actually consumed by US utilities.[215] This is in addition to any nuclear fuel assemblies that may be manufactured in the US and exported for use by utilities abroad. US-based think tank *Third Way*, citing data from the US Energy Information Administration (EIA) and other sources, has estimated that in 2022 US utilities purchased $168 million in processed natural uranium and $344 million in enrichment services.[216] As noted earlier, the EIA has reported that 24% of the SWU delivered to US utilities in 2022 came from Russia.[217]

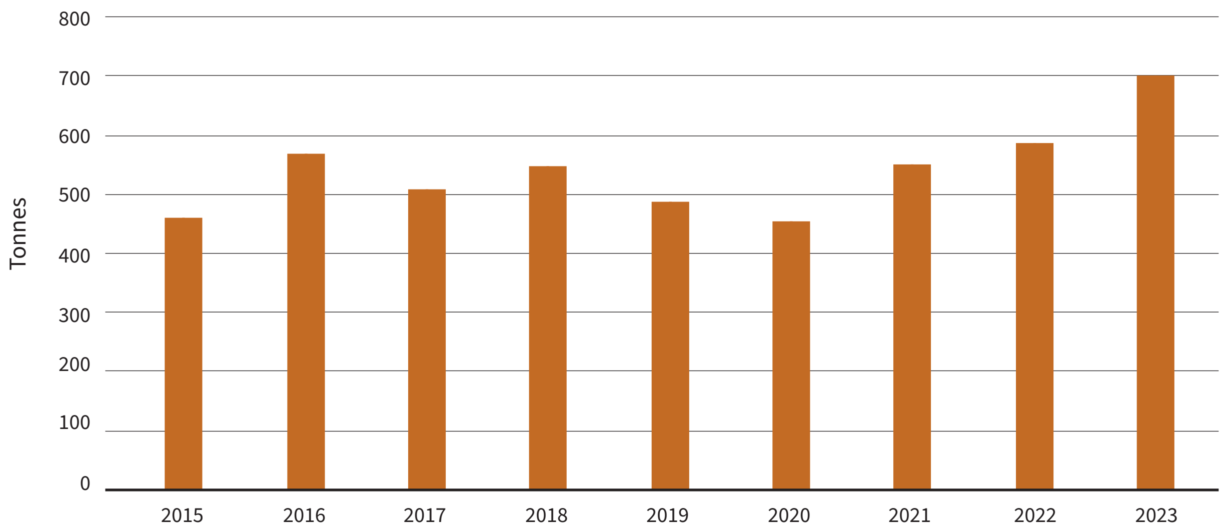
215. Price, Norman and Ahn, 'Western Reliance on Russian Fuel: A Dangerous Game'.
216. *Ibid*.
217. See US Energy Information Administration, '2022 Uranium Marketing Annual Report', June 2023, <https://www.eia.gov/uranium/marketing/pdf/2022%20UMAR.pdf>, accessed 1 November 2023.

Figure 14: US Imports from Russia under HS Code 2844200020, 2015–23 (USD)



Source: Data sourced from the US Census Bureau (HS code 2844200020), accessed 15 February 2024.

Figure 15: US Imports from Russia under HS Code 2844200020, 2015–23 (Tonnes)



Source: Data sourced from the US Census Bureau (HS code 2844200020), accessed 15 February 2024.

History of US Dependency on Russian Enriched Uranium and Efforts to Limit Supply

US reliance on Russian enriched uranium is in part a legacy of the 'Megatons to Megawatts' initiative, which ran from 1995 to 2013 and saw the conversion of 500 metric tonnes of highly enriched uranium from dismantled Russian nuclear weapons into over 14,000 metric tonnes of low enriched uranium for the generation of nuclear energy in the US, accounting for 10% of US electricity production at the time.[218] The agreement was executed by the United States Enrichment Corporation (USEC) and TENEX, with the former accepting low enriched uranium, chemically processed and diluted by TENEX from highly enriched uranium withdrawn from Russian nuclear weapons, and selling it on to utility customers.[219] As a result of this significant Russian supply of enriched uranium into the US nuclear energy supply chain, as well as the longstanding low prices of Russian material, there was little ability or need for domestic enrichment production to compete with Russian supply and the US enrichment industry atrophied.

However, Russian exports of enriched uranium to Western countries, including the US, pre-dates the 'Megatons to Megawatts' initiative,[220] as do concerns over excessive Russian access to the US enriched uranium market and efforts to limit it. In an effort to prevent an influx of cheap Russian enrichment services into the US following the collapse of the Soviet Union, the US nuclear energy industry instigated an anti-dumping petition in 1991.[221] The petition eventually resulted in the adoption in 1992 of the 'Russian Suspension Agreement' (RSA) between the US Department of Commerce and Russia's Ministry of Atomic Energy (succeeded by Rosatom). The RSA, which was amended in 2008 and 2020, introduced formal quotas on the import of Russian enriched uranium into the US.[222]

At present, the only commercial enrichment facility operating in the US is a plant in Eunice, New Mexico owned by Urenco, a joint venture between the UK,

218. Centrus, 'Megatons to Megawatts', <https://www.centrusenergy.com/who-we-are/history/megatons-to-megawatts/>, accessed 17 February 2024.
219. *Ibid*.
220. Oleg Bukharin, 'Understanding Russia's Uranium Enrichment Complex', *Science and Global Security* (Vol. 12, No. 193–218, 2004), p. 200.
221. US Senate, 'Russian Suspension Agreement', hearing before the Committee on Energy and Natural Resources, 110th Congress, Second Session, Senate Hearing 110-422, 5 March 2008, <https://www.govinfo.gov/content/pkg/CHRG-110shrg43015/html/CHRG-110shrg43015.htm>, accessed 17 February 2024.
222. See International Trade Administration, '2020 Amendment to the Agreement Suspending the Antidumping Investigation on Uranium from the Russian Federation', 9 October 2020, section IV.B.1, <https://www.federalregister.gov/documents/2020/10/09/2020-22431/2020-amendment-to-the-agreement-suspending-the-antidumping-investigation-on-uranium-from-the-russian>, accessed 16 February 2024.

the Netherlands and Germany. The company recently announced an expansion of its capacity at the Eunice plant by 15%, with additional enrichment commencing in 2025 and eventually providing an additional 700 tonnes of SWU per year.[223] Several US companies, including Global Laser Enrichment (GLE)[224] LLC and Centrus,[225] also offer enrichment technology and may look to enter (or re-enter) the commercial enrichment market. In October 2023, Centrus launched operations at its enrichment facility in Piketon, Ohio for the enrichment of high-assay low-enriched uranium (HALEU).[226] Commercial US reactors do not currently take HALEU but many advanced reactor models will require HALEU fuel.

Efforts to Diversify Away from Russia and Related Challenges

As discussed earlier, there are some ongoing efforts in the US to diversify away from Russian enriched uranium supply. In December 2023, the US House of Representatives passed a bill that would prohibit the import into the US of ‘unirradiated low-enriched uranium that is produced in the Russian Federation or by a Russian entity’ through 2040.[227] The bill, which at the time of writing was awaiting debate by the Senate, would allow the secretary of energy, in consultation with the secretary of state and the secretary of commerce, to issue waivers for imports of Russian enriched uranium in instances where alternative supply is not available or if such imports would be in the national interest. RSA quotas on imports of any Russian material would still apply and any waivers would be terminated by 1 January 2028.[228] A similar bill was introduced in the Senate in March 2023.[229]

As noted earlier, concerns over the availability of alternative, non-Russian, enriched uranium supply for US utilities have been raised by a number of experts.

223. *World Nuclear News*, ‘Urenco to Expand US Enrichment Plant’, 7 July 2023, <https://world-nuclear-news.org/Articles/Urenco-to-expand-US-enrichment-plant>, accessed 17 February 2024.
224. Global Laser Enrichment, ‘Business’, <https://www.gle-us.com/business/>, accessed 22 February 2024; *Nuclear Newswire*, ‘DOE Rolls out Simplified HALEU Enrichment RFP, Opens Door to LEU from Allies’, 10 January 2024, <https://www.ans.org/news/article-5675/doe-rolls-out-simplified-haleu-enrichment-rfp-opens-door-to-leu-from-allies/>, accessed XXX.
225. Centrus is the successor of the United States Enrichment Corporation (USEC). See US Government Accountability Office, ‘Department of Energy: Transactions Involving USEC Inc. Since 1998’, GAO-15-730, 10 September 2015.
226. Centrus, ‘Centrus Begins Enrichment Operations in Ohio’, 11 October 2023, <https://www.centrusenergy.com/news/centrus-begins-enrichment-operations-in-ohio/>, accessed 17 February 2024. HALEU fuel is enriched to a higher percentage of U-235 (5% to 20%) than LEU. It is used in research reactors. Until the launch of the Centrus facility, Rosatom was the only supplier globally of HALEU fuel.
227. US Congress, ‘H.R.1042 – Prohibiting Russian Uranium Imports Act’.
228. *Ibid.*, section 2, para. 2.
229. Congress, ‘All Information (Except Text) for S.763 – Reduce Russian Uranium Imports Act’, 118th Congress, <https://www.congress.gov/bill/118th-congress/senate-bill/763/all-info>, accessed 17 February 2024.

However, the extent of the challenge that US utilities may face in replacing Russian material with non-Russian supply in the short, medium and long term is the subject of some debate and likely varies between utilities.[230] In comments to media, Urenco leadership has stated that ‘it has enough capacity to replace Russian supplies if Washington bans imports from the country’ and ‘there are no constraints in the short term in replacing Russian materials in the western world’.[231] Some analysts have nevertheless pointed to likely shortages in supply for US utilities should imports of Russian uranium stop, although they have noted that assessing the full impact of a ban on Russian imports is challenging as various utilities are likely to have different dependencies on Russian supply and varying nuclear fuel reserves.[232]

With time, individual utilities and the US nuclear energy sector more broadly will likely become more prepared to withstand the impact of a ban on imports of Russian uranium into the US. In December 2023, the governments of the US, Canada, France, Japan and the UK announced a commitment ‘to pursue at least USD $4.2 billion in government-led and private investment in our five nations’ collective enrichment and conversion capacity over the next three years’.[233] In February 2024, as part of the Emergency National Security Supplemental Appropriations Act, the US Senate approved $2.7 billion in funding to expand the production in the US of LEU and HALEU.[234] The Nuclear Energy Institute – which is the ‘policy organisation of the nuclear technologies industry’ in the US[235] – also supports a ban on imports of Russian uranium, with its leadership noting that: ‘The U.S. commercial nuclear industry is committed to transitioning to a secure domestic nuclear fuel supply, and this bill is an important step toward that goal’.[236]

230. Yanliang Pan, ‘Diversification from Russian Nuclear Fuel Requires Market-Oriented Solutions’, *Bulletin of the Atomic Scientists*, 15 January 2024.; *Bellona*, ‘US Struggles to Free Itself from Russian Enriched Uranium Supplies’, 8 January 2024, <https://bellona.org/news/nuclear-issues/2024-01-us-struggles-to-free-itself-from-russian-enriched-uranium-supplies>, accessed 17 February 2024; Ernest Scheyder and Trevor Hunnicutt, ‘Exclusive: U.S. Utilities Push White House Not to Sanction Russian Uranium’, *Reuters*, 2 March 2022; Price, Norman and Ahn, ‘Western Reliance on Russian Fuel: A Dangerous Game’.
231. Jamie Smyth, ‘US Ban on Russian Uranium Would Boost Western Industry, Says Urenco’, *Financial Times*, 11 February 2024.
232. Scheyder and Hunnicutt, ‘Western Reliance on Russian Fuel’.
233. US Department of Energy, ‘At COP28, U.S., Canada, France, Japan, and UK Announce Plans to Mobilize $4.2 Billion for Reliable Global Nuclear Energy Supply Chain’, 7 December 2023, <https://www.energy.gov/articles/cop28-us-canada-france-japan-and-uk-announce-plans-mobilize-42-billion-reliable-global>, accessed 17 February 2024.
234. Brian Martucci, ‘Domestic uranium enrichment gets $2.7B boost from US Senate’, UtilityDive, 16 February 2024, <https://www.utilitydive.com/news/senate-domestic-uranium-enrichment-nuclear-haleu-advance-reactors-smr/707794/>, accessed 8 March 2024
235. NEI, ‘About NEI’, <https://www.nei.org/about-nei>, accessed 17 February 2024.
236. NEI, ‘NEI CEO Maria Korsnick on the Prohibiting Russian Uranium Imports Act’, 8 December 2023, <https://www.nei.org/news/2023/nei-maria-korsnick-prohibit-russian-uranium-hr1042>, accessed 17 February 2024.

However, some have raised concerns. Centrus, which acts as a broker of enriched uranium (sourcing foreign SWU and supplying SWU and uranium to US and international customers),[237] has raised concerns over potential risks to its supply that may result from restrictions on trade in uranium with Russia.[238] Such restrictions may come in the form of US sanctions on Russian enriched uranium imports, refusal by its US and/or foreign customers to accept Russian SWU, or a decision by Russia to stop exports of uranium to the US.[239] According to its 2023 annual report to the US Securities and Exchange Commission, TENEX is Centrus's largest supplier of SWU, followed by French company Orano.[240] Centrus has commitments with TENEX for the supply of Russian enrichment services (in the form of SWU) to 2028.[241] Despite having access to alternative sources of enriched uranium, in its 2023 report Centrus notes that, short of securing a waiver from the secretary of energy, the proposed ban would preclude the company from importing Russian LEU into the US[242] and that its alternative supply would not be sufficient to replace the Russian LEU it is currently permitted to import under the RSA.[243]

Furthermore, the proposed ban on imports into the US of Russian enriched uranium could mean that a greater proportion of the Russian material that Centrus is committed to purchasing from TENEX may have to be directed to non-US utilities. Due to the RSA quotas, not all of the material that Centrus purchases from TENEX can be sold to US utilities. In its 2023 report, the company notes:

237. Centrus, 'Centrus Energy Corp: Poised for Growth', 16 September 2021, pp. 7–8, <https://static.seekingalpha.com/uploads/sa_presentations/645/74645/original.pdf>, accessed 17 February 2024. The natural uranium and SWU (or enrichment services) that make up LEU may be sold separately. See Centrus, 'Centrus Energy Corp: Poised for Growth', p. 6. Under its supply agreement with TENEX, Centrus only purchases the SWU contained in the LEU and delivers the corresponding amount of natural uranium to TENEX. See Centrus, 'USEC's Supply Agreement with TENEX Takes Effect', 21 December 2011, <https://investors.centrusenergy.com/news-releases/news-release-details/usecs-supply-agreement-tenex-takes-effect>, accessed 17 February 2024; World Nuclear Association, 'US Nuclear Fuel Cycle', updated October 2023, <https://investors.centrusenergy.com/news-releases/news-release-details/usecs-supply-agreement-tenex-takes-effect>, accessed 17 February 2024.
238. US Securities and Exchange Commission, 'Centrus, Form 10-K', pp. 6, 11, 15, 20, 32.
239. *Ibid*.
240. *Ibid.*, p. 14.
241. Andrea Jennetta, 'Proposed Deal Cuts Average US Utility Quota of Russian Uranium to 17% from 20%', S&P Global Commodity Insights, 14 September 2020, <https://www.spglobal.com/commodityinsights/es/market-insights/latest-news/electric-power/091420-proposed-deal-cuts-average-us-utility-quota-of-russian-uranium-to-17-from-20>, accessed 17 February 2024; US Securities and Exchange Commission, 'Centrus Energy Corp., Form 10-Q', p. 25. Under its supply agreement with TENEX, Centrus only purchases the SWU contained in the LEU and delivers the corresponding amount of natural uranium to TENEX. See US Securities and Exchange Commission, 'Centrus, Form 10-K'; World Nuclear Association, 'US Nuclear Fuel Cycle'.
242. US Securities and Exchange Commission, 'Centrus, Form 10-K', p. 20.
243. *Ibid.*, pp. 15, 30, 34.

> We will need to make new sales to place all the Russian LEU we must order to meet our SWU purchase obligations to TENEX. In addition, because the [RSA] quotas do not cover all of the LEU that we must order to fulfill our purchase obligations under the TENEX Supply Contract, we expect that a portion of the Russian LEU that we order during the term of the TENEX Supply Contract will need to be delivered to customers that will use it in overseas reactors.[244]

Centrus also noted prior to 2022 that the company expected to have to deliver some of the LEU it would source from TENEX during the term of its supply agreement with the Russian company to customers for use in overseas reactors.[245] Yet, should a potential ban on imports of Russian material into the US be introduced, and if Centrus commitments to purchase Russian SWU remain unaffected by the ban or other factors, this raises questions over whether a greater fraction of the Russian SWU that Centrus is committed to purchasing from TENEX would need to get sold to customers elsewhere and, if so, how much and to whom.

Should new customers need to be found for Russian material no longer accepted in the US, these are likely to be companies and countries that would probably have purchased Russian SWU directly from Russia anyway. As such, any redirection of Russian SWU from the US to alternative customers following a US ban would not necessarily increase Rosatom's footprint in global supply chains. However, it would also tamper the impact of the US ban on overall Russian access to global enrichment supply chains – simply shifting Russian supply elsewhere. Furthermore, should material that is no longer accepted in the US be sold to China or another country that is still willing to take Russian SWU and has a domestic enrichment capacity, the supply could in theory be used in a displacement strategy in efforts to circumvent existing restrictions on the import of Russian material into the US.

Of course, alternative customers, other than China or other countries that could adopt a displacement strategy, could potentially be found for the excess Russian material, for instance, South Korea, the UAE or some Latin American countries with operating nuclear reactors. However, the willingness of utilities in these countries to purchase enriched uranium no longer accepted in the US would depend on their readiness to accept Russian supply as well as any existing contracts they may have for alternative enriched uranium and enrichment services. These two factors may therefore limit opportunities for – and likelihood of – reallocation of Russian supply to new non-US customers.

244. *Ibid.*, p. 9.
245. *Ibid.*, pp. 9–10.

Furthermore, a ban on imports of enriched uranium into the US may impact on businesses' commitments to source SWU from TENEX. The introduction of a ban might allow companies the opportunity to terminate supply contracts with Russia on the grounds that the US has introduced restriction on such trade, depending on the nature of the restrictions put in place. However, this would not resolve the issue of any supply challenges that may result for US nuclear industry from a loss of access to Russian enriched uranium and enrichment services. As such, seeking a way out of supply contracts may therefore not be the preferred option for TENEX customers. In fact, US companies are likely to seek waivers to allow them to continue purchasing and importing Russian LEU into the US.[246] As such, reallocation of Russian supply from US utilities to utilities in other countries, as described above, may not be necessary. However, the granting of waivers – while maybe necessary to ensure continued security of supply for some in the US nuclear industry – would in itself diminish the short-term impact of efforts to limit Russian access to US nuclear supply chains.

As with some of the adaptations described in the case studies on France and Germany, a ban on the import of Russian uranium into the US may cause some challenges for industry – either as a result of contractual obligations or concerns over security of supply. A ban is therefore likely to result in adaptations which may temper the ban's ability to reduce Rosatom's revenue generation and Russia's presence in global and Western nuclear supply chains, at least in the short term. This is not a reason to forego pursuing such restrictions on imports of Russian enriched uranium into the US, but rather a reminder of the need for a considered approach to the institution of such restrictions – one which takes into account both political objectives and the practicalities faced by industry. To help incentivise and facilitate industry behaviour which aligns with political objectives, the articulation and application of a ban must rely on thorough consultation with customers and suppliers in the US's nuclear energy sector. It needs to be accompanied by the development of domestic and partner enrichment capacity to ensure a sustainable transition away from Russian supply, and must seek to identify and mitigate the ways in which Russia may continue to access global nuclear fuel supply chains despite the introduction of restrictions.

246. *Ibid.*, p. 21.

Conclusion and Policy Recommendations

This report has outlined four case studies that demonstrate the scale of Western and global dependencies on Russian enriched uranium supplies, the economic and contractual challenges that stand in the way of ending these dependencies, the adaptations to efforts by some Western countries and companies to cut Russia out of their nuclear fuel supply chains, and the likely limitations of efforts to cut Russia out of global nuclear fuel supply chains. In particular, Russia may rely on countries still willing or obligated to accept its enriched uranium to implement displacement strategies or simply serve as alternative entry points into markets from which it is being squeezed out. Such strategies simply push the issue of Russian dependency to a different part of the supply chain but do little to ultimately squeeze Rosatom's bottom line and, in some instances, to decrease Western dependencies on Russian enriched uranium.

Of particular concern are trends in trade data that could point to the adoption of a displacement strategy – as may be the case with China. As Beijing may be seeking to increase its role as an exporter of enriched uranium to global markets, including to the US, it could rely on increased imports into China of Russian enriched uranium to facilitate this expansion. An increase in the value of Russian enriched uranium imports by China since 2022 has been accompanied by an increase in the value of Chinese exports of enriched uranium in 2022 and 2023, driven primarily by deliveries to the US. However, publicly available data reviewed for this report is insufficient to conclude definitively whether displacement is actually occurring.

In the case of Europe, increased imports of Russian enriched uranium into France and continued deliveries of Russian material to Germany also raise questions over the effectiveness of unilateral efforts by other players in the European nuclear fuel supply chain to cut dependencies on Russia. While it is difficult to ascertain with certainty the drivers of recent increased imports of Russian enriched uranium into France or to confirm whether and how much Russian enriched uranium may be arriving in Germany through third countries, the willingness of certain countries to continue accepting Russian material may continue to grant Rosatom alternative entry points into the European nuclear fuel supply chain. Should Russian material delivered to Germany be integrated into the future fabrication of VVER nuclear fuel assemblies in cooperation with Rosatom, this would also be counterproductive to efforts by Eastern European VVER operators to diversify away from Russian supplies.

The report also briefly examined US dependencies on Russian enriched uranium supplies, as the US remains the most important importer of Russian enriched uranium. While a prohibition on imports of Russian enriched uranium into the US may cut Russia out of US supply chains, the extent to which such a ban may cause supply challenges for US nuclear fuel supply chains remains the subject of some debate. Furthermore, some of the Russian material that may no longer be accepted in the US may need to be redirected to other customers around the world that are still willing to accept Russian material. While this is unlikely to have a significant impact on the presence of Russian enriched uranium on global markets, as the excess supply is likely to be redirected to countries willing to do business with Russia and which would have probably purchased Russian supply anyway, it highlights again the challenges and limitations inherent to unilateral efforts to cut Russia out of global nuclear fuel supply chains. The case studies presented in this report – including that of the US – also point to the need for close engagement with the nuclear industry to ensure that restrictions on trade in uranium and enrichment services with Russia are developed and implemented in a manner that incentivises and facilitates maximum industry buy-in on the objectives of such restrictions – in this case, sustainable diversification away from Russian enriched uranium supply in Western nuclear fuel supply chains.

The limitations of current restrictions on purchases of Russian enriched uranium and enrichment services described in this report should not serve to dissuade the further introduction of such restrictions. Not only is diversification away from Russia's nuclear industry important for ensuring nuclear energy security in the US and Europe, it is also critical to avoiding the political and moral dissonance inherent in claims to support Ukraine's fight against Russian aggression while continuing to engage in business with a strategically significant Russian state-enterprise. Instead, they should serve as a further reminder to ensure that any future restrictions aim for a multilateral approach, identify and address likely opportunities for circumvention through countries still willing to do business with Russia, are introduced in close consultation with industry and are accompanied by measures that incentivise and facilitate maximum industry buy-in and compliance. The six recommendations outlined below are aimed at facilitating diversification and preventing circumvention, both in instances where continued intake of Russian material is contractually obligated and when it may be being used as part of a deliberate strategy to gain greater market access by competing suppliers.

Recommendation 1: Invest in the further expansion of enrichment capacity in partner countries. While additional capacity from Urenco and Orano is due to come online in 2025 and 2028 respectively, the US, the UK, European and other Western-allied governments must invest in additional enrichment capacity to ensure long-term security of supply and facilitate a sustainable diversification away from Russian supply while limiting negative impacts on Western nuclear industry and energy production. This could include investments in the development of new enrichment technologies that may be easier and quicker to scale up and would allow for the entry into the market of new enrichment service providers. Recent US and UK efforts to support domestic production of HALEU fuel should be commended to this end.[247] Making available competitive government incentives for enrichment service providers to invest in expanded enrichment capacity, as well as incentives for utilities (that is, the customers) to provide guarantees of sustained demand in the form of long-term contracts will also help encourage further investment by enrichers into additional capacity.

Recommendation 2: Once alternative supply can be assured, implement multilateral restrictions on imports of Russian enriched uranium. To increase the effectiveness and limit the negative impacts of any sanctions or restrictions on the Western nuclear sector, any initiatives at diversification should be undertaken only following extensive consultations with relevant actors within the nuclear energy industry and only once sufficient alternative enriched uranium supply has been secured, either through expanded Western and partner enrichment capacity or through enriched uranium inventories. Every effort must also be made to ensure a unanimous approach to sanctions across US, European and other allied markets. The adaptation activities outlined in this report rely on Russia's ability to access some markets while others adopt diversification policies. As such, unilateral efforts by individual countries or companies to cut Russia out of the West's nuclear supply chain will be vulnerable to circumvention.

Recommendation 3: Establish methods for enforcing the 'displacement swap' prohibition under the RSA. The US Department of Commerce, as the authority responsible for monitoring possible circumvention of the RSA provisions, should work with other departments in US government as well as with industry to identify methods for enforcing the prohibition of displacement swaps. To demonstrate that enriched uranium imported into the US was not the result of displacement using Russian material, importers could, for instance, be asked to demonstrate the allocation to various customers of enriched uranium imports into their country or show proof of increases in domestic enrichment capacity to meet demand for exports to the US. Considering the commercial sensitivity of some of this

247. US Department of Energy, 'DOE Announces Next Steps to Build Domestic Uranium Supply for Advanced Nuclear Reactors as Part of President Biden's Investing in America Agenda', 9 January 2024, <https://www.energy.gov/articles/doe-announces-next-steps-build-domestic-uranium-supply-advanced-nuclear-reactors-part>, accessed 18 February 2024; Department for Energy Security and Net Zero, 'UK Invests in High-Tech Nuclear Fuel to Push Putin out of Global Energy Market', 7 January 2024, <https://www.gov.uk/government/news/uk-invests-in-high-tech-nuclear-fuel-to-push-putin-out-of-global-energy-market>, accessed 18 February 2024.

information, government authorities in the country of export could be asked to collate this information and provide assurances on behalf of industry.

Recommendation 4: Adopt prohibitions on displacement swaps alongside other national or multilateral (EU) bans on imports of Russian enriched uranium. Should individual countries or the EU decide to adopt a ban on Russian enriched uranium, they should include prohibitions of displacement swaps, similar to those included in the RSA. Such prohibitions, if enforced as per Recommendation 3, will help close potential loopholes that Russia could exploit to maintain indirect access to markets that are trying to cut Russia out, undermining efforts to squeeze Rosatom's bottom line.

Recommendation 5: Examine and work to address dependencies on Russia across the rest of the nuclear fuel cycle. Uranium enrichment is not the only aspect of the global nuclear fuel supply chain where dependencies on Russia are critical. Rosatom also plays a major role in global NPP construction, uranium conversion and spent fuel management. Cutting dependencies on Russia in one part of the supply chain, while a good start, will not have as great an effect on Rosatom's revenue generation as ensuring that the West and partner countries, as well as undecided customers, have alternative suppliers across the nuclear fuel cycle. Russia and China have invested extensively in their civil nuclear sectors as strategic industries, having understood the long-term dependencies they can create in the countries to which they sell their technology and services. While the economies and the government–industry relations in Russia and China differ significantly from those in Western and partner countries, supporting the development of domestic nuclear industries and their ability to compete internationally should be a priority.

Recommendation 6: Avoid trading dependencies on Russia for dependencies on China. As companies and governments seek to diversify away from Russia in their sourcing of enriched uranium supplies and across the nuclear fuel cycle, China may look to take advantage of openings to present itself as an alternative supplier. It is imperative that Western and partner governments focus on investment in domestic capacity and the capacity of partner countries, not on sourcing services and technology from China. Not only may increased Chinese exports of enriched uranium be backed by increased imports of Russian material (undermining the impact of Western and partner sanctions on the Russian nuclear industry), but allowing Chinese companies to play an important role in nuclear supply chains runs the risk of creating problematic dependencies not dissimilar to those that currently exist on Russia.

About the Author

Darya Dolzikova is a Research Fellow with RUSI's Proliferation and Nuclear Policy programme. Her work focuses on understanding and countering the proliferation of nuclear weapons technology and strategic aspects of civil nuclear technology. She has conducted research on the Iranian nuclear programme and related diplomacy, Iranian and North Korean proliferation-related sanctions evasion, proliferation-related sanctions evasion, nuclear safety in Ukraine, the role of Russia in global civil nuclear supply chains, as well as other issues concerning nuclear technology and proliferation. Prior to joining RUSI, Darya served as the manager of government relations and policy development at Canada's national aerospace industry association. She holds an MA in Security Studies from Georgetown University and a BSocSc in International Studies and Modern Languages from the University of Ottawa.