Royal United Services Institute
for Defence and Security Studies

# Atoms for Sale: Developments in Russian Nuclear Energy Exports

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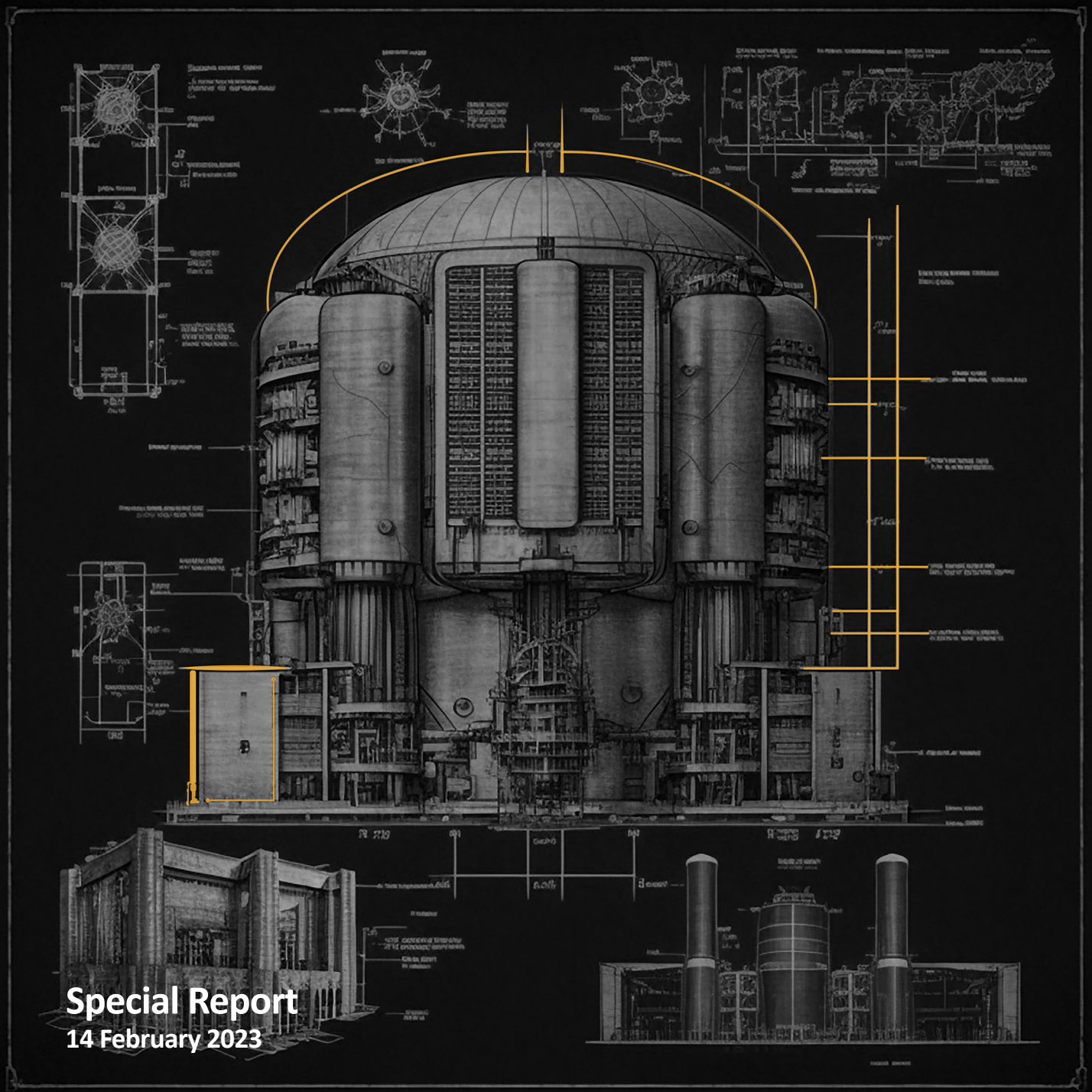

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# Executive Summary

Since Russia's full-scale invasion of Ukraine in February 2022, Western sanctions on the Russian economy have been expanding. Nonetheless, Russia's nuclear energy exports have not come under economic restrictions. The Rosatom State Nuclear Energy Corporation (Rosatom), which has a monopoly over the Russian nuclear industry, has continued exports of nuclear fuel and other goods relevant to the nuclear energy sector. According to Russian customs data, sourced through a third-party commercial trade data provider, Russia has exported just over $1 billion-worth of nuclear energy-related goods and materials since the start of the war in Ukraine.

Some customers that have historically relied on Russian nuclear energy exports – like Ukraine, Czechia and Bulgaria – have sought to diversify away from Russian supplies. However, contractual obligations and technical challenges make diversification slow and complicated – although not impossible. Additionally, generous Russian financing arrangements make Russia an attractive supplier among its other competitors in the nuclear energy sector.

The trade data reviewed by the author shows a drop-off in Russian nuclear exports to some countries in Eastern and Western Europe since the invasion of Ukraine, but also a significant rise in the overall value of Russian nuclear energy exports in 2022. Significant increases in value can be observed in Russian nuclear energy-related exports to China, which appear to be the result of Russian exports of fuel for the Chinese CFR-600 reactor at the Xiapu nuclear power plant (NPP). In a year-on-year comparison between 2021–22, the dataset also shows increases in overall Russian nuclear exports to Hungary, Turkey and India. And while the dataset studied by the author does not span a long enough time frame to draw definitive conclusions on long-term trends in Russian nuclear energy exports, or how Russia's invasion of Ukraine might impact these trends, it does point to the importance for the Russian nuclear energy sector of markets outside North America and traditional European customers.

The primacy among Russian nuclear energy customers of countries that have proven reluctant to support Western sanctions on Russia so far suggests that any EU and US sanctions on Rosatom and Russian nuclear trade need to be coupled with broader diplomatic efforts if they are to be effective in significantly curtailing Russian economic gains from its nuclear energy exports. Focusing efforts on bringing countries like Turkey and Hungary on board with increasing the political and economic pressure on Moscow – including through the provision of viable and sustainable alternatives to Russian nuclear energy-related supplies – will be key. Securing China's cooperation will undoubtedly prove more difficult. As it has in other contexts, Russia will find ways to take advantage of these divisions to its own benefit.

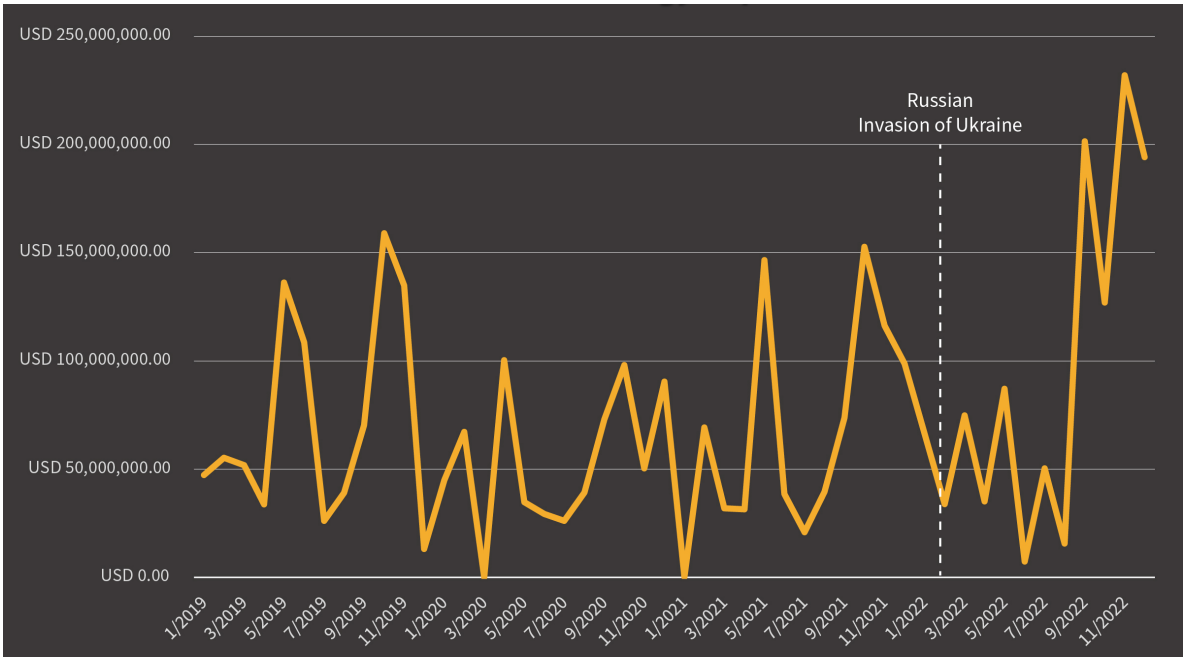
## Pass Go and Collect $1 Billion

Since Russia's February 2022 full-scale invasion of Ukraine, the UK, the US, the EU and others have introduced several rounds of Russia-focused sanctions packages. These measures have targeted both Russian individuals and certain economic sectors in an effort to curb the flow of funds that are enabling Moscow's war effort and enriching those in Russia perpetrating and supporting it. Western sanctions have targeted Russian energy exports as a major contributor to the Russian economy. However, one component of the Russian energy market – the nuclear energy sector – has been left unsanctioned. This omission of Russian nuclear exports from Western sanctions appears to be – at least in part – the result of persistent dependencies in some countries on Russian nuclear energy fuel and reactor technology.[1]

Russian customs data, sourced though a third-party commercial trade data provider and reviewed by the author in collaboration with Bloomberg shows that, between March and December 2022, Russia exported just over $1 billion-worth of materials and technology of relevance to the nuclear energy sector.[2] This trade included exports to members of NATO and the EU. In fact, not only has the value of Russian nuclear-related exports not shrunk since February 2022, the data reviewed by the author suggests that it may be expanding, with a handful of loyal customers still eager to do business with Russia's nuclear sector.

1. Sigrid Melchior et al., 'Russia's Multi-million Euro Nuclear Exports Untouched by EU Sanctions', *Investigate Europe,* 7 October 2022, <https://www.investigate-europe.eu/en/2022/russias-multi-million-euro-nuclear-exports-untouched-by-eu-sanctions/#:~:text=The%20dependency%20on%20Russian%20nuclear,fuel%20elements%20provided%20by%20Rosatom>, accessed 1 February 2023; Nuclear Engineering International, 'Hungary will Veto any EU Sanctions against Russia's Nuclear Sector', 31 January 2023, <https://www.neimagazine.com/news/newshungary-will-veto-any-eu-sanctions-against-russias-nuclear-sector-10558203>, accessed 8 February 2023.
2. Trade data supplied by third-party commercial provider.

**Figure 1:** Monthly Transaction Values of Russian Nuclear Energy Exports Over Time




*Source: Russian customs data obtained through a third-party commercial provider, RUSI; graphic by RUSI OSIA*

*Disclaimer: See information on the limitations of this data in the section titled 'Notes on Methodology and Data'.*

The Russian nuclear energy sector is monopolised by Rosatom State Nuclear Energy Corporation (better known as Rosatom) and its many subsidiaries. The company also appears to have been directly involved in supporting Russia's invasion of Ukraine. Rosatom staff are present at Ukraine's Zaporizhzhya NPP, on the front line of Russia's invasion. According to Ukrainian reports, Rosatom has taken over the management of the plant[3] and have been pressuring the NPP's Ukrainian staff to sign employment contracts with the Russian company.[4] A recent report by the *Washington Post* also detailed apparent offers by Rosatom to provide components, technology and raw materials to the Russian military and Russian weapons manufacturers.[5] However, Rosatom has

3. International Atomic Energy Agency, 'Update 19 – IAEA Director General Statement on Situation in Ukraine', 12 March 2022, <https://www.iaea.org/newscenter/pressreleases/update-19-iaea-director-general-statement-on-situation-in-ukraine>, accessed 6 February 2023.
4. *Interfax-Ukraine*, 'Energoatom Head Urges ZNPP Employees not to Sign Contracts for Work at Rosatom', 11 October 2022, <https://en.interfax.com.ua/news/economic/864745.html>, accessed 6 February 2023.
5. Catherine Belton, 'Russia's State Nuclear Company Aids War Effort, Leading to Calls for Sanctions', *Washington Post,* 20 January 2023.

not come under Western sanctions, despite calls from Ukrainian officials[6] as well as Members of the European Parliament[7] to impose restrictions on Russian nuclear exports. Hungary – which has insisted on maintaining its nuclear cooperation with Russia – has stated that it would veto any such attempt from the EU.[8]

This report presents data and analysis on continued Russian nuclear energy exports since the invasion of Ukraine and highlights some of the difficulties countries may face in diversifying away from Russian supplies. At the same time, it points to the importance of customers outside of Europe and North America for the Russian nuclear energy sector and concludes that Western sanctions on Russian nuclear exports must be coupled with broader diplomatic efforts to curtail dependencies on Russian nuclear energy technology.

## Notes on Methodology and Data

The data presented and analysed in this report was sourced from a third-party commercial trade data provider and captures Russian exports between January 2019 and December 2022.[9] The data includes goods that fall under five nuclear-relevant HS codes – numeric identifiers used to internationally standardise the classifications of traded goods. The HS codes, their associated goods and notes on their relevance to the civilian nuclear fuel cycle are included in Table 1.

As with all customs information datasets, the dataset reviewed by the author in this report is incomplete and may include some inaccuracies – including missing transactions or duplicates of transactions. The dataset also clearly excludes certain export destinations – likely because they do not make their customs data publicly available. For instance, Russian nuclear exports to Iran were not captured in the dataset. The author tried her best to validate the available data by comparing it against another commercial trade dataset from a different third-party provider. Some discrepancies are inevitable when comparing any large datasets and were indeed identified when comparing this dataset against a second one. Furthermore, the availability of data over time was inconsistent across the datasets; data was not available in the second dataset past June 2022, meaning the original dataset could not be validated past that date. However, despite these discrepancies, the alternative dataset does not contradict the analysis presented in this report and, within the timeframe of the data available in the second dataset (January 2019–June 2022), confirms the general trends outlined in this piece. Nevertheless, the author has kept her analysis within the bounds of the available data in the original dataset. The reader

6. Suzanne Lynch, 'Zelensky Calls on EU Holdouts to Sanction Leaders of Russia's Nuclear Energy Giant', *Politico*, 3 February 2023.
7. *World Nuclear News*, 'European Parliament Calls for Russia Sanctions to Include Nuclear', 3 February 2023, <https://www.world-nuclear-news.org/Articles/European-Parliament-calls-for-Russia-sanctions-to>, accessed 8 February 2023.
8. Nuclear Engineering International, 'Hungary will Veto any EU Sanctions against Russia's Nuclear Sector'.
9. The author accessed the data from the third-party commercial trade provider on 26 January 2023. It is accurate as of this date.

should also engage with the data and associated analysis presented with an understanding of these limitations.

It is worth noting that lack of data at certain points in the dataset may indicate either a lack of transactions in that instance or missing transaction data in this particular dataset. As detailed above, the author validated – to the best of her abilities – the overall reliability of the data available but is not in a position to make a final judgement on the origin of gaps in the dataset.

The data for Russian nuclear exports to individual countries tends to be characterised by large peaks and troughs. This is unsurprising, as trade in the nuclear sector is often made up of periodic high-value transactions – such as the delivery of nuclear fuel batches or materials for the construction of nuclear plants – instead of a consistent flow of goods. Furthermore, timelines for nuclear energy projects are significantly longer than those in other energy sectors. Well-planned NPP construction projects take about 11 to 12 years to construct and commission.[10] For instance, the agreement between Russia and Turkey for the construction of the Akkuyu NPP was signed in 2010;[11] construction of the first of the four planned reactors did not begin until 2018.[12] Negotiations in advance of the start of an NPP project can also take considerable time. Commissioned reactors will then operate for decades, requiring fuel, maintenance and servicing – all of which is often bespoke to the reactor.

As such, it is difficult to draw any definitive conclusions from a nuclear trade dataset that only spans four years – as is the case in this instance, or to assess the long-term implication of changes observed in the data from the 10 months since the invasion of Ukraine (March-December 2022). The spikes and drops in trade value captured by the data may not necessarily point to persistent trends. Some of the transactions captured in the dataset for the post-invasion period may also represent an acceleration in the delivery of contracts for goods and materials – such as nuclear fuel – in advance of countries' diversification from Russian supplies. As such, additional data over the coming months and years will be necessary to confirm whether the trade activity seen in the dataset represents persistent trends or one-off occurrences.

As mentioned earlier, the Russian nuclear sector is monopolised by Russian state corporation Rosatom. Due to the volume of transactions, the author could not definitively confirm that all instances of nuclear-related exports from Russia were on behalf of Rosatom and its group of

10. Nick Shykinov, Robert Rulko and Dariusz Mroz, 'Importance of Advanced Planning of Manufacturing for Nuclear Industry', *Management and Production Engineering Review* (Vol. 7, No. 2, June 2016), p. 43.
11. Аккую Нуклеар (Росатом) [Akkuyu Nuclear (Rosatom)], 'Akkuyu NPP Construction Project', <http://www.akkuyu.com/>, accessed 1 February 2023.
12. International Atomic Energy Agency, 'AKKUYU-1', *Power Reactor Information System*, updated 5 February 2023, <https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=553>, accessed 1 February 2023.

companies.[13] However, nearly all of the transactions reviewed by the author within the database appear to have been conducted either by a subsidiary of Rosatom or on behalf of one.

**Table 1:** Nuclear Energy Trade HS Codes

| HS Code | Goods Classification | Nuclear Energy Application |
|---|---|---|
| 840130 | Fuel elements, unirradiated. | Fuel to power a nuclear reactor. |
| 840140 | Parts of nuclear reactors. | As described. |
| 840110 | Nuclear reactors. | As described or components thereof. |
| 284420 | 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. | Materials that can be used in nuclear reactor fuel. |
| 284410 | Natural uranium and its compounds; alloys; dispersions (including metal-ceramics); ceramic products and mixtures containing natural uranium or natural uranium compounds. | Materials that can be used in nuclear reactor fuel but generally require changes in isotopic and/or chemical composition. |

*Source: Russian customs data obtained through a third-party commercial provider, RUSI*

*Disclaimer: The author searched the trade dataset for other nuclear energy-related HS codes, but only those which had trade data associated with them within the dataset have been included.*

## Global Dependencies

As others have detailed elsewhere, Russia occupies a major share of the global nuclear energy market, with dependencies on Russian nuclear fuel supplies particularly high in Central and Eastern Europe, but also apparent in the US and Western Europe.[14] In 2021, there were 44 Russian or Soviet-built VVERs (water-water energetic reactors – a type of pressurised water reactor) operating outside Russia.[15] Seventeen of them were in Ukraine, with the rest spread across 10 other countries. Many of these were built decades ago. However, Russia is continuing to construct nuclear reactors abroad. According to Rosatom's webpage as of January 2023, the company had 34 active NPP construction projects 'at various implementation stages'[16] (although

13. Росатом [Rosatom], 'Предприятия и организации Росатома' ['Enterprises and Organisations of Rosatom'], <https://www.rosatom.ru/about/factories/>, accessed 3 February 2023.
14. Sigrid Melchior et al., 'Russia's Multi-million Euro Nuclear Exports Untouched by EU Sanctions'.
15. International Atomic Energy Agency, 'Country Statistics', *Power Reactor Information System*, updated 5 February 2023, <https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=1101>, accessed 6 February 2023.
16. Rosatom, 'Projects', <https://www.rosatom.ru/en/investors/projects/>, accessed 3 February 2023.

the accuracy of Rosatom's reporting on its construction portfolio has been questioned[17] in the past and others have counted 13 reactors actively under construction at the end of 2021).[18]

Russia's role in the global nuclear market includes not only the construction of nuclear reactors, but also the mining of raw uranium, conversion of uranium ore into fuel-useable compounds, the fabrication of nuclear fuel assemblies, and the provision of other services across the nuclear fuel cycle – 'from assessing and developing key nuclear infrastructure components in customer countries to NPP decommissioning', as the company notes in its 2021 annual report.[19] According to the 2021 report – the latest available – Russia occupied the greatest share of the global uranium enrichment market (38%)[20] (other sources show that it had 46% of the world's total operational and planned uranium enrichment capacity),[21] was second in the world in terms of uranium production (15% of the market)[22] and third in its share of the global nuclear fuel market (17%).[23]

As such, many countries with civilian nuclear energy sectors face significant dependencies on Russian provision of technology, services and fuel for their operation. A May 2022 report by Matt Bowen and Paul Dabbar for Columbia University's Center on Global Energy Policy assessed the degree of dependency of Western markets on Russian nuclear energy supplies.[24] Bowen and Dabbar highlight in particular the key role Russia plays in uranium conversion and enrichment for global markets, including for American and Western European nuclear energy production. In 2021, subsidiaries of Rosatom provided 31% of enrichment services to EU nuclear utilities[25] and

17. Экозащита [Ecodefense], 'No Investors but Putin', 29 May 2020, <https://ecodefense.ru/2020/05/29/no-investors-but-putin/>, accessed 3 February 2023.
18. Matt Bowen and Alec Apostoaei, 'Comparing Government Financing of Reactor Exports: Considerations for US Policy Makers', Columbia University Center on Global Energy Policy, August 2022, <https://www.energypolicy.columbia.edu/wp-content/uploads/2022/08/NuclearFinance-CGEP_Report_111022-1.pdf>, accessed 6 February 2023.
19. Rosatom, 'Performance of State Atomic Energy Corporation Rosatom in 2021', <https://www.report.rosatom.ru/go_eng/go_rosatom_eng_2021/rosatom_2021_eng.pdf>, accessed 1 February 2023.
20. *Ibid*., pp. 18–19.
21. World Nuclear Association, 'Uranium Enrichment', updated October 2022, <https://world-nuclear.org/information-library/nuclear-fuel-cycle/conversion-enrichment-and-fabrication/uranium-enrichment.aspx>
22. Rosatom, 'Performance of State Atomic Energy Corporation Rosatom in 2021', pp. 18-19.
23. *Ibid*.
24. Matt Bowen and Paul Dabbar, 'Reducing Russian Involvement in Western Nuclear Power Markets', Columbia University Center on Global Energy Policy, May 2022, <https://www.energypolicy.columbia.edu/wp-content/uploads/2022/05/RussiaNuclearMarkets_CGEP_Commentary_051822-2.pdf>, accessed 27 January 2023.
25. Euratom Supply Agency, *Euratom Supply Agency Annual Report 2021* (Luxembourg: Publications Office of the European Union, 2021), Table 6, p. 24.

28% to US ones[26]. They point out that replacing Russian uranium enrichment and conversion capacity possible, but that additional alternative capacity will need to be brought online, likely resulting in higher nuclear fuel prices.[27] Alternative nuclear suppliers will also need to be convinced that the resources they invest in expanding their operations will not be in vain should any restrictions on Russian nuclear supplies be rescinded in a few years.[28]

Alternative suppliers would also have to be found for the fabrication of nuclear fuel. A consortium of Western companies has been conducting work on the diversification of VVER fuel supply for years, focusing mainly on the production and licensing of VVER-440 fuel supplies.[29] According to recent industry media reporting, supplies of VVER-440 fuel produced by a collaboration between US energy company Westinghouse Electric Company LLC (Westinghouse) and Spanish company Enusa should be ready for deliveries in 2024.[30] French company Framatome also produces fuel under licence from a Rosatom subsidiary, which is reportedly identical to Russian-produced VVER fuel.[31] Diversification away from Russian nuclear fuel supplies is time consuming, costly and presents technical challenges.[32] Western nuclear fuel production lines need to be adapted, expanded and licensed for the production of VVER fuel, while customer countries need to license new suppliers which – according to one former senior Westinghouse engineer – can take at least five years.[33] However, despite all this – and as has been demonstrated – diversification is possible.

Finally, Bowen and Dabbar note that reactors often rely on unique components produced by the original equipment manufacturer (OEM), which results in significant dependence on the OEM for replacement parts and servicing.[34] The Russian customs data reviewed by the author

26. US Energy Information Administration, 'Uranium Marketing Annual Report – Table 16. Purchases of Enrichment Services by Owners and Operators of US Civilian Nuclear Power Reactors by Origin Country and Year, 2017–21', <https://www.eia.gov/uranium/marketing/table16.php>, accessed 6 February 2023.
27. Bowen and Dabbar, 'Reducing Russian Involvement in Western Nuclear Power Markets', p. 4.
28. *Ibid*., p. 11.
29. Mark Dye, Jan Höglund and Ulf Benjaminsson, 'Diversification of the VVER Fuel Market', *Nuclear Engineering International*, 30 September 2015, <https://www.neimagazine.com/features/featurediversification-of-the-vver-fuel-market-4682502/>, accessed 27 January 2023.
30. *World Nuclear News*, 'Enusa and Westinghouse VVER-440 fuel collaboration', 18 January 2023, <https://world-nuclear-news.org/Articles/ENUSA-and-Westinghouse-agree-VVER-440-fuel-deal>, accessed 6 February 2023.
31. AFP, 'Bulgaria Signs Deal to End Reliance on Russian Nuclear Fuel', *Moscow Times*, 30 December 2022, <https://www.themoscowtimes.com/2022/12/30/bulgaria-signs-deal-to-end-reliance-on-russian-nuclear-fuel-deliveries-a79854>, accessed 6 February 2023.
32. J E Gingold, L Goldstein and A A Strasser, 'The International VVER Fuel Market', The SM Stoller Corporation, <https://inis.iaea.org/collection/NCLCollectionStore/_Public/28/031/28031544.pdf>, accessed 1 February 2023.
33. Jonathan Tirone, Kati Pohjanpalo and Jesper Starn, 'Europe's Other Energy Problem: Relying on Russian Nuclear Fuel', *Bloomberg UK*, 7 April 2022.
34. Bowen and Dabbar, 'Reducing Russian Involvement in Western Nuclear Power Markets', p. 7.

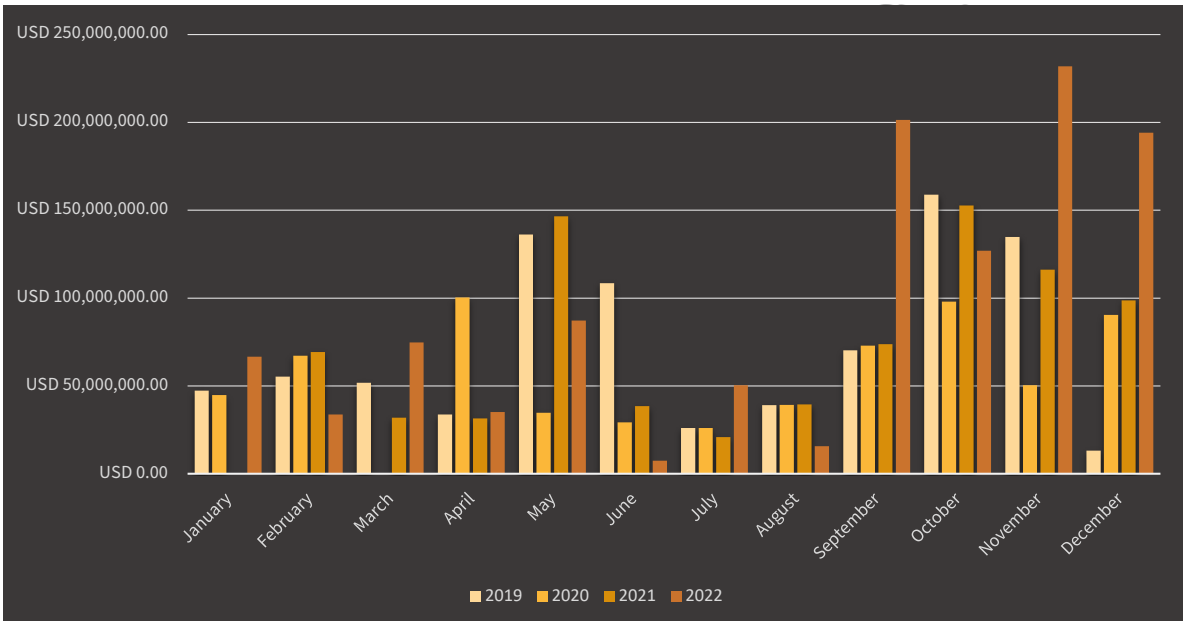
shows Russian nuclear energy-related exports going to 21 different countries between January 2019 and December 2022. New reactors being constructed by Rosatom will also need servicing and spare parts over their lifetimes, which is likely to perpetuate future dependencies on imports from Russia. The Rosatom project for the construction of the El Dabaa NPP in Egypt, for instance, explicitly includes provisions for personnel training and reactor maintenance for the first 10 years of the plant's operations, as well as fuel supply over the plant's lifetime.[35] Even more extensive long-term maintenance and operation provisions could be built into future NPP construction projects – for instance, the 'build-own-operate' model, which is being used for the first time in the construction of the Akkuyu NPP in Turkey[36] and is discussed in more detail later.

## Fuelling Up

While the importance of Russia as a supplier of nuclear technology has been well-established, the dataset reviewed by the author points to an increase in the dollar value of Russian nuclear energy-related exports in the last few months, driven by a handful of countries outside of North America, Western Europe and traditional Eastern European customers. According to the dataset, the value of Russian nuclear energy exports increased considerably in the second half of 2022. In a month-on-month comparison, the dataset examined by the author shows values of 2022 nuclear energy exports exceeding 2021 exports in five out of 10 months captured by the data since the invasion (March – December 2022).

35. Rosatom, 'Projects'.
36. Névine Schepers, 'Russia's Nuclear Energy Exports: Status, Prospects and Implications', *Non-Proliferation and Disarmament Papers* (No. 61, February 2019), EU Non-Proliferation and Disarmament Consortium.

**Figure 2:** Month-on-Month Value of Russian Nuclear Energy Exports




*Source: Russian customs data obtained through a third-party commercial provider, RUSI; graphic by RUSI OSIA*

Both prior to the invasion and since March 2022, Russia's primary nuclear-related exports – by a significant margin – came under HS code 840130 – 'fuel elements, unirradiated'; in other words, fresh fuel for nuclear reactors. According to the trade data reviewed by the author, nuclear fuel exports accounted for about 77% of Russian nuclear exports prior to the invasion, rising to 86% between March and December 2022. Prior to March 2022, the top five destination countries for Russian nuclear fuel in the dataset – by dollar value – were Ukraine, Czechia, China, Bulgaria and Hungary.

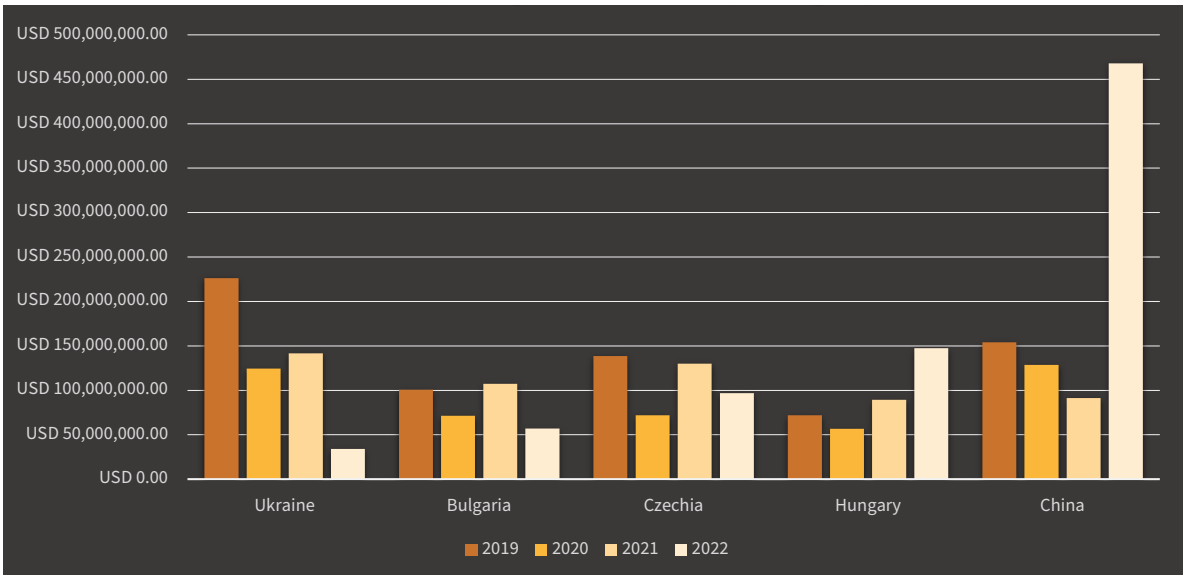
Since Russia's invasion of Ukraine, some of these customers have sought to diversify away from Russian nuclear fuel. Czechia[37] and Bulgaria[38] have reached agreements with French and US suppliers for the supply of nuclear fuel for some of their reactors. However, the deliveries of this fuel are not expected until 2024 in Czechia and 2025 in Bulgaria. The trade data reviewed by the author shows that Russia has continued exporting nuclear fuel into both countries after the invasion, although the value of those imports dropped from 2021 to 2022.

Ukraine is of course the most obvious case of diversification away from Russian nuclear fuel supplies. Hosting 17 VVER reactors, Ukraine has relied heavily on Russian imports of nuclear fuel to keep the units powered. In the last year – and even before then – it became clear that

37. *Associated Press*, 'US, French Companies to Supply Fuel to Czech Nuclear Plant', 28 June 2022.
38. AFP, 'Bulgaria Moves to Replace Russian Nuclear Fuel Supplies', *Radio Free Europe*, 30 December 2022, <https://www.rferl.org/a/bulgaria-replaces-russian-nuclear-fuel/32201287.html>, accessed 3 February 2023.

this dependency was no longer feasible. After Moscow's initial incursion into Ukraine in 2014, Westinghouse was granted contracts to supply nuclear fuel to a number of Ukraine's VVER reactors.[39] The company – which has the capability to produce fuel for VVER-1000 reactors[40] – was reportedly supplying fuel for six of the country's reactors as of April 2022.[41] Ukraine went from being the top export destination for Russian nuclear reactor fuel prior to the invasion to not importing any at all after the end of February 2022.

**Figure 3:** Year-on-Year Value of Russian Nuclear Fuel Exports (HS 840130) to Ukraine, Bulgaria, Czechia, Hungary and China




*Source: Russian customs data obtained through a third-party commercial provider, RUSI; graphic by RUSI OSIA*

In the cases of China and Hungary, the dataset reviewed by the author shows the two countries assuming a larger proportion of Russian nuclear fuel exports since March 2022. In fact, the value of Russian nuclear fuel exports to Hungary in the 10 months between March and December 2022 far exceeds that of any of the previous three years. According to the transaction details captured in the data, the deliveries were for Hungary's Paks NPP. In August 2022, Hungary controversially decided to go ahead with issuing permits for Rosatom construction of two new nuclear reactors at the site.[42]

39. Dye, Höglund and Benjaminsson, 'Diversification of the VVER Fuel Market'.
40. Westinghouse, 'VVER', <https://www.westinghousenuclear.com/nuclear-fuel/vver>, accessed 3 February 2023.
41. Tirone, Pohjanpalo and Starn, 'Europe's Other Energy Problem: Relying on Russian Nuclear Fuel'.
42. Camille Gijs, 'Hungary Moves Ahead with Construction of Russian-built Nuclear Reactors', *Politico*, 27 August 2022, <https://www.politico.eu/article/hungary-approves-construction-of-russian-built-nuclear-reactors/>, accessed 27 January 2023.

The data also shows a clear spike in Russian exports of nuclear fuel to China in the second half of 2022, which appears to be primarily driven by the export – for the first time – of Russian fuel for the CFR-600 fast neutron reactor currently under construction[43] at China's Xiapu NPP in Fujian Province. The supply of fuel for the CFR-600 reactor is part of a set of 2018 Russo-Chinese agreements on nuclear energy cooperation, which includes Russian commitments for the delivery of fuel, equipment and services for the Chinese-built CFR-600.[44] The trade data shows three separate batches of nuclear fuel assemblies being exported to China in September, November and December 2022. This data corroborates public reporting of the fuel deliveries.[45] Data for December 2022 also shows the export to China of control and protection system assemblies for the CFR-600 reactor.

The CFR-600 is a sodium-cooled fast neutron reactor. According to assessments by the US Department of Defense, the reactor could be used as a breeder reactor;[46] this means that the reactor may be capable of producing more fissile material than it consumes. This has raised concerns that the reactor could be used for the production of plutonium,[47] which could in turn be used for fuel in nuclear weapons, among unconfirmed suspicions that China may be expanding its nuclear weapons arsenal.[48] Nevertheless, there is no evidence that China is diverting – or planning to divert – plutonium from the CFR-600 to nuclear weapons production and some experts have suggested that there are more efficient ways for Beijing to increase its weapons-usable plutonium stockpiles than relying on a breeder reactor designed for civilian energy production.[49]

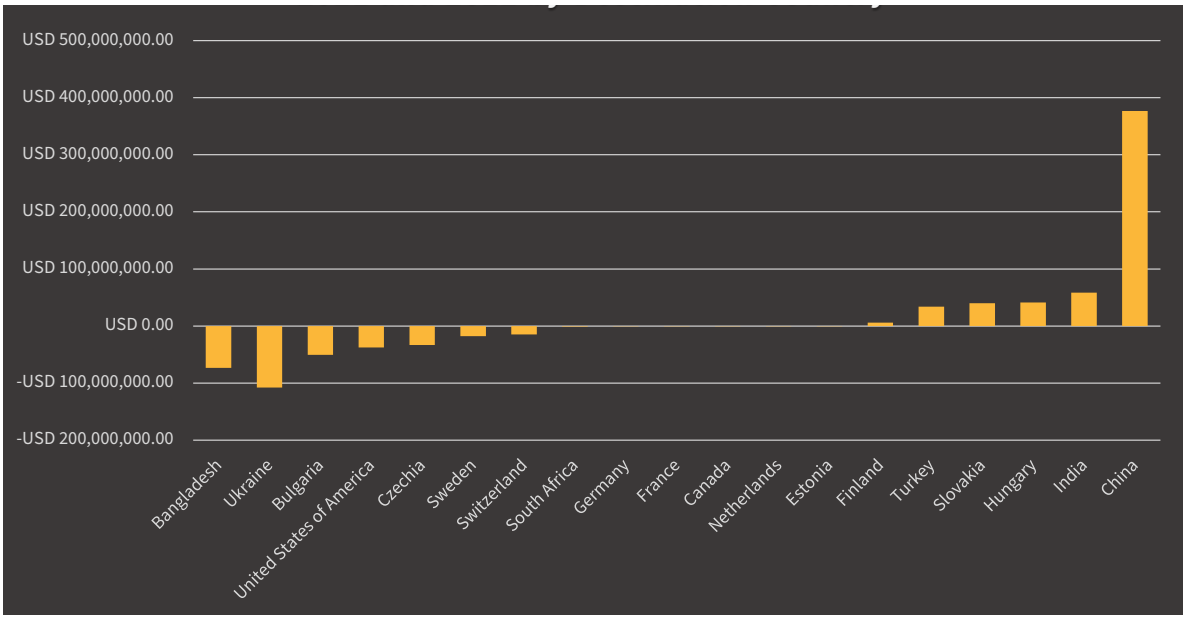
43. International Atomic Energy Agency, 'XIAPU-1', *Power Reactor Information System*, updated 5 February 2023, <https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=1101>, accessed 6 February 2023.
44. Hüseyin Erdoğan, 'Russia, China Ink Four Nuclear Deals in Beijing', *Anadolu Agency*, 9 June 2018, <https://www.aa.com.tr/en/energy/nuclear/russia-china-ink-four-nuclear-deals-in-bejing/20422>, accessed 27 January 2023.
45. Nuclear Engineering International, 'Russia Completes Fuel Deliveries for China's CFR-600 Fast Reactor', 27 January 2023, <https://www.neimagazine.com/news/newsrussia-completes-fuel-deliveries-for-chinas-cfr-600-fast-reactor-10486493>, accessed 27 January 2023.
46. Office of the Secretary of Defense, 'Military and Security Developments Involving the People's Republic of China 2022', US Department of Defense, <https://media.defense.gov/2022/Nov/29/2003122279/-1/-1/1/2022-MILITARY-AND-SECURITY-DEVELOPMENTS-INVOLVING-THE-PEOPLES-REPUBLIC-OF-CHINA.PDF>, pp. 96–97.
47. Timothy Gardner, 'UPDATE 1-China Reactors will Yield Weapons-grade Plutonium – US Commander', *Reuters*, 21 April 2021; Prachi Patel, 'China's New Breeder Reactors May Produce More than Just Watts', *IEEE Spectrum*, 20 December 2022, <https://spectrum.ieee.org/china-breeder-reactor>, accessed 27 January 2023.
48. Sidharth Kaushal, 'China's Evolving Nuclear Arsenal: Trajectories and Future Risks', RUSI Defence Systems, 9 January 2023.
49. Prachi Patel, 'China's New Breeder Reactors May Produce More than Just Watts', *IEEE Spectrum*.

All other Russian nuclear fuel shipments to China recorded in the dataset appear to be for the Russian-built Tainwan-3 VVER reactor. Rosatom is also due to construct four new reactor units at the Tainwan and Xudabao NPPs. One of these began construction on 25 February 2022[50] – the day after Russia's invasion of Ukraine – and the other in May 2022.[51]

## The Nuclear Family

An analysis of trends in overall Russian nuclear energy-related exports, across all HS categories, also point to the emergence of several loyal customers for the Russian nuclear energy market. As many countries look to diversify their sourcing of nuclear energy supplies, a handful of others appear to be increasing Russian imports of nuclear goods and technology.

**Figure 4:** Changes in the Value of Russia's Nuclear Exports Between 2021 and 2022 by Destination Country




*Source: Russian customs data obtained through a third-party commercial provider, RUSI; graphic by RUSI OSIA*

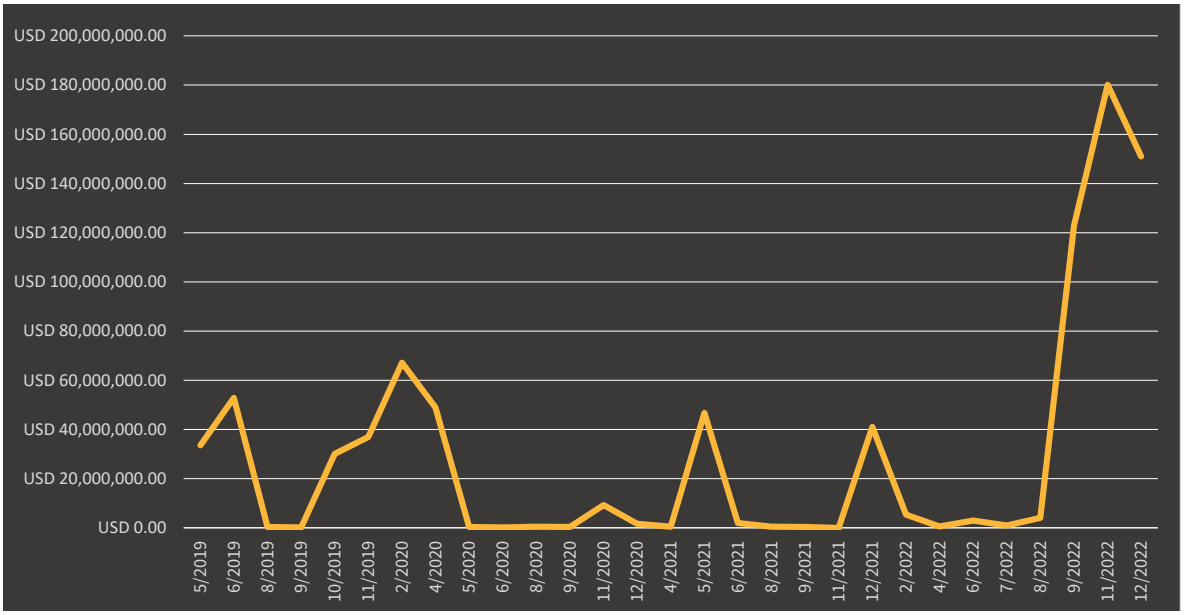
Before March 2022, the dataset shows that the top five destination countries for Russian nuclear exports were Ukraine, China, Czechia, Bulgaria and Hungary, with India not far behind. Since

50. Росатом [Rosatom], '«Первый бетон» залит на стройполщадке энергоблока No. 8 АЭС «Тяньвань» (Китай)' ['"First concrete" poured on the construction site of unit 8 of the "Tainwan" NPP (China)'], 25 February 2022, <https://www.rosatom.ru/journalist/news/pervyy-beton-zalit-na-stroyploshchadke-energobloka-8-aes-tyanvan-kitay/>, accessed 27 January 2023.
51. Rosatom, 'First Concrete Laid at Xudapu NPP Power Unit 4 in China', 19 May 2022, <https://ase-ec.ru/en/for-journalists/news/2009/may/first-concrete-laid-at-xudapu-npp-power-unit-4-in-china/>, accessed 27 January 2023.

March, exports to Ukraine have stopped entirely according to the data. Other destinations for Russian nuclear exports also disappear from the dataset from March 2022 onwards, including the US, Switzerland, Sweden, Canada and the Netherlands. However, even in the three years prior to March 2022, Russian nuclear energy exports to these countries made up a very small proportion of the entire dataset. As mentioned earlier, it is possible that more significant exports took place before 2019 and materials were stockpiled. However, the relatively small proportion of Russian nuclear energy exports to these countries suggests that Western customers – and retaining access to those export markets – will be relatively less important to Russia than customers in other parts of the world.

Russia's priority is likely to be focused on retaining and growing business in a handful of apparently loyal customers that remain less enthusiastic about imposing sanctions on the Russian economy. The data shows that both the relative share and net value of overall nuclear exports to China has skyrocketed, driven almost exclusively by the spike in the value of Russian nuclear fuel exports to China in the second half of 2022, which were discussed earlier. The relative and absolute value of Russian exports to Hungary has also grown, consisting – as before the invasion – almost entirely of nuclear fuel exports. The data also shows a significant amount of Russian nuclear exports going to India in the first half of 2022 – consisting of deliveries of nuclear fuel (HS 840130) and nuclear reactor components (HS 840140) – but dropping off after June of that year.

**Figure 5:** Value of Russian Nuclear Energy Export Transactions to China Over Time




*Source: Russian customs data obtained through a third-party commercial provider, RUSI; graphic by RUSI OSIA*

Another country which – according to the data – continues to import a significant amount of Russian nuclear-related goods and materials, and whose importance in Russia's nuclear export market has grown since March 2022, is Turkey. The data shows that Russian nuclear exports to Turkey took a dip in the first few months of the invasion but have since rallied in both relative and absolute terms. While future trade data will help to determine whether the importance of Turkey as a market for Russian nuclear exports will continue to grow, such a trend would not be surprising. Rosatom is in the process of constructing Turkey's first nuclear power plant – the Akkuyu NPP, on the country's Mediterranean coast. The project is the result of a 2010 agreement signed between the Russian and Turkish governments and – according to Rosatom – is the 'largest project in the history of Russian-Turkish cooperation'.[52]

The project is the first application of the 'build-own-operate' model for nuclear reactor construction; under this arrangement, Rosatom will maintain ownership of the NPP after its construction, selling the generated electricity to a Turkish utility company – thus expecting to make a guaranteed profit off the project.[53] According to the project's webpage, Rosatom companies own nearly 100% of the project.[54] When completed, the Akkuyu NPP will host four VVER-1200 reactors and is expected to generate 35 billion kWh per year – an estimated 10% of Turkey's electricity.[55] Construction of the first reactor began in April 2018[56] and of the fourth in July 2022.[57] Descriptions of Russian exports to Turkey within the dataset reviewed by the author clearly identify shipments of nuclear reactor parts and other technology for the construction of the Akkuyu NPP.

As mentioned in the methodology section of this report, it is difficult to draw any definitive conclusions on long-term trends in Russian nuclear exports just from looking at four years of trade data and especially from any movement in the 10 months following the invasion of Ukraine. The trends observed in the post-invasion trade data align with expectations on shifts in Russian nuclear energy customers, as a result of efforts in some countries – and publicly reported resistance in others – to diversify away from Russian nuclear energy supplies. However, additional data over the coming months and years will help confirm – or disprove – these apparent trends. For now, the observed increases in Russian nuclear energy exports to certain destinations in the reviewed dataset are best viewed as general confirmation of these

52. Аккую Нуклеар (Росатом) [Akkuyu Nuclear (Rosatom)], 'Akkuyu NPP Construction Project'.
53. Schepers, 'Russia's Nuclear Energy Exports: Status, Prospects and Implications', *Non-Proliferation and Disarmament Papers*, p. 4.
54. Аккую Нуклеар (Росатом) [Akkuyu Nuclear (Rosatom)], 'Company's History', <http://www.akkuyu.com/companys-history>, accessed 1 February 2023.
55. Аккую Нуклеар (Росатом) [Akkuyu Nuclear (Rosatom)], 'Project History', <http://www.akkuyu.com/project-history>, accessed 1 February 2023.
56. International Atomic Energy Agency, 'AKKUYU-1', *Power Reactor Information System*.
57. International Atomic Energy Agency, 'AKKUYU-4', *Power Reactor Information System*, updated 5 February 2023, <https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=1082>, accessed 1 February 2023.

countries' commitments to nuclear cooperation with Russia, rather than a rapid expansion of these relationships since the start of 2022.

## In For a Penny

Besides the aforementioned dependencies and difficulties in diversifying suppliers, several factors continue to make Russia an attractive supplier for existing and new customers. One key consideration is Moscow's willingness to extend attractive financing schemes for its NPP construction projects abroad. As Matthew Bowen and Alec Apostoaei highlight in a recent report on government financing of nuclear reactor exports, the debt and equity arrangements that Rosatom is able to provide are government-backed and their conditions are not limited by restrictions placed on US, French and South Korean competitors by the Organisation for Economic Co-Operation and Development (OECD).[58] As such, the authors note, Russian financing arrangements are consistently more generous and attractive than other suppliers are able to provide.

Such financing arrangements likely serve as an important motivator for countries that may not be able to front the costs of an NPP construction project themselves. Equally, they create commitments that are financially difficult to disentangle from down the road. For instance, Rosatom's construction of two new units at Hungary's Paks NPP is expected to cost €12.4 billion, with Russia providing €10 billion as a loan[59] under a repayment period of 16 years.[60] Russia is also providing Egypt with a $25 billion loan for the construction by Rosatom of the El Dabaa NPP, out of a total estimated cost of $60 billion.[61] The repayment term for that arrangement is reportedly 22 years.[62] In Bangladesh, Russia extended a loan for $11.4 billion, with a repayment term of 20 years for the construction of the Rooppur NPP.[63] The loan represents 90% of the total original cost of the project.[64]

Differences in the regulatory requirements for the export of US nuclear technology versus nuclear exports from Russia as well as other major suppliers may also allow Rosatom to be

58. Bowen and Apostoaei, 'Comparing Government Financing of Reactor Exports: Considerations for US Policy Makers'.
59. *Ibid*., p. 15.
60. *Ibid*., p. 15.
61. 'Russia Lends Egypt $25 billion for Daaba Nuclear Power Plant', *Al-Monitor*, 23 February 2020, <https://www.al-monitor.com/originals/2020/02/power-plant-nuclear-egypt-russia-loan.html>, accessed 3 February 2023.
62. Bowen and Apostoaei, 'Comparing Government Financing of Reactor Exports: Considerations for US Policy Makers', p. 15.
63. *TASS*, 'Russia Extends $11.38 bln Loan to Bangladesh to Build Nuclear Power Plant', 13 January 2017.
64. *World Nuclear News*, 'Bangladesh, Russia Link $12.65 billion Rooppur Plant Deal', 29 December 2015, <https://www.world-nuclear-news.org/NN-Bangladesh-Russia-ink-12.65-billion-Rooppur-plant-deal-29121501.html>, accessed 25 January 2023.

a more nimble and attractive supplier, at least in relation to US competitors.[65] In instances where the US wishes to make significant transfers of nuclear material or technology, US law generally requires the conclusion of a peaceful nuclear cooperation agreement under Section 123 of the Atomic Energy Act (commonly known as a '123 Agreement').[66] These agreements outline requirements around specific non-proliferation criteria that recipient countries must meet in order to receive US technology; 123 Agreements are reviewed – and may therefore be rejected or delayed – by the US Congress.[67] Furthermore, these agreements require periodic renewal. The expiry of the US' 123 Agreement with South Africa in December 2022 has meant that Westinghouse lost its US Nuclear Regulatory Commission licence to export nuclear fuel components to the country's Koeberg NPP.[68] As others have outlined elsewhere, while Russia also includes non-proliferation and export-control measures in its nuclear cooperation agreements, they are less extensive than those applied by the US.[69]

## Conclusion

As the trade data reviewed by the author demonstrates, Russia's nuclear export sector has continued to thrive since Moscow's invasion of Ukraine. This trade in nuclear technology will directly benefit state corporation Rosatom, which appears to be actively supporting Russia's invasion of Ukraine. Some have called for the Russian nuclear industry to be sanctioned. Others have taken it into their own hands to find alternative suppliers for their nuclear energy sectors. On 5 February, Kyiv took the step of sanctioning 200 entities connected to the Russian nuclear sector.[70] A few days earlier, the European Parliament passed a resolution calling for sanctions on Rosatom and an embargo on imports of Russian uranium.[71] Such actions are helpful and should be actively pursued as part of broader national and multilateral efforts to place economic pressure on Moscow and Russian entities supporting Russia's invasion and atrocities in Ukraine.

65. Schepers, 'Russia's Nuclear Energy Exports: Status, Prospects and Implications', pp. 5–6.
66. Nuclear Regulatory Legislation, 113th Congress, 2nd Session (Volume 1, Number 11); National Nuclear Security Administration, '123 Agreements for Peaceful Cooperation', updated 7 December 2022, <https://www.energy.gov/nnsa/123-agreements-peaceful-cooperation>, accessed 6 February 2023.
67. US Department of State, '123 Agreements', 6 December 2022, <https://www.state.gov/fact-sheets-bureau-of-international-security-and-nonproliferation/123-agreements/#:~:text=The%20President%20approves%20the%20123,disapproval%20has%20not%20been%20enacted>, accessed 6 February 2023.
68. Jonathan Tirone and Paul Burkhardt, 'Eskom Weighs Nuclear Fuel Impact After US-South Africa Pact Ends', *Bloomberg UK*, 25 January 2023.
69. Schepers, 'Russia's Nuclear Energy Exports: Status, Prospects and Implications', pp. 5–6.
70. Президент України [President of Ukraine], Указ Президента України No 57/2023 [Order of the President of Ukraine No. 57/2023], 5 February 2023, <https://www.president.gov.ua/documents/572023-45713>, accessed 8 February 2023.
71. European Parliament, 'MEPs Say Work on Ukraine's EU Future Must Start Now', Press Release, 2 February 2023, <https://www.europarl.europa.eu/news/en/press-room/20230130IPR70207/meps-say-work-on-ukraine-s-eu-future-must-start-now>, accessed 8 February 2023.

By sanctioning Rosatom and its subsidiaries, the US and EU can make it more difficult for the corporation to operate within the international financial system and to access certain services – like insurance – that it would need to move its wares to customers.

Yet, as demonstrated by the trade data reviewed by the author, Russia's most important customers for nuclear energy exports are located outside Western Europe and North America, and Russia appears to be increasingly reliant on business from countries that have shown less enthusiasm for sanctioning its economy. As such, for any US and EU sanctions on Rosatom and the Russian nuclear energy industry to be effective in significantly curtailing Russian economic gains from its nuclear energy exports, they will need to be coupled with broader diplomatic efforts to encourage and support diversification away from Russian supplies.

Focusing efforts on bringing countries like Turkey and Hungary on side to increase the political and economic pressure on Moscow will be key. It remains unclear to what extent these countries will maintain – or expand – their nuclear cooperation with Russia moving forward although incentives and restrictions to diversification clearly exist, as detailed in this report. Finding ways to support a sustainable shift away from dependence on Russian nuclear fuel and technology and towards alternative suppliers will be key to ensuring that emerging trends suggested by the data assessed for this report do not become permanent ones.

However, securing the cooperation of China – Russia's most important customer in nuclear energy exports – when it comes to curtailing Russian access to its nuclear energy market is an undoubtedly tall order. As it has already demonstrated, Beijing is likely to remain the persistently weak link in Western efforts to effectively apply sanctions against the Russian economy.[72] As long as international consensus on condemning and sanctioning Russia's invasion of Ukraine remains divided, Russia will find ways to benefit from these divisions.

72. Ian Talley and Anthony DeBarros, 'China Aids Russia's War in Ukraine, Trade Data Shows', *Wall Street Journal*, 4 February 2023.

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