



DUAL-USE ZIRCONIUM

Assessment of Russian production, raw-material base, and the effectiveness of international trade restrictions

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KEY FINDINGS

01

Zirconium is a critical dual-use resource, essential to both civil and military sectors. It functions as an integral component to nuclear power reactors, nuclear icebreakers, and nuclear submarines – a core element of Russia's nuclear triad. Zirconium enhances the efficiency of modern military hardware, including gas turbine engines, ammunition, and composite armour.

02

Without zirconium, the nuclear fuel cycle in both civil and military domains would be severely constrained.

03

Russia is the only country that possesses a fleet of nuclear icebreakers, powered by reactors with zirconium cladding. These vessels are crucial for Arctic development and for maintaining navigation along the Northern Sea Route.

04

JSC Chepetskiy Mechanical Plant, a subsidiary of TVEL/Rosatom, plays a crucial role in the Russian zirconium sector. The plant is a global manufacturer of zirconium alloys, supplying components to more than 70 reactors across 15 countries. It serves Russia's military-industrial complex, its nuclear fleet, and both civil and defence energy sectors. The enterprise provides structural materials for all of Russia's nuclear installations.

05

Russia's zirconium resource base is extensive yet underdeveloped. Key challenges include remote deposits, high extraction costs, and reliance on complex multi-stage processing technologies.

06

Prior to 2022, Russia relied heavily on imported zirconium feedstock, notably from Ukraine. Russia's exploration of domestic deposits has only partly mitigated the shortfall.

07

The Netherlands has been providing nearly half of Russia's zirconium raw materials since early 2024. Other key exporters to the Russian market include India, China, and Spain.

08

The existing sanctions regime on Russia's zirconium and its nuclear sector remains fragmented and insufficient. At the EU level, there are no comprehensive restrictions on Rosatom or its subsidiaries. Member states such as Hungary, France, and Bulgaria are blocking tougher measures due to their own energy dependency. Thus, Russia retains access to European markets, foreign currency revenues, and critical equipment, while strategically leveraging its nuclear technologies as a tool of soft power.

ZIRCONIUM AND ITS PROPERTIES



Zirconium (Zr) is a chemical element, it has atomic number 40, and is a lustrous, greyish-white metal

The most significant zirconium-bearing mineral is **zircon** (ZrSiO_4), an ore that yields both zirconium, and the rare metal hafnium.

Chemically, zirconium resembles titanium; it is refractory and highly resistant to corrosion from alkalis, acids, salt water, and other agents. Like titanium, it is predominantly utilised in its oxide form (ZrO_2). Pure zirconium is primarily implemented in nuclear energy sector,¹ while commercial grades typically contain 1-3% hafnium, a closely related metal.

Zirconium occurs in the Earth's crust at an average concentration of around 130 mg/kg (and 0.026 $\mu\text{g/L}$ in seawater). There are more than 30 known zirconium minerals, but only zircon (**ZrSiO_4**) and **baddeleyite (ZrO_2)** are of practical significance. Zirconium is the 18th most abundant element in the crust; it occurs more frequently than nickel, chromium, zinc, or lead. However, zirconium rarely forms large or rich deposits of its own. Instead, it occurs in complex ores and placer deposits alongside titanium, iron, tantalum, niobium, and rare-earth metals, where it is primarily a byproduct component.

The majority of zircon and baddeleyite concentrates, accounting for roughly 80% of production, are utilised as zirconium oxide (ZrO_2) without further chemical processing.^{2,3}

The main areas of use of zirconium compounds:



01



02



04



03



05



06



07

- 01. ceramic production
- 02. manufacturing of non-stick coatings
- 03. as an alloying element in high-grade steel
- 04. production of refractory materials
- 05. manufacturing of medical implants
- 06. military sector
- 07. nuclear energy

Zirconium dioxide has military applications and is widely used as a **thermal barrier ceramic coating in aircraft gas turbine engines and power turbines**.^{4,5} A thin layer of zirconium ceramics on turbine blades shields them from gases exceeding 1500 °C, increasing engine efficiency. Other compounds, such as zirconium boride (ZrB_2) and yttria-stabilised zirconia (YSZ)^{6,7,8}, are employed in **supersonic aircraft and missiles**. They form part of the composite materials used in payload fairings, which protect against pressure and aerodynamic heating, and also serve as alloying agents in high-grade steel.

Nuclear energy is another primary field of application. Purified, hafnium-free metallic zirconium is utilised in specific structural components of nuclear reactors, but primarily as cladding^{9,10} that isolates atomic fuel (uranium or plutonium) from the coolant. Uranium fuel is loaded into hollow tubes known as fuel rods (TVEL). Virtually all fuel assemblies in PWR/VVER, BWR, and related reactor types employ zirconium cladding.^{11,12} Zirconium-based alloys are preferred for their mechanical strength, radiation resistance, and minimal neutron absorption.

Zirconium is also applied in **optical coatings**, although these uses account for a relatively negligible volume of the metal. Zirconium oxide is regarded as a promising material for **non-volatile memory (memristors) and transistors**. Pure zirconium dioxide has not yet been widely adopted in electronics, as its crystal lattice exhibits poor conductivity at room temperature. However, Russian scientists are experimenting with ways to enhance its properties.¹³

GLOBAL ZIRCONIUM RESERVES



Australia



USA

Zirconium mining is confined to a handful of countries that are rich in placer deposits of heavy mineral sands. The average zircon content in these sands varies widely – from fractions of a per cent to 8-10%. The reserves are spread unevenly; over 30% are located in Australia, and around 25% in the United States.

Known zircon reserves amount to approximately 74 million tonnes.¹⁴ As of 2023, global production of zircon concentrates (including both zircon and baddeleyite) was estimated at around 1.6 million tonnes. **Australia** is the global leader, accounting for nearly half of this volume, with an output of roughly 500,000 tonnes. **South Africa** ranks second, producing between 300,000 and 400,000 tonnes. Other significant producers include **China, Indonesia, the United States, Mozambique, Senegal**, and several other countries.

Ukraine's share of zircon accounted for several per cent of the global reserves until 2022.¹⁵ The largest deposits are located in Donetsk Oblast and the Azov area. In Ukraine, zircon concentrate is produced mainly as a by-product of titanium operations in Irshansk and Vilnohirsk. **Brazil, India, Kenya, Madagascar, Russia, and several other countries contribute a combined 25% to global output.**

According to the IMARC Group, the global zirconium market amounted to **USD 2.1 billion** in 2024.¹⁶ Precedence Research valued the sector at **USD 2.08 billion** for the same year, predicting a rise to USD 2.24 billion in 2025, and a projected doubling of market volume by 2034.¹⁷

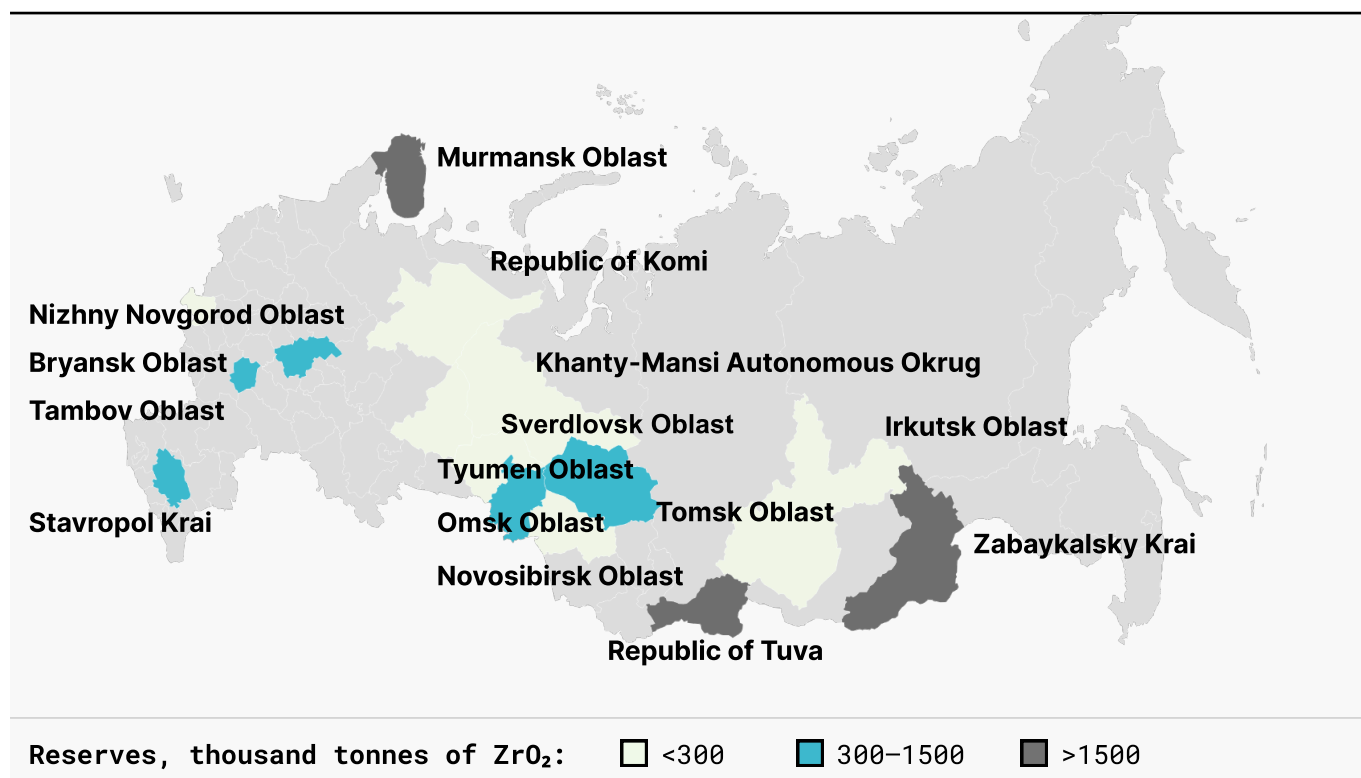
Leading producers include Iluka Resources Limited (Australia), Rio Tinto (Australia), Tronox Holdings PLC (United States), Kenmare Resources PLC (Ireland), and Eramet Source (France).

ZIRCONIUM RESERVES IN RUSSIA



Zirconium is among the main categories of strategic mineral resources under Government Order No. 2473-r of the Russian Federation (30 August 2022).¹⁸ It falls within the so-called third group of mineral resources – **import-dependent and deficit materials**.

As of 1 January 2023, Russia's balance reserves of zirconium, distributed across 19 separate deposits, totalled 12.4 million tonnes of ZrO₂ equivalent.¹⁹ Off-balance sheet reserves across the country accounted for a further 6.6 million tonnes of ZrO₂ equivalent.



Various deposits across Russia contain viable zirconium components; however, economic and technological hurdles currently impede their development. **In 2022, active mining operations targeted only 3.2% of the reserves**, while a further 26% remained in the development phase. The remaining deposits fall under the unallocated subsoil fund.

The Russian zirconium market faces several key challenges:

- 01. Complex ore mineralogy and fine grain size, which hinder beneficiation;
- 02. High costs associated with developing deep-seated deposits;
- 03. Reliance on multi-stage processing circuits involving flotation, gravity separation, and magnetic separation.

Ultimately, Russia possesses an extensive zirconium resource base that remains largely underdeveloped.

The primary zirconium producer in Russia is **JSC Kovdorsk Mining and Processing Plant** in Murmansk Oblast. Until 2017, the plant exported almost its entire output (96-100%); however, since 2018, the share of domestic consumption has risen up to 60%. Current estimates suggest that the reserves at this deposit won't be depleted until at least 2125, and a transition to underground mining is scheduled for 2025.

The second major producer is **JSC Tugansk GOK Ilmenit**, located in Tomsk Oblast. The company has been subject to U.S. and Ukrainian sanctions since 15 January 2025.^{20,21,22} In 2022, it accounted for 2.6% of Russia's zirconium output. Alongside expanding operations at the Tugan titanium-zirconium deposit, developers are preparing the Zashikhinsk deposit in Irkutsk Oblast, where the beneficiation of tantalum rare-earth ores is expected to yield up to 8,000 tonnes of zircon concentrate annually.

Russia relies almost entirely on imported zirconium raw materials. Until 2022, between 98% and 100% of its zircon concentrate arrived from abroad. Between 2018 and 2020, more than half of Russia's zircon imports originated from Ukrainian enterprises.²³ Large-scale domestic production of zircon concentrate began only in 2022, following the launch of operations at the Tugan titanium-zirconium deposit. Plans are currently underway to commission the second phase of the Tugansk Mining and Processing Plant. Once completed, extraction could increase to 15,000 tonnes per year – a volume sufficient to fully meet national demand for zirconium raw materials.

Russia consumes between 6,000 and 12,000 tonnes of zircon concentrate annually. Globally, the ceramics, anti-stick coatings, and refractory industries dominate zirconium consumption, accounting for 54%, 14%, and 13% of the market, respectively. By contrast, Russia directs over 60% of its zirconium feedstock to the nuclear sector for the production of metallic zirconium.²⁴

The primary consumer, JSC Chepetskiy Mechanical Plant (TVEL/Rosatom),²⁵ ranks as one of the world's largest producers of rolled zirconium alloys. Other facilities, including JSC Klyuchevsk Ferroalloy Plant (Sverdlovsk Oblast), JSC Obninsk Research and Production Enterprise Tekhnologiya named after A.G. Romashin (subject to U.S.²⁶ and EU²⁷ sanctions), JSC EKON, and LLC Technoceramika (Kaluga Oblast), manufacture powdered zirconium dioxide and advanced ceramics used in the aviation, aerospace, and transport industries.

Alloy producers such as LLC OrionSpecSplav-Gatchina and JSC Uralredmet (currently under U.S. sanctions²⁸) utilise limited volumes of zircon-bearing feedstock and secondary materials. JSC Uralredmet supplies its output to VSMPO-AVISMA Corporation for the manufacture of titanium alloys, which are subsequently used in the military industry.²⁹

Following 2022, Russia lost access to Ukrainian imports and faced supply disruptions from so-called "unfriendly" countries. To mitigate the resulting shortfall, Moscow intends to draw on materials from "friendly" states, employ parallel import schemes, and redirect a portion of its baddeleyite exports toward domestic consumption.³⁰

Russia is also exploring overseas joint ventures to extract zirconium and titanium feedstock in "friendly" countries, such as Vietnam and South Africa. Russia then supplies the mined materials to its domestic market.³¹

SIGNIFICANCE FOR RUSSIA'S MILITARY-INDUSTRIAL COMPLEX



Armoured vehicles



Aircraft

Armoured vehicles, aircraft and munitions production

Following Russia's military aggression against Ukraine in 2014, JSC Chepetskiy Mechanical Plant supplied tubular, titanium, and zirconium products to Russian military factories. These facilities manufacture combat aircraft, naval vessels, and other military hardware.³²



Munitions production

Although used in relatively small volumes, zirconium and its compounds are vital military and dual-use materials. Specifically, the sanctioned company **JSC United Engine Corporation** is a major consumer of zirconium products, applying yttria-stabilised zirconia (YSZ) as a thermal barrier coating on gas turbine engine blades.³³ This widely used practice protects engine components from overheating.³⁴ As a key supplier of engines for the aviation, naval, space, and energy sectors, JSC United Engine Corporation oversees a holding structure comprising approximately 78 enterprises. These entities control around 85% of Russia's engine-building assets, the vast majority of them directly serving the needs of the Russian military-industrial complex.

Zirconium also has military application in blasting caps, tracers, and igniters.³⁵ This suitability stems from the metal powder's low auto-ignition temperature (180-250°C) combined with a high combustion temperature, which can reach 3,000°C. When mixed with oxidisers, zirconium produces smokeless propellant.

A composite material of aluminium oxide alloyed with zirconium oxide is regarded as a promising option for enhancing ballistic properties and reinforcing armour.



Nuclear weapons



Nuclear energy



Fleet

Nuclear weapons, nuclear energy and fleet

The aforementioned **JSC Chepetskiy Mechanical Plant** serves both economic and military purposes, holding a range of military and nuclear licences. Initially established as a cartridge factory, it has evolved into the world's largest – and Russia's sole – producer of zirconium and its alloys, alongside other specialised metallic products, including titanium and calcium components. The plant supplies structural materials for all nuclear installations in the country. Today, it constitutes a core element of Russia's nuclear complex and functions as Rosatom's primary metallurgical hub.

JSC Chepetskiy Mechanical Plant accounts for 18% of the global zirconium rolled products market, 80% of the Russian calcium metal market, and produces 70% of the country's titanium welding wire. The enterprise also holds leading positions in the production of hafnium, niobium, titanium, tantalum, and low-temperature superconducting materials.³⁸ The plant supplies zirconium products to more than 70 nuclear reactors across 15 countries and plays a vital role in the Russian economy.³⁹

Without zirconium, the nuclear fuel cycle in both civil and military domains would be severely constrained. Reactor efficiency – whether in systems producing plutonium for nuclear warheads or uranium for nuclear energy – would be significantly reduced. Moreover, zirconium is integral to the reactors of nuclear submarines, which carry nuclear weapons. As a result, zirconium indirectly underpins the functioning of Russia's nuclear facilities and ensures the combat readiness of its nuclear triad.

The critical step in producing nuclear-grade zirconium involves removing hafnium, a technically demanding process due to the chemical and physical similarities between the two elements. In 2021, JSC Chepetskiy Mechanical Plant constructed and commissioned a facility capable of producing high-purity zirconium tetrachloride with a hafnium content below 0.01%.⁴⁰

JSC Chepetskiy Mechanical Plant also participates in the implementation of several unique Russian nuclear technologies. Specifically, the plant manufactures zirconium components for two KLT-40S pressurised water reactors; these units power the Akademik Lomonosov – the world's first floating nuclear power station. Since 2015, JSC Chepetskiy Mechanical Plant has produced seamless, thin-walled hexagonal tubes for a new generation of nuclear-powered icebreakers.^{41 42}

The Akademik Lomonosov nuclear power station, source – the Internet



Russia is effectively the only country that operates a fleet of heavy nuclear icebreakers.⁴³ These vessels are important to Arctic development and enable regular transit along the Northern Sea Route. All ships are operated by Atomflot, a subsidiary of the state corporation Rosatom.

HOW RUSSIA PROFITS FROM ZIRCONIUM



Nuclear
fuel



Finished
products

Although the zirconium market is relatively small, it holds significance for Russia's economy through the export of high-technology products. Rosatom generates foreign currency by supplying nuclear fuel and technologies – effectively exporting zirconium-based products in the form of fuel assemblies. For example, an RBMK reactor contains approximately 180 tonnes of zirconium alloys, while a VVER-1000 reactor contains around 33 tonnes in its core (equivalent to 30-40 tonnes per gigawatt).⁴⁴ All of these materials are produced domestically in Russia and exported as part of nuclear power projects. As a result, zirconium generates revenue indirectly through nuclear exports. Besides, zirconium-bearing materials may themselves constitute export commodities: Russia can sell surplus baddeleyite (as it has done previously), zirconium compounds such as dioxides and carbides, and finished products, including tools and specialised equipment.

TVEL supplies reactor fuel to dozens of countries, including Hungary, Czechia, Slovakia, China, India, and Belarus, and all of the assemblies incorporate Russian zirconium. Thus, nuclear-fuel exports effectively amount to exports of zirconium products,⁴⁵ except where production is licensed in China.⁴⁶

In 2024, TVEL Fuel Company (a subsidiary of Rosatom) generated revenues exceeding RUB 341 billion – an increase of nearly 9% compared with 2023.⁴⁷

Rosatom, source – the
Internet



Russia's access to nuclear fuel technologies, sustained by the steady import of zircon-bearing feedstock, enables the country to manufacture components that are critical to the global nuclear industry while bolstering its own economy through the production of high-value-added goods. Russia imports zircon-bearing ores, processes them domestically, and applies its technological capabilities to expand military capacity – by equipping naval and non-military nuclear vessels – and to generate revenue by exporting nuclear power plant equipment. At the same time, these exports cultivate the "soft power" by creating technological dependence among partner countries. President Vladimir Putin has recently suggested the possibility of restricting exports of uranium, nickel, titanium, and other commodities⁴⁸ – a classic political tactic designed to create uncertainty.

Regarding the EU market, Rosatom's products are supplied to the Slovak nuclear power plants Mochovce and Bohunice (the contract being extended until 2030),⁴⁹ the Paks nuclear power plant in Hungary, and various facilities across the Czech Republic, Bulgaria, and Finland.^{50,51}

ANALYSIS OF EXPORTS AND IMPORTS (2024-2025)

To analyse imports and exports, we examined the supply of zirconium and its products using the following HS codes:

HS code	Description
26151000	Zirconium ores and concentrates
28256000	Germanium oxides and zirconium dioxide
28274990	Chloride oxides and zirconium chloride hydroxides
28369950	Zirconium carbonate
74071010	Copper bars, rods and profiles of refined copper
81092100	Unwrought zirconium and zirconium powders, specifically those containing less than 1 part hafnium to 500 parts zirconium by weight
81099100	Wrought zirconium and articles of zirconium, containing less than 1 part hafnium to 500 parts zirconium by weight
81099900	Other wrought zirconium and zirconium articles

Table 1. HS codes selected for the study

The conclusions should be regarded as provisional. A comprehensive understanding of trade flows of zirconium and zirconium products to and from Russia requires further research. Certain transactions may not be reflected in the customs dataset reviewed, while some products may have been declared under alternative or erroneous codes.

Customs data indicates that between January 2024 and April 2025 Russia imported zirconium and zirconium-based products worth **more than USD 33 million**.

HS Code	Description	Amount (USD)
26151000	Zirconium ores and concentrates	30 225 788
28256000	Germanium oxides and zirconium dioxide	1 987 236
28274990	Chloride oxides and zirconium chloride hydroxides*	549 610*
81099100	Wrought zirconium and articles of zirconium, containing less than 1 part hafnium to 500 parts zirconium by weight	4 611
81099900	Other wrought zirconium and zirconium articles	356 017
Total		33 123 262

Table 2. Zirconium imports by Russia, source: Russian customs data

* HS code **28274990** also includes oxides and hydroxides that may not contain zirconium, and these were excluded from the calculations

Russia predominantly purchases unprocessed zircon ore and its concentrates (91.24%).

It is worth noting that deliveries under certain HS codes were either negligible in volume or absent. This is primarily because nuclear-grade zirconium compounds with a hafnium content below 1:500 remain subject to export controls and sanctions imposed by the EU⁵², the United States⁵³ and the UK⁵⁴. Regarding the latter, the UK prohibits both the import of zirconium dioxide from Russia and its re-export to third countries.⁵⁵

In 2023, Russia imported USD 34.3 million worth of zirconium products, compared with USD 41.7 million in 2022.

The Netherlands accounts for nearly half of all supplies, while India, China, and Spain also remain major suppliers to Russia.

Country	Supply share (per cent)	Amount (USD)
Netherlands	43.27	14 331 450
China	14.83	4 912 797
India	13.48	4 466 239
Spain	11.2	3 709 157
Indonesia	10.35	3 428 070
UAE	1.82	602 130
Sri Lanka	1.46	484 388
Italy	1.31	433 450
South Africa	0.95	314 385
Australia	0.71	234 153

Figure 3. Contribution of countries exporting zirconium to Russia. Source: Russian customs data

The Dutch company **Eggerding Industrial Minerals B.V.**, which operates in South Africa, supplies a substantial portion of Russia's zirconium feedstock. During the aforementioned period, the company sourced approximately USD 6 million worth of material, working through a network of intermediary firms. One such intermediary is Evalis, registered in the UAE in 2023, which supplies feedstock originating from the Dutch company. Aleksandr Bulokhov,⁵⁶ the founder of the Estonian firm Estream OÜ, also owns Evalis. Estream OÜ purchases zirconium for Russia's LLC PK Litprom and LLC Estrim. Since the outset of the full-scale war, the latter has emerged as Russia's largest importer of zirconium products. In 2022, companies linked to Bulokhov also sought to procure zirconium and titanium ores from Ukraine.⁵⁷

Supplier	Supply share (per cent)	Amount (USD)
01 . Eggerding Industrial Minerals B.V.	14.96	6 079 531
02 . Evalis DMCC	11.07	4 498 227
03 . Sukaso Ceracolors Private Limited	9.76	3 966 417
04 . Zircosil Spain SL	8.64	3 509 695
05 . PT Monokem Surya	8.44	3 428 070
06 . Gulbrandsen Technologies (GTI)	6.95	2 822 465
07 . Estream OU	6.02	2 445 380
08 . Guizhou Redstar Developing Co. Ltd	4.17	1 696 106
09 . Arima Minerals Processing fze	1.82	602 130
10 . Evalis DMCC On Behalf Of Eggerding Industrial Minerals B.V.	2.21	898 154

Figure 4. Companies that supply zirconium to Russia. Source: Russian customs data

Note: Entries 02 and 10 correspond to a single legal entity.

As for exports, between January 2024 and April 2025 Russia exported zirconium and zirconium-based products worth **USD 26.5 million**.

HS Code	Description	Amount (USD)
26151000	Zirconium ores and concentrates	7 252 069
28256000	Germanium oxides and zirconium dioxide	2 192 802
28274990	Chloride oxides and zirconium chloride hydroxides	6 064
81099100	Wrought zirconium and articles of zirconium, containing less than 1 part hafnium to 500 parts zirconium by weight	17 128 302
Total		26 579 237

Table 5. Russia's export of zirconium. Source: Russian customs data

China, Japan, the Czech Republic, and South Korea received the bulk of these exports. **Overall, Russia's exports may be broadly classified into two primary categories: (1) baddeleyite concentrate from the Kovdorsk Mining and Processing Plant, and (2) ultra-pure zirconium, along with equipment for nuclear fuel assemblies (TVELs).**

Export destination	Export share (per cent)	Amount (USD)
China	62.22	16 537 830
Japan	16.78	4 459 376
Czech Republic	11.62	3 088 650
South Korea	4.9	1 301 191
India	2.93	779 569
Germany	1.53	405 815
Turkey	0.01	3 846
Unknown	0.01	1 981
Uzbekistan	<0.01	813
Mongolia	<0.01	164

Figure 6. Zirconium importers from Russia. Source: Russian customs data

China National Nuclear Corporation became the largest purchaser of Russian nuclear-related products. In 2024-2025 alone, it acquired USD **15.82 million** worth of components for fuel assemblies intended for the Tianwan Nuclear Power Plant. A significant batch of hafnium-free rods worth USD 1.3 million was sold to the **Korea Atomic Energy Research Institute.**

Other customers include **Hindustan Aeronautics Limited (HAL)**, an Indian state-owned aerospace and defence company. HAL procures zirconium oxide specifically to maintain and repair engines for Russian-designed aircraft. Deliveries go through LLC AT Spetstekhnologiya, while the contracting party remains Russia's Rosoboronexport, which is subject to sanctions in the EU, Ukraine, Japan, Canada, and other countries.

Importer	Share of total exports (%)	Amount (USD)
China Nuclear Industry & Industry Corporation CNEIC	59.54	15 825 299
Corrigo Fertilizers FZE	15.29	4 064 281
Eurochem Trading Middle East DMCC	6.07	1 612 254
Tamiya Company Limited	5.31	1 411 950
Korea Atomic Energy Research Institute	4.9	1 301 191
Ashon International DMC	4.39	1 166 130
Hindustan Aeronautics Limited Corporation	2.91	774 200

Figure 7. Companies purchasing zirconium from Russia. Source: Russian customs data

Zirconium feedstock continues to reach sanctioned Russian enterprises. **LLC Deluxe Holding** imported more than USD 7 million worth of zirconium feedstock and supplied it to the **Moscow Machine-Building Enterprise named after V. V. Chernyshev**, which manufactures engines for MiG fighter aircraft and Mi-38 helicopters, as well as to **JSC NPP Krasnoznamyonets**, a producer of explosive materials.⁵⁸

SANCTIONS ON THE INDUSTRY



Sanctions on the Zirconium industry in the Russian Federation



Lack of trade with EU companies

With no significant sanctions pressure, Russia's zirconium industry increases production, focusing primarily on the needs of the military-industrial complex and the nuclear power sector.

Worldwide production of high-quality, nuclear-grade zirconium is confined to a handful of enterprises in the United States, France, China, Japan, and India, and specifically, Russia's Chepetskiy Mechanical Plant. As a result, Russia operates a fully integrated production base capable of supplying its nuclear sector, fuel manufacturing, and military technologies without significant reliance on external supplies.

In 2022, the EU debated sanctions on Russian zirconium and the nuclear industry, but certain member states blocked the proposals at the last minute due to their dependency on Rosatom. Specifically, Hungary openly announced it would veto any restrictions on Russia's nuclear energy and fuel cycle, citing the complete dependency of its Paks Nuclear Power Plant on Russian fuel. France and Bulgaria likewise opposed sanctions targeting Russia's nuclear sector.⁵⁹

Eventually, the EU has failed to impose any direct restrictions on Rosatom or its subsidiaries.

This indicates that Russia's nuclear corporation and zirconium-related enterprises have retained the ability to trade with European companies, generate revenue, and procure the equipment required to sustain their operations and expand Russia's military capabilities.

RECOMMENDATIONS

- 01** Several countries have already banned the export of nuclear-grade zirconium to Russia. However, this measure is insufficient, as Russia possesses the technology to process zirconium domestically. Limiting the sale of all zirconium-bearing materials is crucial, as they remain vital for the aviation industry, serve as potential components of composite armour, and are essential in the production of nuclear fuel and weapons.
-
- 02** Following Russia's full-scale invasion of Ukraine, Europe banned or restricted the import of many Russian energy resources and metals. However, nuclear materials, particularly zirconium used in nuclear power plants, have remained effectively exempt from sanctions. As of 2024, Russia still supplied approximately 40% of the EU's enriched uranium, and 19 Soviet-designed reactor units in Europe continued to rely on Rosatom⁶⁰ fuel. Reducing this dependency and securing alternative technologies and contractors is therefore pivotal. In 2024 alone, EU countries imported around EUR 700 million⁶¹ – worth of nuclear materials from Russia – funds that continue to finance Russia's war machine. An immediate step across all allied jurisdictions must be a full ban on Russian nuclear fuel imports and zirconium raw materials originating from Russia.
-
- 03** Allied states must coordinate their sanctions policy against Rosatom and its affiliated companies. So far, only a few nations – the United States, Canada, and the United Kingdom – have imposed restrictions, which are still insufficient to produce a substantial effect. A unified, comprehensive approach is required, such as simultaneously adding Russia's key zirconium enterprises to the sanctions lists of the U.S., EU, UK, Japan, Australia, and other allied jurisdictions.
-
- 04** Allied governments should expand sanctions to include the individuals and legal entities that import zirconium into Russia, supporting its military-industrial complex. This measure would affect JSC Chepetskiy Mechanical Plant (INN 1829008035), JSC Uralredmet (INN 6606002529), JSC Klyuchevsk Ferroalloy Plant (INN 6652002273), JSC Obninsk Research and Production Enterprise Tekhnologiya named after A.G. Romashin (INN 4025431260), as well as distributor companies that facilitate the supply of feedstock: LLC PK Litprom (INN 7816492511), LLC Estrim (INN 7817120403), LLC Deluxe Holding (INN 7838077580), among others.
-
- 05** Sectoral sanctions should include a comprehensive ban on the export and import of zirconium and its compounds to and from Russia. Foreign subsidiaries of state-owned corporations help Russia to bypass sanctions, so freezing their assets and operations is vital.
-
- 06** States that currently depend on Russian zirconium and nuclear fuel should reorient their markets towards alternative suppliers. There are plenty of major zircon concentrate exporters worldwide, including Australia, South Africa, Mozambique, and Indonesia. They offer clear opportunities to replace Russian raw materials. In the nuclear sector, nations should prioritise expanding partnerships with companies such as Westinghouse, Framatome, and India's Nuclear Fuel Complex (NFC), as they can supply fuel and zirconium components for both Western and Soviet-designed reactors.

Several countries have already taken significant steps in this direction. Ukraine, the Czech Republic, Finland, and others are actively transitioning to Westinghouse fuel, thereby reducing their reliance on TVEL.^{62,63,64} To bolster these efforts, Western nations must invest in expanding production capacity – specifically by establishing a full domestic cycle for zirconium alloys and fuel assemblies within the EU. To ensure long-term energy security, Europe must sustain investments in facilities for enrichment, conversion, and production of fuel-rod cladding, as well as develop spent-fuel reprocessing infrastructure.

SOURCES

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