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India in the Global Uranium Supply Chain: Assessing Energy Security, Strategic Partnerships, and Emerging Geopolitical Challenges

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Abstract

The growing global emphasis on clean energy has renewed the strategic importance of uranium as the primary fuel for nuclear power generation. For India, achieving energy security while fulfilling its commitment to net-zero emissions by 2070 requires a significant expansion of nuclear energy, despite limited domestic uranium resources. This paper analyzes India's role in the global uranium supply chain by examining the structure of the nuclear fuel cycle, the nation's reliance on imported uranium, and the geopolitical and economic challenges related to supply concentration, transportation vulnerabilities, and price volatility. It further explores the strategic significance of partnerships with uranium-producing countries, particularly in Central Asia, and assesses the implications of China's expanding presence in global uranium markets. The study argues that strengthening India's uranium security requires a diversified import strategy, overseas resource investments, enhanced domestic exploration, resilient transport corridors, and accelerated implementation of the country's three-stage nuclear programme. By linking energy security with geopolitical developments, the paper highlights the need for a comprehensive and long-term approach to ensure a reliable uranium supply for India's expanding nuclear energy sector.

Keywords: Uranium Supply Chain, Nuclear Energy, Net Zero Targets, Price Volatility, Central Asia, Strategic Partnership, Dependence

Introduction

Uranium is a naturally occurring, weakly radioactive element. For decades, uranium has been regarded as a strategic raw material due to its unparalleled energy density and its essential role as a nuclear fuel. In reactor use, uranium's fission energy content vastly exceeds that of fossil fuels, enabling a steady supply of baseload power with minimal carbon emissions. It may become a clean energy transmission material. It shows the strategic importance of uranium beyond that of a common commodity. As a result, uranium is now viewed not only through the lens of typical boom-bust commodity cycles but also as a long-term strategic asset in an era of decarbonization and power supply uncertainty. Currently nuclear power electricity generation of the world accounts for 10%, but in the upcoming decades, it will change, because of net zero goals.

India in that context is most vulnerable to this situation. India has set the target for net zero emissions in the Paris Convention for Climate Change by the year 2070. Currently, India relies on coal for about 48%

of its energy generation, and Nuclear energy only accounts about 3%. With the increased demand of power, it will not be sufficient enough. There are many major blocks in the civil nuclear energy generation such as domestic abundance of Uranium, dependence on foreign players, supply chain problems, rising geopolitical tensions, overreliance on some countries, price volatility etc.

Understanding the uranium supply chain –

Nuclear power technology involves a complex supply chain including uranium mining, uranium conversion and enrichment, fuel fabrication, construction, operation, maintenance, and decommissioning of plants and reactors and storage, processing, and disposal of nuclear waste.

There are three main stages of the nuclear supply chain—

The first stage concerns the recovery of natural uranium through mining and other methods. Kazakhstan is the largest producer of uranium, with around 43% of the global supply. Other major producers are Canada, Namibia, Australia, Uzbekistan, Russia, and Niger. The largest identified recoverable resources are in Australia (28% of the global resources), Kazakhstan (13%), Canada (10%), Russia, and Namibia (10% each).

The second stage of activities in the supply chain concerns uranium conversion and then enrichment. Before being enriched, mined uranium needs to be converted to uranium hexafluoride. Conversion plants are operating commercially in a few countries—Canada, France, Russia, China, and the USA.

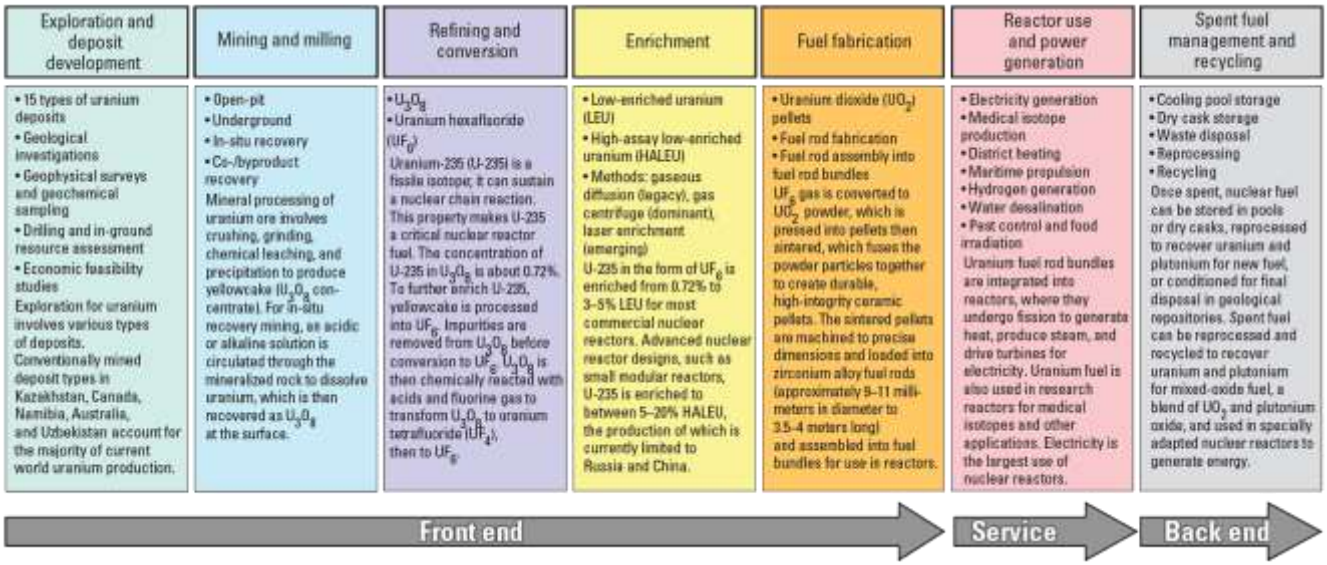
Most of the approximately 500 commercial nuclear power reactors operating or under construction require uranium enriched in the U-235 isotope. Natural uranium contains 0.7% of the U-235 isotope, while the remaining 99.3% is mostly the U-238 isotope. Most reactors are light water reactors that require uranium to be enriched from 0.7 to 3.5% U-235 in their fuel. (World Nuclear Association)

While there has been a significant oversupply of enriched capacity worldwide in recent years, enriched uranium is significantly sensitive and capital-intensive, which hinders the market entry for new suppliers. As nuclear enrichment capacity is closely linked to the production of nuclear weapons (for nuclear bombs, however, enrichment to atleast 90% of U-235 is necessary). A country that wants to develop such capacity must accept rigorous international scrutiny; otherwise, it will fail to get essential technological support and face sanctions. Few commercial enrichment suppliers are Russia's Rosatom (with nearly half of the global capacity), Urenco, and French Areva.

The third stage concerns the supply of nuclear reactors and plant construction, including the provision of adequate fuel rods, the servicing of the infrastructure, and the disposal of spent fuel. Today there are about 440 nuclear power reactors operating in 33 countries and generating approximately 10% of the world's electricity. (60 under construction, mostly in Asia).

Suppliers of nuclear reactors and power plants are very few, with six countries—Russia, USA, France, China, Korea, and Japan—accounting for 94% of supply.

From around the 2010s, SMRs (small modular reactors) have been the newest development in this category. It can generate electricity without needing big power plant infrastructure, although it is still in an early stage.



(Fig. 1)

Challenges regarding supply chain for India

Domestic abundance of uranium

India relies on coal for about 48% of its energy generation. India had a long constraint on uranium production (which is essential for nuclear electricity production) due to limited domestic uranium deposits. The uranium deposit that India has is low ore quality, and India has limited extraction capacity. Although India has domestic uranium deposits, their uranium concentration ranges between only 0.02 and 0.45%, which is significantly lower than the global average of 1.2%. Major domestic uranium resources and production sites are located in Jharkhand and Andhra Pradesh. India currently has 7 operational uranium mines. Additional uranium deposits have been identified in Meghalaya, Rajasthan, and Telangana. Total uranium resources are estimated to be around 4.3 lakh tonnes. Uranium Corporation of India Limited (UCIL) manages several mines, with over 80,000 tonnes of reserves allocated to it. Nearly 40% of these reserves have already been extracted, prompting ongoing exploration across 15 states.

Although it is still not sufficient for India's energy needs. India currently consumes about 1500-2000 tonnes of uranium annually, with demand estimates at 1884 tonnes in 2025. With nuclear expansion plans, annual uranium demand may increase to about 5400 tonnes in the coming years. Even with increased mining, domestic production may meet only about 30% of total demand, making imports essential. India currently imports more than 70% of its uranium. Major contributors are Uzbekistan, Kazakhstan, Canada, Russia, etc. These import dependencies make India vulnerable to nuclear market concentration.

Supply chain risks

The global uranium market has a high concentration of supply among a small number of producing countries, creating structural vulnerabilities and potential bottlenecks. Kazakhstan produces 2/5th to nearly one half of global uranium output. In 2022, Kazakhstan produced approximately 22,000 tU, which is 43% of the world's mine supply, far exceeding the output of the 2nd largest producer, Canada. Around half of economically recoverable uranium is located in Australia, Kazakhstan, and Canada, which become highly sensitive in disruption. The top three producing countries, Kazakhstan, Canada, and Australia, collectively

account for approximately 70-75% of global uranium mine output, indicating a highly concentrated market structure.

The uranium supply chain faces multiple categories of risk, including geopolitical, regulatory, resource base, operation and technical, product dependency, currency exchange rates, and financial and transportation of radioactive material.

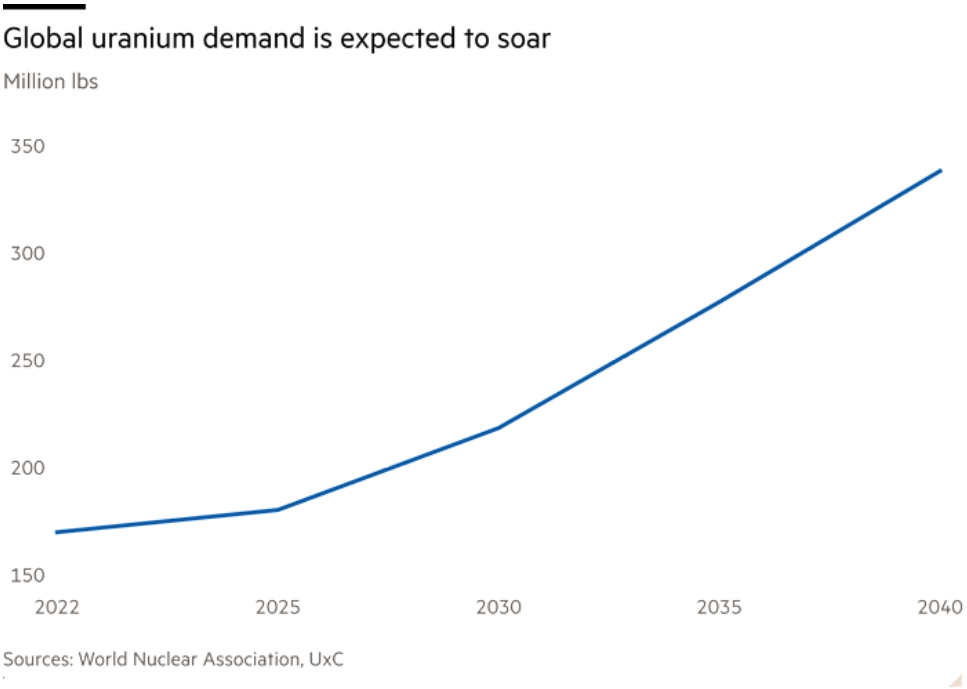
For India, securing the uranium for civil nuclear energy and net zero carbon emission goals is essential. These global supply chain risks possess great challenges that India needs to overcome.

Price Volatility

Uranium prices are particularly sensitive to shocks, including supply disruptions, export restrictions, or large purchasing tenders. This volatility complicates investment planning for producers and increases procurement risk for utilities.

Around the 2010s, uranium prices were flat or declining because of reactor retirements (especially in Europe and Japan) and improvement in fuel efficiency. In 2023, the uranium prices started going up. The major reasons for that are net zero emission targets, new reactor construction in Asia, life extension of existing plants, and restart of previously idled reactors, notably in Japan.

According to the World Nuclear Association, there will be a 28% increase in annual uranium requirements by 2030 relative to 2023, driven by an 18% expansion in global nuclear generation capacity. Uranium demand will surge to double in 2040. OECD/NEA-IAEA indicates that even conservative scenarios entail significantly higher uranium consumption by 2040, while high-growth pathways aligned with aggressive climate targets could more than double uranium use by mid-century. In the COP-28 more than 30 countries pledged to triple global nuclear capacity by 2050, which will affect uranium prices in upcoming decades and will impact India's nuclear procurement goals.



(Fig. 2)

Dependence on Central Asia

Central Asia holds major concentrations of uranium deposits. Kazakhstan holds nearly 43% of exports of total global nuclear supply. Other than Kazakhstan, Uzbekistan, Kyrgyzstan, and Tajikistan are also rich in uranium deposits. India imports its uranium primarily from these Central Asian countries and other countries such as Russia, Canada, etc. Kazakhstan had previously been one of India's important uranium suppliers alongside Canada. In 2015, PM Modi visited Astana, where the two sides signed a contract for the supply of 5,000 tonnes of uranium over five years. In 2026, Kazakhstan's Kazatomprom and India's Department of Atomic Energy signed a contract, which was valued at $4 billion. It ranks among the largest uranium supply management in Asia and exceeds 50% of Kazatomprom's total book asset value. It's scale signals that India-Central Asia cooperation in this domain is shifting from episodic commodity trade towards a structured strategic axis.

Uzbekistan emerges as the second important regional actor within this region. India already has experience with long-term purchases of Uzbek uranium. A 2019 contract provided for the supply of 1100 MTU of natural uranium.

This data shows India's growing interest in uranium in this region. With increased interest also come challenges, from transport corridor challenges to overreliance on specific locations for important uranium nuclear reactors. Which might become critical in a conflict situation and will affect India's nuclear supply chain.

China's Expanding Uranium Strategy

China has been investing in nuclear energy aggressively. It is expanding its current nuclear power plant capacity to combat carbon emissions. China is also expanding on foreign investment in the uranium market. Chinese companies have acquired stakes in uranium assets abroad. For instance, they have acquired stakes in uranium mines in Kazakhstan, Namibia, and other resource-rich countries.

In Kazakhstan, China General Nuclear Power Group (CGN) and others have joint ventures that provide a stable supply of Kazakh uranium for China's reactors.

Similarly in Africa, a Chinese firm is the majority owner of Namibia's Husab mine, one of the world's largest uranium mines.

Transport and Corridor Risks

India's major uranium is supplied by Central Asian partners. But the big problem is that India does not have a direct sea route connecting to it. It is dependent on some transport corridors, which are vulnerable. The main route connecting to it is through the Caspian and the Caucasus through Iran or through Afghanistan and Pakistan. Each route carries its own constraints. Through Caspian is developing but remains an expensive and complex multimodal route. Railways, ports, ferries and Caspian infrastructure require time and investment. The Iranian route through Mangystau, Kazakhstan, and onward to the posts of Bandar Abbas or Chabahar port is convenient for India but politically vulnerable due to tensions surrounding Tehran. Trans-Afghan routs are more sensitive still. They depend on stability in Afghanistan, on the state of Kabul's relationship with Islamabad and on the reliability of border crossings. The region's southern connectivity thus remains as political as it is an infrastructural challenge.

Uranium, however, carries different commercial logic from ordinary commodities. Its logistics are more complex, but its strategic value is higher. Uranium is compact, expensive, and critical to long-term energy security, in contrast to bulk cargo like grain or coal, where transport costs quickly erode commercial

viability. Reliable suppliers of such a resource, therefore, command a premium even under difficult geographies.

Probable recommendations

Diversify suppliers

Dependence on some regions for vital nuclear energy is very risky. In turbulent times it may become very dangerous. For this reason, India must diversify its uranium supply chain. In this regard, India is currently expanding its uranium supply. India signed a long-term contract with Canada in which Canadian company Cameco will supply about 22 million pounds (around 1,000 tons) of uranium to India between 2027 and 2035. Also, India and Australia signed a finalization of the Administrative Arrangement **under the** India–Australia Civil Nuclear Cooperation Agreement.

Long-term contracts

Uranium prices are decided by the uranium market, which is very volatile. In the last some years, countries have decided to sign long-term partnership deals to overcome this market volatility and procure uranium for their needs. India is no exception in this regard. India signed a long-term deal with Kazakhstan and Canada to procure its critical uranium supply and overcome market prices.

Overseas mining investment

India is dependent on a foreign uranium supply, as it does not have enough domestic supply. India needs to invest more in overseas mining. Some countries such as Australia, Canada, Namibia, Niger, and South Africa have great uranium deposits. Indian companies are exploring overseas uranium mining opportunities to strengthen long-term supply security.

Strengthen transport corridors

India's major uranium is supplied by Central Asian countries such as Kazakhstan, Uzbekistan and also Russia. The major problem with Central Asian countries is that India does not have a direct connecting route to it. For that, India is dependent on some key routes, which may become a choke point in a conflict. For that, India and Russia have made a connecting transport route, INSTC (International North South Transport Corridor), which connects India to Russia via Central Asia and Chabahar Port in Iran. But it might become irrelevant in a major conflict, which we have seen in the US-Israel-Iran conflict. For that, India needs to come up with new transport corridors to have safe passage of the uranium supply.

Expand domestic exploration

India has some domestic uranium, but it is not sufficient enough. Currently seven uranium mines are operational in India. Additional uranium deposits have been identified in Meghalaya, Rajasthan, and Telangana. The total uranium resources are estimated to be 4.3 lakh tonnes. Nearly 40% of these resources have already been extracted, prompting ongoing exploration across 15 states.

Accelerate thorium transition

India's three-stage nuclear power program was formulated by Dr. Homi J. Bhabha in the 1950s to achieve energy independence by utilizing the country's abundant thorium reserves. The indigenously designed and built Prototype Fast Breeder Reactor (PFBR) at Kalapakkam in Tamil Nādu successfully attained its first

criticality recently, which is a major breakthrough for India's three-stage nuclear program. India needs to accelerate its nuclear power program to attain self-sufficiency in power generation.

Conclusion

India's pursuit of energy security and net-zero goals will increasingly depend on a stable and resilient uranium supply chain. Although domestic production is improving, it remains insufficient to meet the country's growing nuclear energy requirements, making external partnerships indispensable. However, dependence on a limited number of suppliers, geopolitical uncertainties, transport bottlenecks, and volatile uranium markets pose significant long-term challenges.

To strengthen its energy security, India must diversify uranium imports, expand overseas mining investments, improve transport connectivity, enhance domestic exploration, and accelerate its thorium-based nuclear program. A balanced strategy that combines domestic capacity with strategic international partnerships will be essential for ensuring a secure, sustainable, and geopolitically resilient nuclear future.

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