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# A NUCLEAR STRANGLEHOLD: RUSSIA'S UNSANCTIONABLE POSITION IN THE NUCLEAR INDUSTRY

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# Executive Summary

*"Nuclear power has been the world's fastest-growing source of industrial-scale energy in every decade since the 1950s…Putin sees the payoff for winning the race for uranium. He has already given Russia a significant head start, and he's still running faster than anyone else. No one in the United States or Europe has even entered the race." – Marin Katusa*

Almost a decade on from the release of Marin Katusa's 'The Colder War: How the Global Energy Trade Slipped from America's Grasp', we revisit those same themes today, but with a forensic focus on Russia's nuclear sector.

The war in Ukraine has emphasised the extent to which Russia has control in these markets, placing energy security as priority number one at both a domestic and national level. In his book, Katusa describes '*The Putinisation of Uranium'*, a way in which Vladimir Putin has for two decades strategically positioned Russia to make them an indispensable player within global nuclear markets.

Russia's grip on nuclear markets cannot be credited to Putin alone, with the country's first nuclear power plant being built in Obninsk in 1954. By 1969, the country was pioneering uranium enrichment using gas centrifuges, a revolutionary innovation that cemented Russia's position as a global leader in uranium services. This was at a time when nuclear power was, commercially, a nascent energy source, but between 1970-1990 saw its growth surge, particularly in the western world.

Today, nuclear energy is once again enjoying a renaissance. There is almost global consensus that nuclear energy will be one of the key solutions to combat climate change, due to its scalable, baseload power that will run irrespective of the sun shining or the wind blowing.

Understanding the importance of nuclear in global energy markets also displays a harrowing reality, in that Russia is the dominant player across aspects of both nuclear reactor construction, and the fuel supply.

This report will give some sense of this dominance, emphasising how Russia's involvement in the nuclear industry is not confined to energy production, but social initiatives, economic prosperity, and widespread accessibility.

Western economies, particularly the United States, have for years become so accustomed to the reliability of Russian nuclear fuel, that innovation in their domestic systems has stagnated. This has resulted in a black swan event like Russia's invasion of Ukraine causing global chaos, particularly in countries that had become complacent around energy security and their respective supply chains.

There are few options to resolve this, at least not in the short term. As we will discuss, the nuclear supply chain is a complex process made up of highly technical component parts. This has resulted in a bifurcated market particularly in the front-end of the fuel cycle, where only a handful of countries globally have the ability to commercially produce these services.

To wholly replace Russian influence in the global nuclear industry is nigh impossible. Ultimately, there are countries where the war holds less significance than others, and one country's loss will likely be another's gain. We are witnessing unparalleled growth in the nuclear sector, where Russia through their state nuclear company, Rosatom, have established themselves as the market-leader.

They have capitalised on this growth, not only through nuclear construction expertise, but through their control of the conversion and enrichment stages of the nuclear fuel cycle. Russia's position in the nuclear industry today is testament to the way in which Putin has played his game of economic chess using energy as his key pieces, he understands that a nations energy is a nations security, and he wants to ensure that when energy is discussed, Russia have a seat at the table.

# Contents

# The Nuclear Fuel Cycle

*"The Ukraine story actually had a more direct impact on the fuel side both in terms of demand and supply than even Fukushima did back in 2011." Jonathan Hinze, President, UxC*

To fully quantify the Russian grip on the nuclear sector, understanding the fuel cycle is paramount. The nuclear fuel cycle describes the process that raw uranium (the metal out of the ground), must go through in order to become capable of powering nuclear reactors, and ultimately the disposal of nuclear waste.

The front-end of the fuel cycle (mining to fuel fabrication) is a series of industrial processes that takes around two years, and only a handful of countries have the infrastructure, technology, and expertise to commercially perform these operations.

See below an overview of these components:

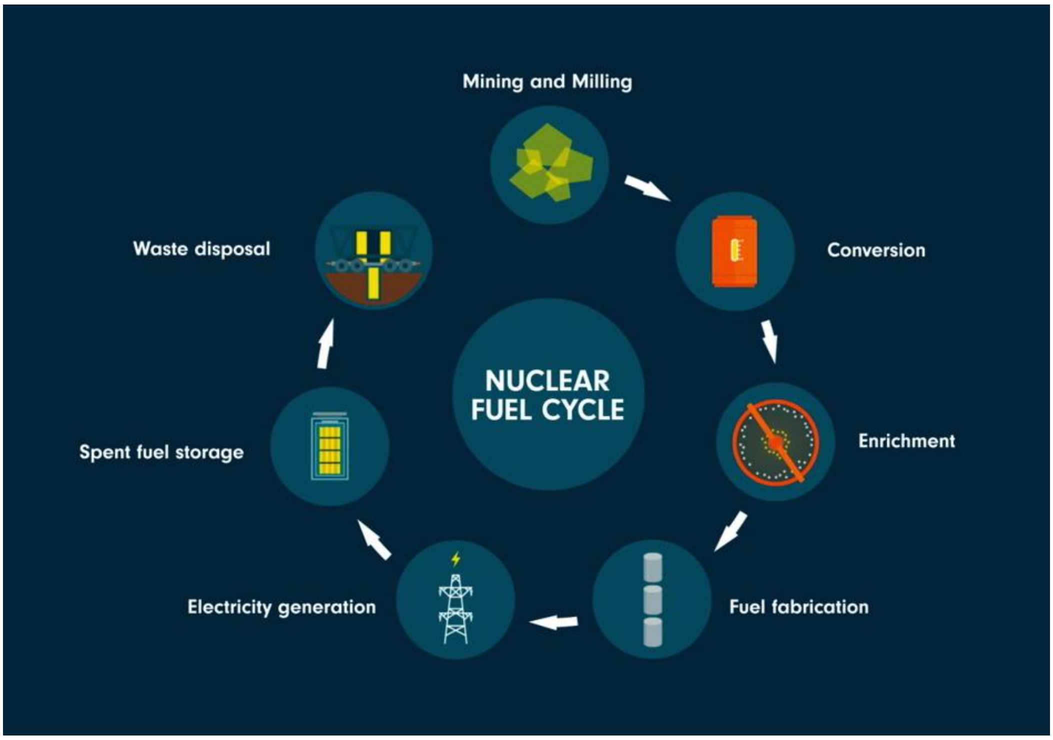


*Figure 1: The Nuclear Fuel Cycle – IAEA [1]*

## Mining & Milling:

Once uranium deposits have been discovered, uranium ore can be extracted through a variety of different methods. For the purpose of this report, we will not go into detail on these methods but please refer to our broader report 'The Case on Uranium' for more detail.

Mined uranium ores are normally processed by grinding the ore materials to a uniform particle size and then treating the ore to extract the uranium by chemical leaching. The milling process commonly yields dry powder-form material consisting of natural uranium, often referred to as "yellowcake", which is sold on the uranium market as U3O8.

[1] https://www.iaea.org/newscenter/multimedia/videos/what-is-the-nuclear-fuel-cycle

It is important to understand at this point that U3O8 is only 0.711% of the U-235 isotope, the isotope required to generate nuclear fission. Nuclear reactors require an isotopic mix of at least 3-5% U-235.

## Conversion:

Conversion is the process of turning U3O8 into uranium hexafluoride, or UF6. A solid at room temperature, UF6 becomes gaseous at 57°C (134°F). At this stage of the cycle, the uranium hexafluoride conversion product still has the natural isotopic mix (0.711% of U-235).

## Enrichment:

To get the isotopic mix to its required level of 3-5% U-235, the UF6 produced from natural uranium sources (conversion) must be enriched to a higher concentration of the fissionable isotope before being used as nuclear fuel in such reactors. This process is called enrichment and is commonly done using gas centrifuges.

Also worth noting is that the level of enrichment for a particular nuclear fuel order is specified by the customer according to the application they will use it for – more on this later.

## Fuel Fabrication:

Uranium has now been enriched to its desired level, and the output is referred to as 'Enriched Uranium Product', or 'EUP'. At this point, it is converted into uranium dioxide (UO2), prior to being fabricated into fuel pellets. These pellets are about 1cm x 1cm but have the energy density equivalent to 17,000 cubic ft of natural gas, 120 gallons of oil, or one ton of coal.

These pellets are then stacked into their fuel rods and loaded as fuel assemblies into nuclear reactors to create energy from a controlled chain reaction.

For the scope of this report, we will not go into detail on spent fuel storage or waste disposal, but again please refer to our broader report should you wish to learn more. [2]

As you might have guessed, Russia is not only involved in many of these components but leads global production of them. As we will learn, this strategy built by Putin over two-decades has ensured not only Russia's participation, but domination of the nuclear sector.

# Russia's Nuclear Stranglehold

## Mining

While Russia only accounts for ~5% of global uranium production, they have substantial domestic reserves estimated at over one billion lbs. Domestic uranium production is conducted by a monopoly, ARMZ Uranium Holding, a subsidiary of state-owned nuclear giant Rosatom. A successor of one of the largest mining complexes built by the Soviet Union, ARMZ is a global leader in uranium production and is believed to rank second globally in terms of reserves.[3]

While Russia is not a dominant player in global uranium production, they have both operational and financial interests in a variety of foreign mining projects that casts an extremely wide net in terms of influence. In fact, if you aggregate Russia's domestic uranium deposits with their foreign projects, the Russian sphere of influence could contribute 140m lbs of uranium per year, or 74% of current global annual demand. [4]

[2] https://oceanwall.com/wp-content/uploads/2023/04/Uranium-Report-April-2023.pdf
[3] https://www.e-mj.com/features/russian-uranium-mining/
[4] Katusa, M. (2015). *The colder war : how the global energy trade slipped from America's grasp*

The majority of Russia's foreign mining projects are located in Kazakhstan (via Uranium One), where we have estimated that they have between 286-348m lbs worth of interest. For clarity, the current interest in Budenovskoye is unknown but we estimate that it is between 25-50%. Budenovskoye is expected to account for more than 10% of global uranium output within three years.

| | Total Ore Reserves (m lbs) | Rosatom Interest (%) | Rosatom Interest (m lbs) |
|---|---|---|---|
| **Khorasan** | 76.56 | 30% | 22.97 |
| **SMCC** | 165.88 | 70% | 116.12 |
| **Karatau** | 78.98 | 50% | 39.49 |
| **Akbastau** | 79.64 | 50% | 39.82 |
| **Zarenchnoe** | 9.24 | 50% | 4.62 |
| **Budenovskoye** | 250.8 | 25%-50% | 62.70-125 |
| | | | **Total: 285.71-348.41** |

*Figure 2: Russian Interest in Kazakh Uranium Mines* [5]

Uranium One is one of the portfolio companies of Rosatom, and another significant player in uranium mining specifically outside of Russia. Uranium One previously had uranium assets in the US, Canada, South Africa and Australia, and still has major uranium operations in Kazakhstan, Tanzania, and Namibia.

In November 2022, Rosatom announced plans to begin the process for commercial mining at the Mkuju River deposit in Tanzania.[6] According to Uranium One, assessed and inferred reserves amount to 58,600 tonnes or 129m lbs.

Also worth noting is this project is not at the mercy of uranium prices in nearly the same way as Western projects, with Rosatom Deputy Head, Kirill Komarov, stating that even the current level of uranium prices would render it "*quite profitable*" to mine there.

In Namibia, Uranium One has been running a uranium exploration project called Wings, which is estimated to be one of the country's largest reserves.[7] While the two operating mines in Namibia are wholly owned by the Chinese, Uranium One has invested over $50m since the launch of Project Wings, with potentially $300m more to come, making a sizeable contribution to the national budget and broader economy.

Total resources were confirmed by a JORC compliant technical report amounting to: indicated resources of 30m lbs, inferred resources of 21m lbs and an exploration potential of 88m lbs.

Additionally, the company have committed to social work in the area through educating and developing local talents, including the enrolment of Namibian students into Russian universities to then ultimately be employed on Project Wings.

This puts Russian interest in Kazakh, Namibian and Tanzanian uranium projects at over half a billion lbs, enough to supply the entire US reactor fleet for well over a decade.

Perhaps the most famous example of Russian involvement in foreign uranium projects was in Mongolia, its neighbour to the south-east. While there are currently no operating uranium mines in Mongolia, its history depicts how Russia have exerted control over nations it considers part of its "*near-beyond*" as Katusa refers to it.

[5] https://www.kazatomprom.kz/storage/07/eng_annual_report_110523_fin4wbwrex2_y2ndvd6cvxnc.pdf
[6] https://interfax.com/newsroom/top-stories/85232/
[7] https://rosatomnewsletter.com/centralafrica/spreading-wings-in-namibia/

Russia and Mongolia co-developed the Dornod uranium mine together between 1988-1995, where Russia fronted the majority of the costs and the workforce peaked near 10,000 people. Once abandoned in 1995, interest returned eight years later in 2003 when Canadian-based, Khan Resources, took a majority stake in the project alongside the Mongolian government (as a partner). [8]

Once again, Putin's thirst for control was evident, when in 2010 Mongolia agreed to give Russia a 51% interest in any uranium mining projects that the Mongolian government were developing, forcing Khan out of the picture where the matter is now "*entombed in international litigation*". [9]

These examples give some perspective into how engrained Russia have become not only on the operational side of their foreign uranium ventures, but the economic and social side as well. Having control over the first stage of the fuel cycle is one thing, but as we know, uranium has a long journey ahead before it can be serviceable to a nuclear reactor, which is where the Russian grip drastically tightens.

## Conversion

A reminder, the second component of the fuel cycle is called conversion, a process that converts uranium oxide to uranium hexafluoride (UF6), or 'hex' for short. Currently, conversion plants are operating in only four countries globally; Canada, France, China, and Russia (a closed US plant is reopening in 2023).

| Company | Country | Location | Nameplate capacity (tU) | Capacity utilization (%) | Capacity utilization (tU) |
|---|---|---|---|---|---|
| **Orano (2022)** | France | Pierrelatte & Malvési | 15,000 | 60% | 9,000 |
| **CNNC (2022)** | China | Lanzhou & Hengyang | 15,000 | 73% | 11,000 |
| **Cameco (2022)** | Canada | Port Hope | 12,500 | 85% | 10,600 |
| **Rosatom (2022)** | Russia | Seversk | 12,500 | 96% | 12,000 |
| **ConverDyn (2022)** | USA | Metropolis | 7,000 | 0% | 0 |
| **Total** | | | **62,000** | **69%** | **42,600** |

*Figure 3: Estimated global primary conversion capacity 2022*

Russia is the dominant player in the conversion market, accounting for close to 30% of global production. The market for conversion has been operating in a supply deficit for several years, but much like the market for U3O8 and EUP, has relied on inventories which have been drawn down to historically low levels, causing prices to rise 800% between 2018-2023.

The chart below shows the current and projected supply/demand outlook in the conversion market.[10] It highlights the growing demand for UF6 over the next 20 years, and how idled capacity will be unavailable from 2026, meaning new, primary production is going to have to come online in the next few years even if we keep Russian conversion capacity in the market.

[8] https://world-nuclear.org/information-library/country-profiles/countries-g-n/mongolia.aspx

[9] Katusa, M. (2015). *The colder war : how the global energy trade slipped from America's grasp*

[10] https://world-nuclear.org/getmedia/9a2f9405-1135-407a-85c8-480e2365bee7/nuclear-fuel-report-2021-expanded-summary.pdf.aspx

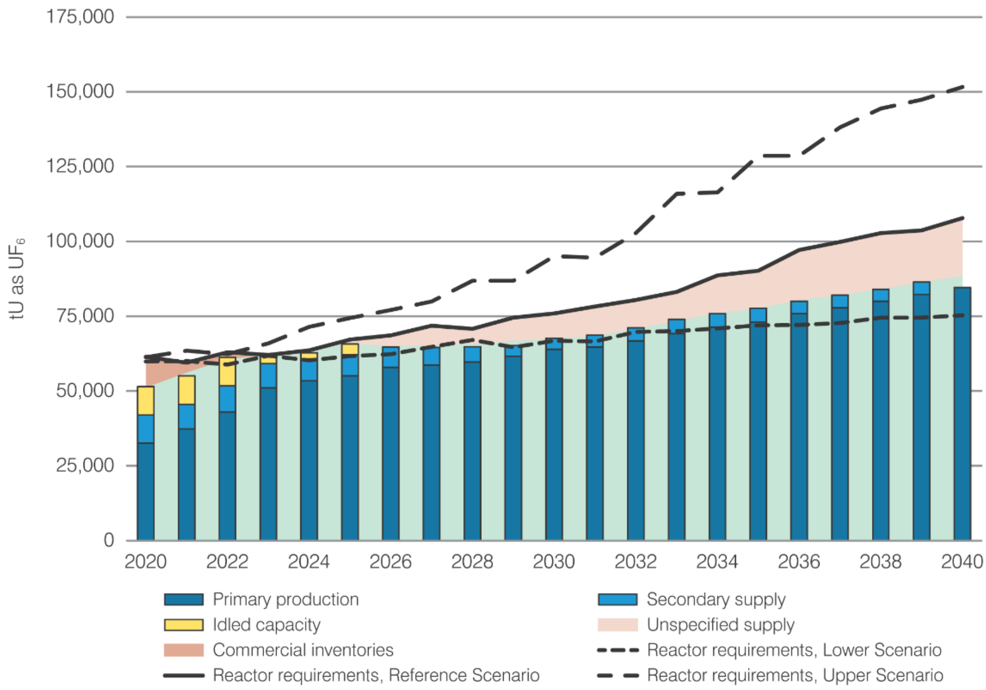


*Figure 4: Projected UF6 conversion supply vs demand [11]*

It is estimated that between ConverDyn and converters in Europe and Canada, total capacity is around 32,000 tU per year. Remove Russia, and there would be a deficit of 10,000-12,000 tU.[12]

As you can see from the Figure 3, there is spare conversion capacity that is not currently being used, so, would ramping up production be enough to supplement a removal of Russian conversion capacity?

The answer is, not for a while.

Firstly, CNNC have been actively increasing their conversion output from around 8,000 tU in 2020 to 11,000 tU in 2022, meaning the company is operating at 73% of nameplate.

Worth highlighting is that the numbers in Figure 3 are estimates for the conversion capacity that China will require to supply the needs of its domestic reactor fleet, in other words, this capacity is not available for open-market consumption.

In Canada, Cameco are currently running at 85% of their nameplate, with plans to go to 96% by 2024. Interestingly, this move to 96% is purely to satisfy their long-term contracts, in other words, this is not going to be available on the open market.

In 2017, ConverDyn shut down Metropolis in the US given weak market conditions, but with prices on the rise, is expected to restart in 2023, although our understanding is this is currently delayed. At maximum capacity, ConverDyn could produce up to 7,000 tU.

Orano had initially expected to produce 13,000 tU in 2022 given a transition to its new COMURHEX II facility, but due to some operational issues only produced 9,000 tU. Keeping in mind its full production potential is 15,000

[11] https://world-nuclear.org/getmedia/9a2f9405-1135-407a-85c8-480e2365bee7/nuclear-fuel-report-2021-expanded-summary.pdf.aspx
[12] https://www.ans.org/news/article-4909/on-the-verge-of-a-crisis-the-us-nuclear-fuel-gordian-knot/

tU per annum (cannot be extended beyond this), there is some flexibility here should they be able to resolve current issues.

In December 2022, Westinghouse received a UK government grant to explore uranium conversion services at the company's Springfields facility in Lancashire, England.[13] The £13m award will be used to prepare the necessary design and enabling work to begin new conversion capability, starting in 2028.

So, if Orano, Converdyn, Cameco, and CNNC are able to return to nameplate capacity, that would provide 49,500 tU to the market. The World Nuclear Association (WNA) estimates around 62,500 tU of demand today, meaning without Russia, even at nameplate, we will require new primary productive capacity. This will require billions in investment for capacity that will not come online until the end of the decade. In addition, there is little incentive to make these large investments without firm contractual commitments that Russian competition will be a thing of the past.

Agnieszka Kaźmierczak, Director General of the ESA – the company that maintain the supply of nuclear materials and fuel for EU utilities - recently highlighted that due to chronic under-capacity worldwide, it could take "*seven to 10 years*" to replace Rosatom, conditional on significant investments in the sector.[14]

Russia have once again capitalised on a process that they know requires deep technological and infrastructural expertise, a process that they know requires years of preparation to get right, and that is inherent to the process of delivering nuclear energy.

## Enrichment

In its natural form, uranium is made up for two isotopes; U-235 and U-238, they differ in mass and can therefore be separated through enrichment.

Uranium enrichment is the process of enriching uranium from 0.711% U-235 (the fissile isotope), to between 3-5%. This is the required enrichment level for most PWRs and BWRs (nuclear reactors) producing nuclear power in the world today. The Separative Work Unit (SWU) is a unit that defines the effort required in the enrichment process to separate these two isotopes to their desired levels, as such, enrichment costs are referred to in terms of $/SWU.

| Country | Company and Plant | Capacity (thousand SWU/yr) |
|---|---|---|
| France | Areva, Georges Besse I & II | 7500 |
| Germany-Netherlands-UK | Urenco: Gronau, Germany; Almelo, Netherlands; Capenhurst, UK. | 13,700 |
| USA | Urenco, New Mexico | 4900 |
| Russia | Tenex: Angarsk, Novouralsk, Zelenogorsk, Seversk | 27,700 |
| China | CNNC, Hanzhun & Lanzhou | 6300 |
| Other | Various: Argentina, Brazil, India, Pakistan, Iran | 66 |
| | **Total SWU/yr** | **60,166** |
| | **Requirements (WNA reference scenario)** | **50,205** |

*Figure 5: Estimated Global Primary Enrichment Capacity 2020* [15]

[13] https://info.westinghousenuclear.com/news/westinghouse-beis-award
[14] https://www.politico.eu/article/europe-just-cant-quit-russia-for-nuclear-power/
[15] https://world-nuclear.org/information-library/nuclear-fuel-cycle/conversion-enrichment-and-fabrication/uranium-enrichment.aspx

As we can see above, the Russian dominance in enrichment is significantly higher than in conversion, with over 45% of global capacity. Much like conversion, uranium enrichment is strategically sensitive and capital intensive, creating significant barriers to entry for any new supplier. Hence, there are relatively few commercial enrichment suppliers operating a limited number of facilities worldwide.[16]

Putin understands the importance of enrichment, and through Rosatom subsidiaries TENEX and TVEL, developed an enrichment stranglehold that supplies more than 30 utilities, in 16 different countries, and close to one in five global reactors. [17]

The current state of the enrichment market is one in transition. As with many global supply chains, there is a movement to remove Russian influence to enhance domestic energy security and defund Putin's war efforts. Uranium enrichment is a particularly difficult process to remove Russia given their productive dominance and competitive pricing.

In addition, much like for conversion, Chinese enrichment capacity should not be seen as available to the open market. Zhang Hui of Harvard University's Kennedy School of Government, states China's enrichment capacity "*is just able to meet (or match) its own domestic reactors' needs.*" [18]

Given tightening fundamentals and the uncertainty of future supply out of Russia, it was unsurprising to see SWU prices skyrocket in 2022 following Russia's invasion of Ukraine (+130% since Jan'22).

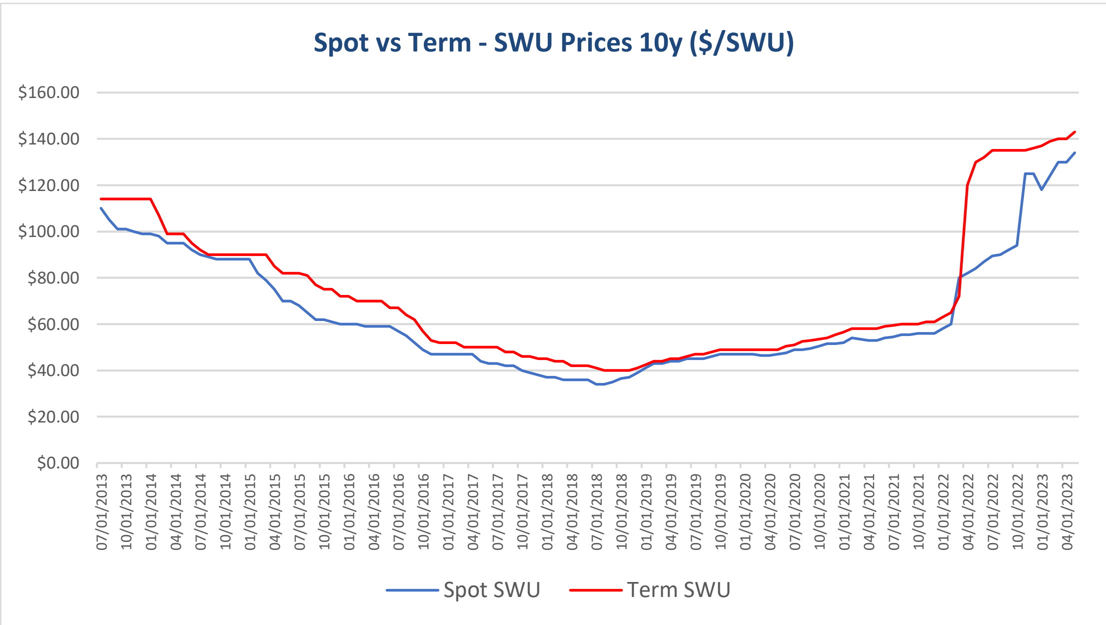


*Figure 7: Spot vs Term - SWU Prices 10y* [19]

Despite this, very few contracts have been awarded that directly support new capacity expansions. Those looking to remove Russian involvement in their fuel delivery will need to rely on significant investment in western enrichment capacity, while also shifting away from underfeeding (see definition below). [20]

[16] https://world-nuclear.org/information-library/nuclear-fuel-cycle/conversion-enrichment-and-fabrication/uranium-enrichment.aspx
[17] rosatom.ru/en/rosatom-group/fuel-and-enrichment/
[18] https://www.washingtonpost.com/business/2023/01/21/uranium-imports-russia-nuclear/
[19] https://www.uxc.com/c/prices/UxCPriceData.aspx
[20] *The utilities which buy uranium from the mines need a fixed quantity of enriched uranium in order to fabricate the fuel to be loaded into their reactors. The quantity of uranium they must supply to the enrichment company is determined by the enrichment level required (% U-235) and the tails assay (also % U-235).*

Already, enrichers in the West have started to reduce their underfeeding in order to increase EUP output, but this process is still in its infancy and won't fully transfer to overfeeding under 2025.

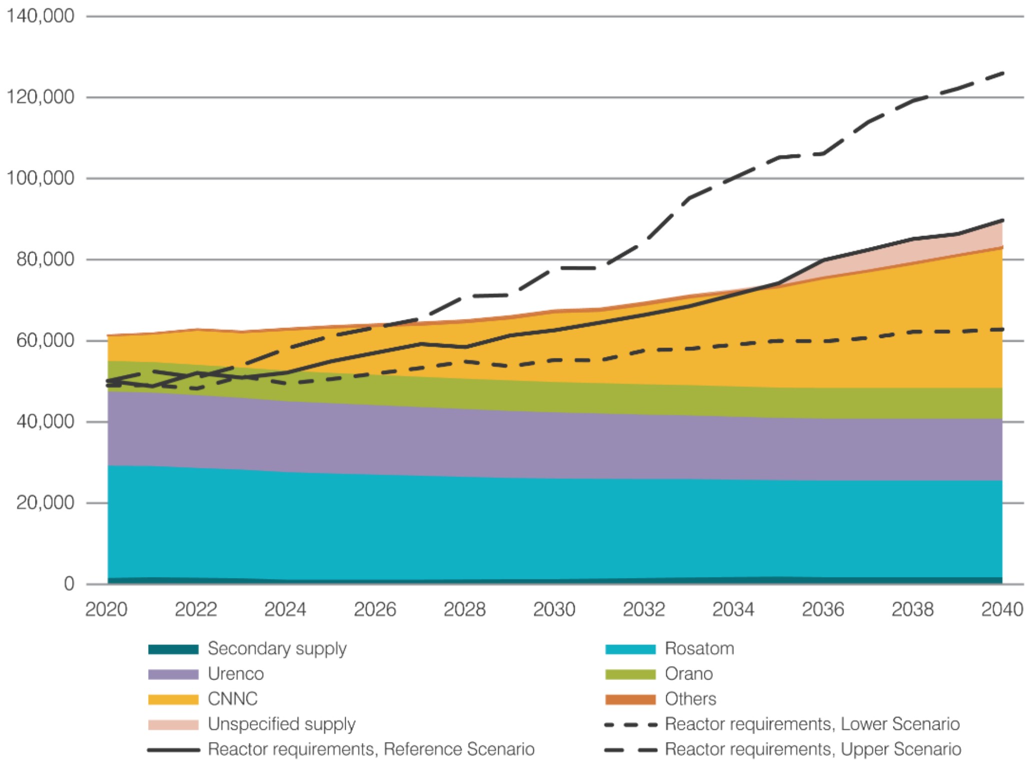


*Figure 7: World Enrichment Demand Scenarios vs Installed Capacity, Thousand SWU* [21]

The key point here is that regardless of a switch to overfeeding across the world's enrichment facilities, removing Russian enrichment supply in the open market will lead to a supply gap. Estimates from consultants UxC at the 2023 World Nuclear Fuel Cycle (WNFC) conference in The Hague stated that *"assuming at least 25% of Russian capacity remains available, new conversion and enrichment capacity is not needed until later in the decade"*.

Worth highlighting at this point is a concept that is core to our uranium thesis around the importance of fuel. The fuel buyer will never get in trouble for the price they pay for uranium, but for not securing its supply. The cost of shutting down a nuclear power plant represents hundreds of millions of dollars in costs and is therefore not an option. Not to mention the impact that a removal of a reactor would have on the grid and the associated cost of electricity.

As such, a supply gap of any kind is not an option, a case in point as to why we are yet to see significant sanctions on Russian nuclear fuel.

## Russian Enrichment

The history of Russia's involvement in uranium enrichment dates back to the 1940s where the Soviet Union built four large industrial uranium enrichment plants which all initially used gaseous diffusion (the first commercial process for enriching uranium). From 1964, gas centrifuges were introduced which produced highly enriched

*This is the contracted or transactional tails assay, and determines how much natural uranium must be supplied to create a quantity of Enriched Uranium Product (EUP) – a lower tails assay means that more enrichment services (notably energy) are to be applied. The enricher, however, has some flexibility in respect to the operational tails assay at the plant. If the operational tails assay is lower than the contracted/transactional assay, the enricher can set aside some surplus natural uranium, which it is free to sell (either as natural uranium or as EUP) on its own account. This is known as underfeeding - https://world-nuclear.org/information-library/nuclear-fuel-cycle/conversion-enrichment-and-fabrication/uranium-enrichment.aspx*

[21] https://world-nuclear.org/getmedia/9a2f9405-1135-407a-85c8-480e2365bee7/nuclear-fuel-report-2021-expanded-summary.pdf.aspx

uranium (HEU) for the Soviet Cold War nuclear stockpile. Production ceased in 1988 because of huge quantities of excess HEU (estimates of 1,250 tons of uranium enriched to 90%) which is where the story becomes relevant to the nuclear fuel landscape of today. [22]

## Megatons to Megawatts

On August 31st 1992, President George Bush announced the initiation of the Megatons to Megawatts Program, an agreement between Russia and the United States to convert 500 metric tons of excess weapons-grade uranium called highly-enriched uranium, or HEU (enough for 20,000 warheads) into 15,000 tons of low-enriched uranium (LEU), or as we have referred to it so far, 'EUP'.

Over the following two decades, up to 10% of the electricity produced in the US was generated by fuel fabricated using LEU from the Megatons to Megawatts program, or 50% of their enriched uranium requirements. The conversion and dilution of HEU was conducted in Russia, where it was sent to the then US Enrichment Company (USEC) in exchange for natural uranium. Over the course of the program, the United States sent more than $8bn to Russia for their comparatively cheap enrichment services. [23]

The agreement made sense for all parties. They were ridding the world of powerful weaponry, while also providing fuel for a clean and scalable source of electricity generation. But the true issue would arise because of complacency.

*"Given that it's not economically advantageous to add new capacity to a market that's already fully supplied, there should not be any surprise that there isn't sufficient capacity outside of Russia…The government wanted our utilities buying Russian uranium for a long time. Pivoting isn't something you do overnight."* – John Kotek, Senior VP, Nuclear Energy Institute

Over the course of the program, the US enriched no uranium, understanding that the agreement with Russia made their own enrichment capabilities obsolete given much higher costs of production. USEC who previously enriched uranium for US utilities would act as a broker, selling Russian LEU to US utilities at much higher prices than which they bought it.

## US Enrichment

After a financial restructuring in 2014, USEC re-emerged as Centrus Energy (LEU: NYSE) with the aim to expand the Company's operations.

Today, while the Megatons to Megawatts program has run its course, the US still have no domestic enrichment capacity (enrichment facility in New Mexico is owned and operated by Urenco). Centrus are developing enrichment capabilities for next-generation nuclear fuel (high-assay low-enriched uranium), however, have continued to make the vast majority of their revenue on marginal sales from Russia (TENEX) to US utilities.

The TENEX supply contract extends through 2028 and is subject to quotas and other restrictions under the Russian Suspension Agreement (RSA) which governs exports of Russian uranium products to the US. The RSA was extended on October 6th 2020 when the US Department of Commerce and Rosatom signed a final amendment to the agreement extending it through 2040 at the earliest.[24] Under this agreement, Russian uranium exports are only allowed to meet an average of 17% of US enriched uranium demand over the next 20 years, down from 20% today, aiming to reduce US reliance on Russian uranium over the years.

[22] https://scienceandglobalsecurity.org/archive/sgs19podvig.pdf
[23] https://www.centrusenergy.com/who-we-are/history/megatons-to-megawatts/
[24] https://www.federalregister.gov/documents/2020/10/09/2020-22431/2020-amendment-to-the-agreement-suspending-the-antidumping-investigation-on-uranium-from-the-russian

*"The amount of SWU we must purchase from TENEX under the TENEX Supply Contract exceeds our current Order Book and, therefore, we will need to make new sales to place all the Russian LEU we must order to meet our SWU purchase obligations to TENEX." – Centrus Annual Report, 2022* [25]

The current order book is approximately $1bn and extends through 2029. Centrus made $196m in revenue selling SWU to US utilities in 2022, the majority of which was processed in Russia.

On March 9th 2023, Joseph Dominguez, President and CEO of Constellation, stated the company had enough inventory and contracts to meet the needs of its fleet of 21 reactors until 2028, but that "*in the world of nuclear fuel, 2028 is tomorrow."* The United States, he said, is "*on the verge of a crisis."* [26]

This further highlights Russia's foothold in the US nuclear fuel market, something that has been three decades in the making and thus cannot be resolved overnight. Likewise, the incentive to build out new capacity in the US is limited without a firm commitment that Russian fuel services will no longer be permitted on US soil.

*"With Russian capacity in the market, the market is oversupplied with enrichment, but it would be savagely undersupplied without Russian supply. That creates a lot of uncertainty that inhibits investment."* - David Leistikow, Vice President, Centrus Energy

This same concept applies globally, there needs to be contractual commitments away from Russia for the significant capital required to build out new conversion and enrichment capacity. These commitments must be permanent, particularly if we are to see new capacity be built in the West.

Inevitably, there are countries where Russian nuclear fuel will still be imported, countries where Russia's invasion of Ukraine does not hold the same level significance perhaps. Above all, Russia has established a presence not only in the fuel cycle, but reactor construction as well, which presents a new obstacle entirely.

## HALEU

High-assay low-enriched uranium (HALEU), is the fuel required for next-generation nuclear reactors. In fact, nine out of the 10 advanced reactors funded by Washington are designed to use HALEU.

HALEU is uranium that has been enriched so that the concentration of the fissile isotope U-235 is between 5-20% of the mass of the fuel. This is higher than the 3-5% U-235 concentration, or "assay," of Low-Enriched Uranium (LEU) that fuels the existing fleet of light water reactors.[27]

The only commercial supply of HALEU is currently from Rosatom subsidiary, TENEX. As a result, those who have been pioneering the development of advanced reactors had no choice but to obtain their research fuel from Russia, with some ordering their first fuel load from TENEX as well.

The lack of available options in the HALEU market has been of detriment to the reactor developers, who are unsure that the product they are designing and ultimately marketing for sale will have the fuel required to service it.

"*Nobody wants to order 10 reactors without a fuel source, and nobody wants to invest in a fuel source without 10 reactor orders*" – Daniel Poneman, CEO, Centrus Energy

Centrus are one the few companies investing heavily in HALEU and were due to start production at the start of 2023. However, delays in the supply of the storage containers they required were a result of the global pandemic, and as such, commercialisation has been pushed back.

[25] https://investors.centrusenergy.com/static-files/412577b8-1b85-4416-9b3a-191e54d02bfa
[26] https://www.ans.org/news/article-4909/on-the-verge-of-a-crisis-the-us-nuclear-fuel-gordian-knot/
[27] https://www.centrusenergy.com/what-we-do/nuclear-fuel/high-assay-low-enriched-uranium/

The news was welcomed in February 2023 that Centrus has completed construction of a cascade of advanced uranium enrichment centrifuges as well as most of the associated support systems, putting the company on track to begin demonstrating HALEU production by the end of 2023. This will be the first new US-owned, US-technology enrichment plant to begin production in 70 years.[28]

However, the volumes being produced will not be commercially viable for several years, with the company indicating that "*a full-scale HALEU cascade, consisting of 120 individual centrifuge machines, with a combined capacity of approximately 6,000 kilograms of HALEU per year (6 MTU/year), could be brought online within about 42 months of securing the funding to do so.*"

Furthermore, the 'chicken and egg' scenario also means that while existing enrichment companies, such as Urenco, Orano, and GLE could make HALEU, there will be reticence to be too focused on building highly capital intensive HALEU infrastructure without contractual commitments and confidence that this will be a profitable market. Industry estimates are that establishing a commercial-scale production capability would cost more than $500 million. [29]

The bottom line is, if advanced-reactor developers are looking to obtain HALEU outside of Russia, they will have to wait several years. This is already having an impact, with Bill Gates, founder of TerraPower (a company developing its Natrium plant in Wyoming which will require HALEU), saying the project has been delayed at least two years due to a lack of advanced reactor fuel sources outside of Russia. [30]

### Fuel Fabrication

Fuel fabrication is the last step in the process of turning uranium into nuclear fuel rods. Given the large amounts of energy that nuclear fission delivers, the fuel must be held in a robust physical form that can withstand high operating temperatures and intense neutron radiation over a period of several years, while maintaining their shape. [31]

These pellets are batched into assemblies and the fuel rods form the majority of a reactor core's structure. Most importantly, these fuel assemblies are specifically designed for their reactor type meaning utilities have limited choices in terms of suppliers outside of their original manufacturers.

## Construction, Maintenance & Refuelling

Today there are about 440 nuclear power reactors operating in 32 countries, with a combined capacity of about 390 GWe. In 2021 these provided 2,653 TWh, about 10% of the world's electricity. [32]

[28] https://www.centrusenergy.com/news/centrus-completes-construction-and-initial-testing-of-haleu-demonstration-cascade-expects-to-begin-production-by-end-of-2023/
[29] https://oilprice.com/Alternative-Energy/Nuclear-Power/Russias-Uranium-Dominance-Threatens-Americas-Next-Gen-Nuclear-Plans.html
[30] https://www.nucnet.org/news/lack-of-fuel-could-delay-bill-gates-natrium-reactor-by-two-years-12-4-2022
[31] https://world-nuclear.org/information-library/nuclear-fuel-cycle/conversion-enrichment-and-fabrication/fuel-fabrication.aspx
[32] https://world-nuclear.org/information-library/current-and-future-generation/plans-for-new-reactors-worldwide.aspx#:~:text=Today%20there%20are%20about%20440,notably%20China%2C%20India%20and%20Russia.

The main type of nuclear reactors operating in the world today are Pressurised-Water Reactors (PWRs), accounting for about 70% of global reactors. [33]

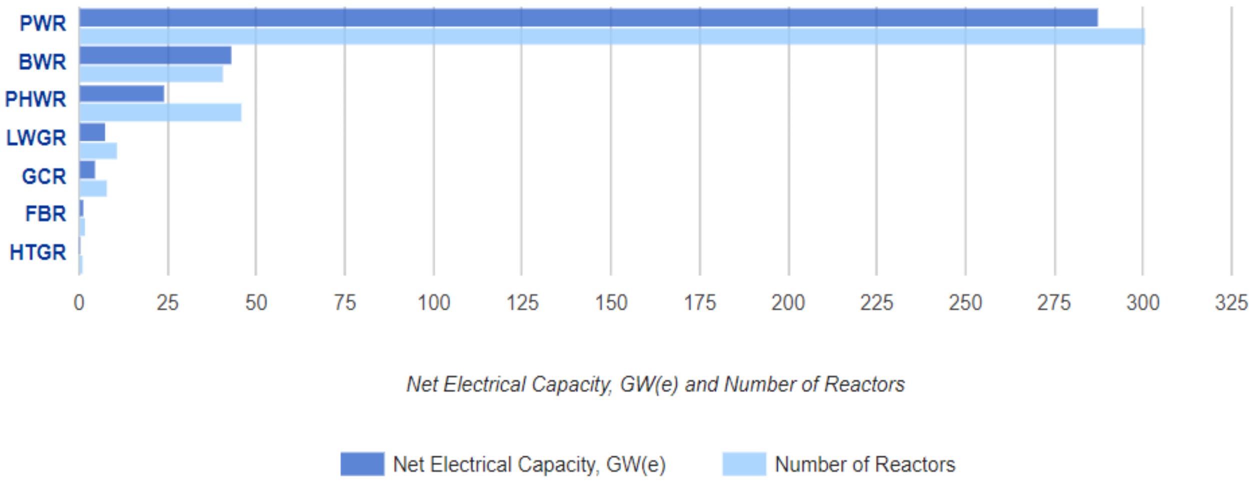


*Figure 8: Operating Nuclear Reactors Globally by Type* [34]

For context, Russian nuclear reactor designs are all PWRs, but are referred to as VVER ("*water-water energetic reactor*"). These designs were originally developed in the 1970s, and for simplicity have been split into three different versions for this report (there are also different designs within these): [35]

- VVER-440 (MW) – Gen II
- VVER-1000 (MW) – Gen III
- VVER-1200 (MW) – Gen III+

Russia has exported more reactors in recent decades than any other major supplier, in fact, close to one in five reactors globally are either in Russia or built by Russia.[36]

Domestically, Rosatom has unveiled plans to build 29 new nuclear reactors by 2045 in Russia, including 12 new nuclear reactors by 2035.[37]

But it is the foreign projects that Russia is involved with that hold the most weight.

With 23 reactors operating, and 27 under construction globally (excluding Ukraine and Russia where there are another 53 operating and 26 under construction), Russia has a strong foothold in the construction of nuclear power plants.

[33] https://www.world-nuclear.org/uploadedFiles/org/WNA/Publications/Nuclear_Information/Pocket%20Guide%20Reactors.pdf
[34] https://pris.iaea.org/PRIS/WorldStatistics/OperationalReactorsByType.aspx
[35] https://www.rosatom.ru/upload/iblock/0be/0be1220af25741375138ecd1afb18743.pdf
[36] https://www.energypolicy.columbia.edu/wp-content/uploads/2022/05/RussiaNuclearMarkets_CGEP_Commentary_051822-2.pdf
[37] https://www.enerdata.net/publications/daily-energy-news/russia-plans-build-29-new-nuclear-reactors-2045.html#:~:text=A%20plan%20to%20develop%2012,(225.5%20TWh%20in%202021).

| Country | Plant | Type | Status |
|---|---|---|---|
| Armenia | Armenian 2 | VVER-440 | Operating |
| Belarus | Belarusian 1 | VVER-1200 | Operating |
| Belarus | Ostrovets 1-2 | x2 VVER-1200 | Operating |
| Bulgaria | Kozloduy 5-6 | VVER-1000 | Operating |
| China | Tianwan 1-4 | VVER-1000 | Operating |
| Czech Republic | Temelin 1-2 | VVER-440 | Operating |
| Czech Republic | Dukovany 1-4 | VVER-1000 | Operating |
| Hungary | Paks 1-4 | VVER-440 | Operating |
| India | Kudankulam 1-2 | VVER-1000 | Operating |
| Iran | Bushehr 1 | VVER-1000 | Operating |
| Slovakia | Mochovce 3-4 | VVER-440 | Operating |
| | **Total Reactors: 26** | | |

*Figure 9: Global Russian Designed Operating NPPs Excluding Russia & Ukraine [38]*

| Country | Plant | Type | Est. cost ($/bn) | Status |
|---|---|---|---|---|
| Armenia | Metsamor 3 | VVER-1000 | 5 | Contracted |
| Bangladesh | Rooppur 1-2 | x2 VVER-1200 | 13 | Construction Started |
| China | Tianwan 7-8 | x2 VVER-1200 | 3 | Construction Started |
| China | Xudabao 3-4 | x2 VVER-1200 | 8 | Construction Started |
| Egypt | El Dabaa 1-4 | 4 x VVER-1200 | 30 | Construction Started |
| Hungary | Paks 5-6 | 2 x VVER-1200 | 12.5 | Contracted |
| India | Kudankulam 3-4 | VVER-1000 | 6 | Construction Started |
| India | Kudankulam 5-6 | 2 x VVER-1000 | 8 | Construction Started |
| Iran | Bushehr 2-3 | x2 VVER-1000 | 10 | Construction Started |
| Slovakia | Bohunice 1&2 | 2 x VVER-440 | 3 | Planned |
| Turkey | Akkuyu 1-4 | x4 VVER-1200 | 25 | Construction Started |
| Uzbekistan | Lake Tudakul | 2x VVER-1200 | 13 | Planned |
| | | | **Total ($/bn): 136.5** | |

*Figure 10: Export Sales and Prospects for Russian NPPs Excluding Russia & Ukraine (post-Soviet) [39]*

Others estimate that the scope of Rosatom's presence extends as far as 73 different projects in 29 countries, and altogether, Russia's nuclear energy diplomacy has been formalised in 54 countries. [40]

Interestingly, the WNA highlights that the Ministry of Foreign Affairs is responsible for promoting Russian technologies abroad, including the implementation of various Rosatom officials in Russian embassies.

Support for nuclear is engrained in Russian state-policy. In 2016, Rosatom and the Bank for Development and Foreign Economic Affairs (Vnesheconombank) agreed to develop their cooperation to support Rosatom's

[38] https://pris.iaea.org/pris/
[39] https://world-nuclear.org/information-library/country-profiles/countries-o-s/russia-nuclear-power.aspx
[40] https://doi.org/10.1038/s41560-023-01228-5

investments in projects overseas. Importantly, Rosatom said that "*it will contribute to the growth of the Russian economy and the expansion of Russia's presence in the global nuclear energy market".*

Figure 10 shows the current order book for Russian made VVERs globally, representing costs close to $150bn. Other estimates show the Rosatom foreign orders to be as high as $200bn.[41]

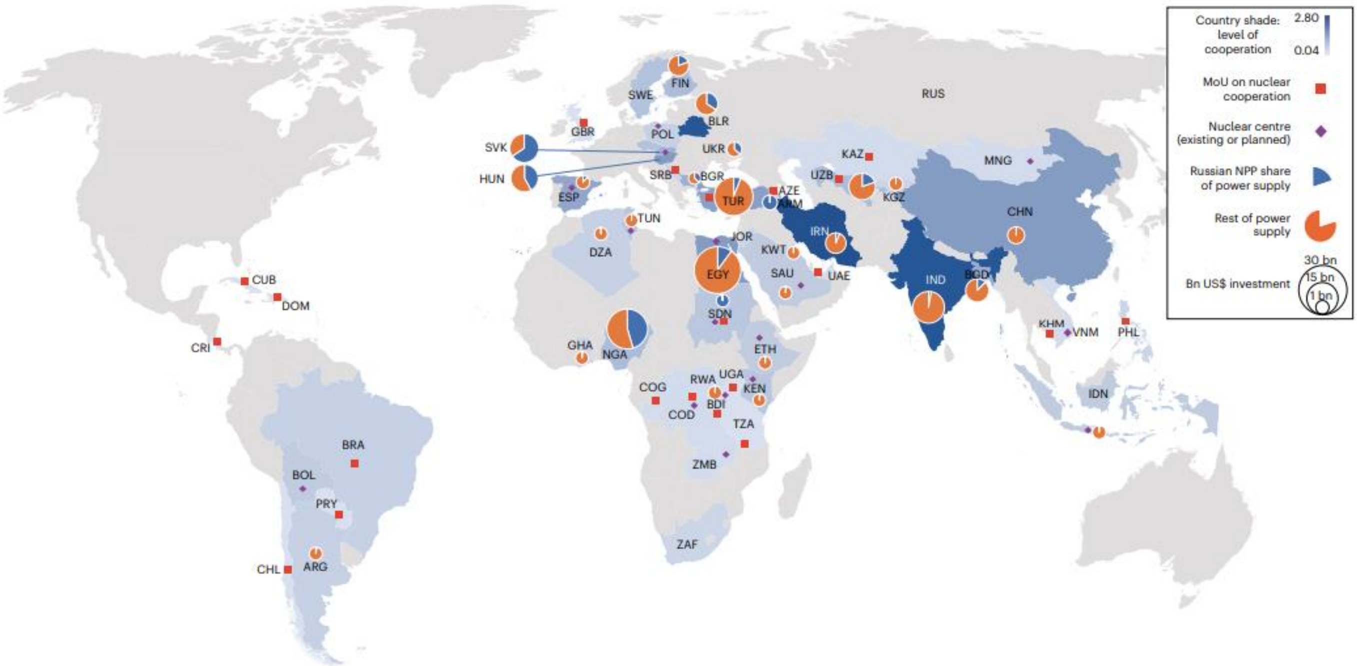


*Figure 11: Russian nuclear engagements around the world [42]*

Figure 11 gives an overview of the importance of these reactors to the various countries in which they operate, in terms of contribution to the country's broader electricity output. We once again see the integral role Rosatom plays in international energy strategies, and thus, how it can establish influence within a plethora of different countries. We also note that in terms of NPP construction, the North America has no exposure to Russia, however, as we have discussed are heavily reliant on them for nuclear fuel.

Within reactor construction, there are two more elements key to this report:

- The favourable financing provided by Russia for these projects
- The recurring revenue they will receive in perpetuity for at least the life of the reactor

Let's start with the latter.

## A One-Stop Nuclear Shop

Global operators of nuclear reactors have significant reliance on the original equipment manufacturers (OEMs) given the unique components that their OEM designed and built for their specific reactor type.

Additionally, the nature of the industry tends to be conservative considering the substantial power inherent to nuclear fission. As such, reactor operators would much prefer maintenance services to be conducted by the plant OEM as they are most familiar with the design.

[41] Russia / Despite 'Geopolitical Situation', Rosatom Expects Exports To Increase 15% :: NucNet | The Independent Nuclear News Agency
[42] https://www.nature.com/articles/s41560-023-01228-5

This was referenced in a recent report from the University of Colombia which outlines components of nuclear plants that require the OEMs of VVERs involvement on a recurring basis: [43]

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

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

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

In addition, Russian operators and experts will often remain involved once the reactor itself is online, particularly in countries where the skillsets are not necessarily available such as the Middle East, sub-Saharan Africa, and South America. This makes nuclear not only widely accessible but further cements Russian involvement in these projects which as we know can run for 80-100 years.

In other cases, where local experts will be the ones operating the reactor throughout its lifecycle, they will be trained by Russian engineers and rely on the OEM for further training during the plant's lifetime.

As such, Rosatom's main advantage lies in its ability to be a '*one stop nuclear shop'* for all needs, the only supplier providing an '*all-inclusive package'* whereby the customer does not need to engage different parties of the reactor build and upkeep from different sources.[44]

The Columbia University note referenced above estimates that "*the purchases of capital supplies required to run the existing global fleet is $4.3 billion annually."* In other words, reactor maintenance is a $4.3bn a year industry for Russia.

The question therefore is, are there any alternatives?

### Alternatives

Realistically, there is one alternative that could supplement at least some Russian services in aspects such as fuel fabrication, and maintenance.

Westinghouse is one of the world's leading suppliers of nuclear technology, infrastructure, and fuel, and are the only realistic Western alternative to Russian nuclear services.

From a fuel perspective, Westinghouse have, for many years, produced the fuel required for VVER-1000 reactors, and as such, will be able to supplement some of the fuel requirements for these reactors globally.

However, for the smaller VVER-440 reactors, Westinghouse still had not produced a successful fuel design when Russia invade Ukraine. However, at the recent World Nuclear Fuel Market (WNFM) conference in Slovenia, Westinghouse's President of Nuclear Fuel, Tarik Choho noted that the company had proceeded with investments in VVER fuel development right after the invasion started, highlighting that Eastern European utilities in particular are taking dramatic steps to shift away from TVEL (Russia).

[43] https://www.energypolicy.columbia.edu/publications/reducing-russian-involvement-western-nuclear-power-markets/
[44] https://rosatomnewsletter.com/2023/03/22/cooperation-in-nuclear-energy/

Westinghouse are also winning contracts in plant construction in Europe.

Evidence of these changes can be seen in the case studies below:

- In October 2022, Poland awarded Westinghouse the contract to build its first nuclear power plant. US Energy Secretary, Jennifer Granholm, noted after the decision: "*This announcement also sends a clear message to Russia: We will not let them weaponize energy any longer…the West will stand together against this unprovoked aggression, while also diversifying energy supply chains and bolstering climate cooperation.*" [45]
- In November 2022, Finnish power company Fortum announced it will begin buying nuclear fuel from Westinghouse having used solely Russian fuel for its reactors since 2008. [46]
- In December, Westinghouse signed a 10-year agreement to supply nuclear fuel to one of the existing Bulgarian units from 2024. Then, in March 2023, Westinghouse and Kozloduy NPP in Bulgaria signed a MoU to initiate planning for the potential deployment of one or more of its AP-1000 reactors at Bulgaria's Kozloduy nuclear power plant. [47]
- The Czech Republic signed a deal in March 2023 for Westinghouse to supply nuclear fuel for the Dukovany nuclear plant, eliminating the country's dependence on Russia for such fuel where TVEL was previously the sole supplier. [48]
- In January 2023, Westinghouse formalised an agreement, first announced in September 2022, to expand cooperation with Spain's nuclear fuel company Enusa on the manufacturing of nuclear fuel for Russia-made VVER-440 pressurised water reactor designs. [49]
- Slovakia is also trying to cut its Russian links for supplies to its VVER-440 reactors with CEO of the country's nuclear operator saying, "We launched an international tender for new supplies of nuclear fuel a month ago". Westinghouse are in the discussion for this contract. [50]

The general picture is clear. Westinghouse will be a beneficiary of the trend to remove Russian influence in the nuclear supply chain, be it in fuel markets or construction. As to whether or not the company will be able to capitalise on the recurring revenue opportunity for maintenance and component parts, remains to be seen.

### Project Financing

While Russian technology and expertise in nuclear reactor construction is inevitably best-in-class, they also offer by far the most favourable financing options for these reactors.

While there are various cases where Russia has offered significant loans and financing for nuclear projects they are developing, a stand-alone case study is that of Turkey, where Russia is building four units for what will be the country's first nuclear power plants.

It was this project where Rosatom first introduced the 'Build-Own-Operate' (BOO) model, which allows Rosatom to keep the majority ownership of the facility while bearing the upfront and ongoing financial and operational burden.

This model gives another glimpse at how Rosatom and Russia become embedded in the infrastructure of the nations in which they have nuclear projects. Rosatom Overseas expects to be operating 24 BOO's by 2030.[51]

[45] https://www.politico.eu/article/poland-picks-westinghouse-to-build-its-first-nuclear-power-plant/
[46] https://www.reuters.com/business/energy/finlands-fortum-turns-us-bid-replace-russian-nuclear-fuel-2022-11-22/
[47] https://world-nuclear-news.org/Articles/Westinghouse-signs-MoU-for-AP1000-in-Bulgaria
[48] https://apnews.com/article/czech-westinghouse-nuclear-fuel-cez-rosatom-42bd1f8b2be09fa9cb218157bfd122c3
[49] https://www.nucnet.org/news/westinghouse-and-enusa-formalise-agreement-for-vver-440-reactor-designs-1-4-2023
[50] https://intellinews.com/czechia-and-slovakia-accelerate-decoupling-from-decades-long-nuclear-partnership-with-moscow-256446/
[51] https://world-nuclear.org/information-library/country-profiles/countries-o-s/russia-nuclear-power.aspx

| Country | Plant | Status | Cost | Financing |
|---|---|---|---|---|
| Bangladesh | Rooppur 1-2 | Under Construction | $13bn | Russia is providing $500m then $1.5bn to cover 90% of the first unit's construction [52] |
| Belarus | Ostrovets 1-2 | Operating | $34bn | Russia financed the majority of the project. Establishing loan project for over 25 years [53] |
| Belarus | Belarusian 1 | Operating | $11bn | Russia issued a loan of up to $10bn [54] |
| Egypt | El Dabaa 1-4 | Under Construction | $30bn | The project is financially supported by Rosatom through a Russian loan amounting to $25bn [55] |
| Finland | Hanhikivi | Cancelled | $7.9bn | Russia allocated $2.3bn from the country's sovereign wealth fund [56] |
| Hungary | Paks 1-2 | Operating | $10bn | Russia provided low-interest finance to cover 80% of the €12bn cost [57] |
| Hungary | Paks 5-6 | Contracted | $12.5bn | Russia will finance most of the project with a $10bn loan [58] |
| India | Kudankulam 3-4 | Under Construction | $6bn | Russia to provide financing of up to $3.4bn [59] |
| India | Kudankulam 5-6 | Under Construction | $8bn | Russia loaned India $4.2bn to help fund construction [60] |
| Jordan | Unknown | Cancelled – negotiations taking place again April 2023 | $10bn | Russia was to contribute at least 49% of the project's $10bn cost [61] |
| South Africa | Unknown | Cancelled due to unconstitutionality | $76bn | In 2014, Rosatom offered to provide up to eight nuclear reactors to South Africa by 2023, in a $50bn strategic partnership between the two countries [62] |
| Turkey | Akkuyu 1-4 | Under Construction | $25bn | Rosatom to build, own and operate the Akkuyu plants as a $20bn project [63] |
| Vietnam | Ninh Thuan 1 | Cancelled | $9bn | Russia was to finance at least 85% of the $9bn for this first plant and then $500m for a nuclear science and technology centre [64] |

*Figure 12: Case Studies of Rosatom NPP Financing*

[52] https://world-nuclear.org/information-library/country-profiles/countries-a-f/bangladesh.aspx
[53] https://world-nuclear.org/information-library/country-profiles/countries-a-f/belarus.aspx
[54] https://www.ft.com/content/a98322de-96f7-11e7-b83c-9588e51488a0
[55] https://www.reuters.com/article/us-egypt-russia-nuclear-idUSKCN0YA1G5
[56] https://www.world-nuclear-news.org/Articles/Russia-approves-$2-3-billion-funding-for-Hanhikivi
[57] https://world-nuclear-news.org/Articles/Hungary-gets-agreement-to-delay-Paks-II-loan-repay
[58] https://www.world-nuclear-news.org/Articles/Hungarian-minister-highlights-importance-of-nuclea
[59] https://economictimes.indiatimes.com/news/politics-and-nation/russia-to-give-3-4-billion-credit-for-two-more-atomic-power-plants-in-tamil-nadu/articleshow/15020087.cms?from=mdr
[60] https://economictimes.indiatimes.com/industry/energy/power/units-5-6-at-kudankulam-nuclear-power-plant-to-cost-rs-50000-crore/articleshow/58959079.cms?from=mdr
[61] https://www.reuters.com/article/us-jordan-nuclear-russia-idUSKBN0MK2QD20150324
[62] https://www.economist.com/middle-east-and-africa/2017/03/16/south-africas-love-affair-with-russia
[63] https://www.enerdata.net/publications/daily-energy-news/rosatom-changes-akkuyu-nuclear-plant-builder-russian-owned-firm-turkey.html#:~:text=Akkuyu%20Nuclear%20is%20building%20the,although%20further%20delays%20are%20possible.
[64] https://www.world-nuclear-news.org/nn-russia-signs-framework-agreement-for-vietnams-ninh-thuan-1-03081501.html

The cost of building a nuclear power plant is so high that it is the job of the state to finance such projects, and even they often cannot afford to. In those cases, Rosatom has often stepped in, offering credit lines guaranteed by the Russian government and in some cases long-term contracts to provide fuel for or even run the plant. [65]

## Trade Routes

We have written extensively on this subject in the past, discussing how the St Petersburg trade route is currently the only commercially viable option for Kazakh-uranium being sent to the West.

We concluded that the alternative routes for Kazakh-uranium via the Trans-Caspian Route (TITR) faced significant hurdles that would create a bottleneck in uranium exports should the primary St Petersburg route become unavailable due to sanctions. Full report referenced below. [66]

While uranium has successfully been shipping via the TITR, requests for expanding the quota permitted via this route have so far failed due to a lack of transit permissions from Azerbaijan and Georgia.[67]

In addition, a nascent route from Kazakhstan to China has been mentioned as an alternative to the St Petersburg route, but we have similar conclusions around the viability of this route due to a lack of Chinese infrastructure and incentive to export uranium to the US via Shanghai.

As such, Russia still holds the dominant hand in terms of the transport of nuclear fuel out of Central Asia (40% of global supply).

## Sanctions

Despite thousands of sanctions on Russia to date, there have been none impacting the operations of the uranium and nuclear industries directly.

Even when you see headlines such as "New UK sanctions on Russian energy to include Rosatom and nuclear energy", the fine print details read: *"…sanctions will be placed on Matex, which produces composite materials based on carbon fibre for Rosatom that could be used for military purposes, and Triniti, whose research and development into laser physics is directly funded by the Russian Federation's State Defence Order".*[68]

There have been calls for the EU to include Rosatom in their next wave of sanctions, with particular calls from Ukraine.[69] On January 11th 2023, an entry to the European Commission called for sanctions against Rosatom: [70]

- Does the Commission intend to propose sanctions against Rosatom and its subsidiaries and have the firm's projects discontinued?
- Does the Commission back the introduction of strict export control measures in order to prevent Western equipment and technology from being supplied to Atomflot and Rosatom?

The 10th and 11th packages of sanctions from the EU excluded Rosatom, despite calls from several EU member states to target the company by "*limiting imports of nuclear fuel, stopping new investment into power plants, and restricting exports to Russia that will benefit this industry".* [71]

[65] https://edition.cnn.com/2023/03/06/energy/russia-nuclear-industry-no-sanctions/index.html
[66] https://oceanwall.com/wp-content/uploads/2022/10/Transport-Report.pdf
[67] https://www.reuters.com/markets/commodities/worlds-biggest-uranium-miner-seeks-extra-shipping-capacity-bypassing-russia-2022-10-26/
[68] https://www.power-technology.com/news/new-uk-sanctions-russian-energy-include-rosatom-nuclear-energy/
[69] https://www.reuters.com/business/energy/ukraine-expects-eu-include-russias-rosatom-next-sanctions-2023-01-09/
[70] https://www.europarl.europa.eu/doceo/document/E-9-2023-000068_EN.html
[71] https://www.euractiv.com/section/europe-s-east/news/pressure-mounts-on-eu-to-sanction-rosatom-in-next-russia-sanctions-package/

In the US, despite multiple gatherings in the senate to discuss the issue of sanctioning Russia's nuclear industry, no date has been specified when these initiatives will be put into action. Once again, while the headlines read: "*Bill banning uranium imports from Russia passes US House subcommittee*", giving the impression that something has been actioned, the details of the bill include waivers allowing the import of Russia LEU if the US determines there are no alternatives for US utilities, or if shipments are in the national interest.

The details of this bill are below: [72]

*IN GENERAL. —The importation into the United States of low-enriched uranium, including low-enriched uranium obtained under contracts for separative work units, that is produced in the Russian Federation, whether or not such low-enriched uranium is derived from highly enriched uranium of weapons origin, may not exceed—*

- *"(I) in calendar year 2023, 578,877 kilograms;*
- *"(II) in calendar year 2024, 476,536 kilograms;*
- *"(III) in calendar year 2025, 470,376 kilograms;*
- *"(IV) in calendar year 2026, 464,183 kilograms;*
- *"(V) in calendar year 2027, 459,083 kilograms.*

In other words, by 2027, the US expects to still be importing over one million lbs of LEU from Russia.

While widespread national sanctioning has yet to hit the Russian nuclear industry, there have been some cases of self-sanctioning.

The earliest example of this was Vattenfall in Sweden which ended nuclear fuel deliveries from Russia on the day of their invasion of the Ukraine.[73]

In addition, Finland suspended a power plant construction project with Rosatom, decreasing the corporate portfolio to 34 power units in the pipeline, where Rosatom are now seeking compensation for the "*unlawful termination*" of the Hanhikivi I project. [74]

An overlooked consideration is retaliatory sanctioning from Russia who could ban the export of uranium products to the US and other countries which have imposed sanctions.

Sanctioning Rosatom comes with many moving parts. We note that while gaps in mining the raw material and conversion components can be filled in the short-medium term, there are very limited and often no alternatives for Russian conversion and enrichment capacity, construction expertise, or reactor maintenance services.

In addition, the 27 reactors Russia has under construction in other nations creates the potential for projects that will not reach completion should those countries decide to sanction Rosatom or Russia more broadly.

Even if one country, or a handful of countries sanction Rosatom, how much impact will it really have in defunding Putin's war chest? While the intent is understandably more important than the end-cost, it will require a global effort for any meaningful impact to be made on Russia's bottom line.

Even then, there are countries where Putin's invasion of Ukraine holds less significance, and thus will maintain their relationship with Russia. China is one such example which is particularly significant for Rosatom given the country's mammoth nuclear growth strategy. In other words, if the US nuclear industry sanction Russian nuclear fuel exports, couldn't they just sell to China, India, South Korea, Japan, and the likes instead?

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[72] https://www.congress.gov/bill/118th-congress/house-bill/1042/text
[73] https://group.vattenfall.com/press-and-media/newsroom/2022/vattenfall-stops-delivieries-of-russian-nuclear-fuel
[74] https://www.world-nuclear-news.org/Articles/Rosatom-seeks-compensation-for-cancelled-Finland-p

The answer to this lies ahead, and is beyond the scope of this report, but we would expect that with nuclear capacity growing globally in-light of the war on climate change, that demand for Rosatom's various product-lines in nuclear will continue to grow, not retract.

## Conclusion

The current obstacles that are facing global economies in removing Russia from their nuclear supply chains is no mistake, it is decades of work coming to fruition.

As Paul Dorfman, Chairman of the Nuclear Consulting Group puts it: "*… [the problem is a] Russian doll's worth of interlocking dependencies*".[75]

The nuclear industry is a highly bifurcated ecosystem with numerous moving parts. As we have seen, only a handful of countries can deliver the services needed for the different components of the nuclear supply chain.

But only one can do it all.

Putin's plan goes beyond fuel requirements, plant construction, and favourable financing, but delves deep into social infrastructures through funding education initiatives, and employment prospects, particularly in the places that need it most.

Russia has a stranglehold on the nuclear industry that cannot be replaced in the short or even medium term, and as such, most Russian nuclear operations remain unsanctionable.

[75] https://markets.businessinsider.com/news/stocks/will-the-eu-sanction-russias-nuclear-industry-1032274892

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