Online ISSN : 3049-3455
Mineral Metal Energy Oil Gas and Aggregate
Contents available at: www.informaticsjournals.co.in/index.php/2MEOGA
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A Company in a Uranium Ore-Deficient Country Can Venture into Nuclear Power

Jayanta Bhattacharya

Former Professor, Department of Mining Engineering and Former Founding Professor, The School of Environmental Science and Engineering, Indian Institute of Technology, Kharagpur—721302, West Bengal, India; jayantaism@gmail.com

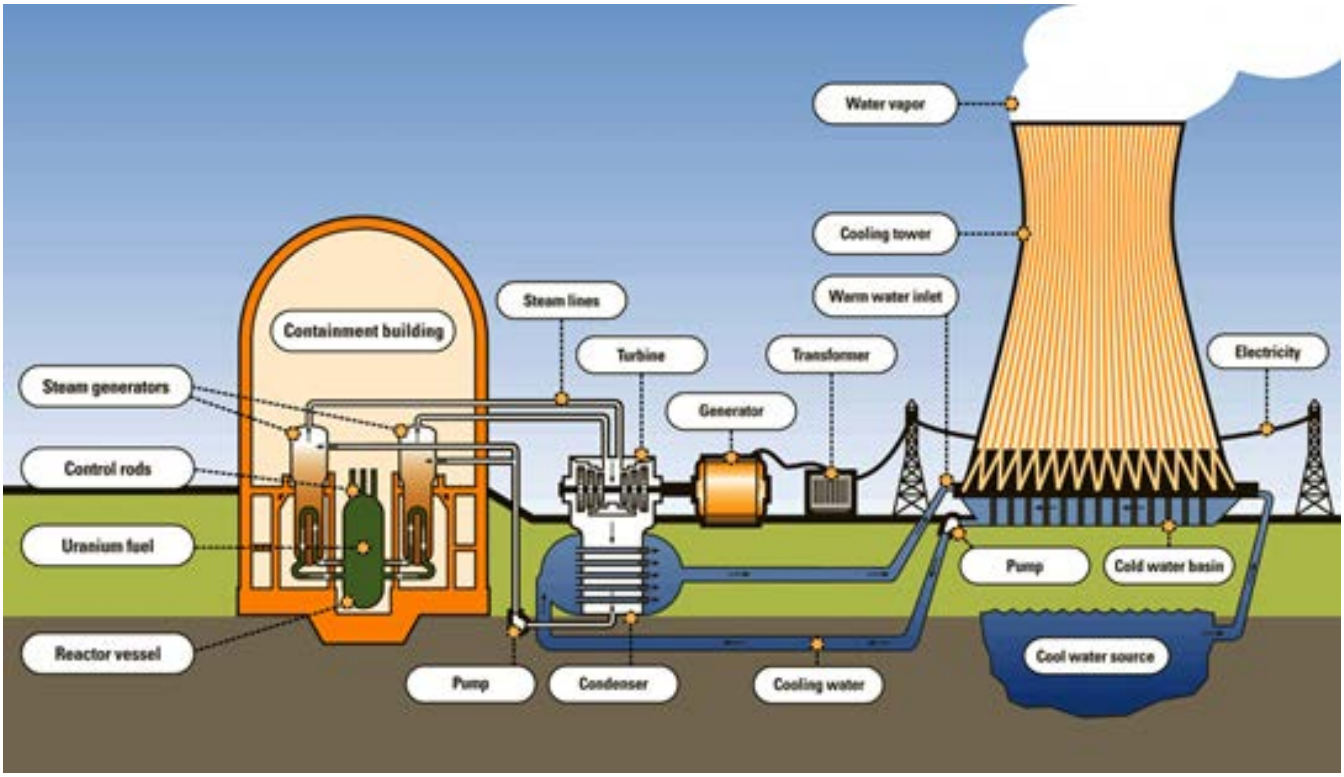


Figure. A nuclear power plant.

1.0 Background

For a country or independent utility aiming to efficiently structure its uranium supply strategy, the key lies in balancing long-term stability with flexibility and risk management. This typically involves securing multi-year supply contracts with established producers to lock in reliable and predictable uranium deliveries, while also maintaining the option to purchase from the spot market to address short-term needs or capitalize on favourable pricing. Diversifying sources—across regions like Kazakhstan, Canada, Australia, and Africa—helps reduce geopolitical risk, and building strategic stockpiles can buffer against global disruptions. Smaller players often benefit from participating in international fuel assurance programs like the IAEA's LEU Bank or engaging in fuel leasing arrangements, which reduce the burden of owning full fuel cycle infrastructure. Additionally, partnering

with fuel fabrication vendors or bundling procurement and fabrication services streamlines logistics. Strategic investments in foreign uranium projects, even as minority stakeholders, can offer preferential access to supply while reinforcing diplomatic and trade relationships. Altogether, a lean but diversified approach combining contracts, diplomacy, and reserves creates a robust, secure, and cost-effective uranium supply chain. Countries that lack domestic uranium resources can still develop efficient and sustainable nuclear power programs through strategic planning and international collaboration. These are the steps that either governments or companies adopt together.

1. Secure Reliable Uranium Supply

Even without domestic uranium, countries can import uranium through long-term contracts with major exporters (e.g., Kazakhstan, Canada, Australia), join international uranium procurement consortia, like the IAEA's LEU (Low Enriched Uranium) Bank, which acts as a fuel reserve and invest in uranium mining abroad to secure stakes in foreign operations (e.g., China in Niger, India in Kazakhstan).

2. Embrace the Nuclear Fuel Cycle Options

To reduce dependency on fresh uranium, the countries can invest in fuel Recycling/reprocessing. Countries like France and Japan reprocess spent fuel to extract usable plutonium and uranium (e.g., MOX fuel), can develop Thorium-based reactors: Thorium is more abundant and some countries (like India) are investing in this alternative nuclear fuel and can build advanced reactors (Gen IV, fast breeder reactors) can use spent fuel or depleted uranium more efficiently.

3. International Cooperation and Partnerships - Government Roles

- Collaborate with experienced nuclear nations for technology, training, and regulatory frameworks. Governments looking to secure partnerships with exporting nations already burdened with full order books can adopt a strategic, multifaceted approach centered around diplomacy, long-term collaboration, and mutual benefit. First and foremost, they can engage in high-level bilateral diplomacy to elevate the importance of the partnership beyond a commercial transaction—framing it within the context of strategic energy cooperation, climate goals, and regional stability. Governments can offer long-term procurement contracts, which provide financial security and production planning advantages for exporters, making the importing country a more attractive and reliable client amidst intense global demand.
- Another key approach is co-investment in upstream supply chains—governments can facilitate or directly invest in mining, enrichment, or fuel fabrication infrastructure in exporting countries, sharing the burden of capital and increasing production capacity. This creates a win-win scenario where exporters gain capacity and funding, while importers secure access. In addition, governments can foster joint Research and Development (R&D) programs, particularly in next-generation nuclear technologies or fuel recycling, further deepening interdependence and positioning themselves as value-adding partners rather than just buyers.
- For countries like Japan or South Korea that rely heavily on imports, technology exchange agreements, skills training programs, and industrial partnerships that support local workforce development in the exporting nation can also be influential. Finally, leveraging multilateral frameworks and trade alliances can help pool demand across countries, offering economies of scale and smoother logistics for exporters already at capacity. Ultimately, the key is to shift the relationship from a transactional supplier-client model to a strategic alliance based on shared investment, innovation, and long-term security of supply.
- Join nuclear energy partnerships like the IAEA, Generation IV International Forum (GIF), and others.

To join international nuclear energy partnerships like the International Atomic Energy Agency (IAEA), the Generation IV International Forum (GIF), and others, a country must demonstrate political commitment, technical readiness, and alignment with global nuclear norms. For the IAEA, membership typically requires being a member of the United Nations and submitting a formal application, which is reviewed by the IAEA Board of Governors and approved by the General Conference. The applicant must also agree to implement nuclear safeguards

and uphold non-proliferation obligations, particularly through the Nuclear Non-Proliferation Treaty (NPT). In the case of the Generation IV International Forum (GIF), membership is reserved for countries that are IAEA and NPT signatories with significant nuclear research and development capabilities. Joining involves signing the GIF Framework Agreement, which outlines cooperation terms, intellectual property rights, and responsibilities in collaborative R&D projects. Similarly, institutions like the OECD Nuclear Energy Agency (NEA) require OECD membership and an advanced nuclear infrastructure, while forums like the International Framework for Nuclear Energy Cooperation (IFNEC) are more open and voluntary, allowing participation from a broader range of nations. Across all these platforms, nations must demonstrate peaceful intentions, establish competent regulatory bodies, invest in human capital, and often engage in bilateral agreements to strengthen credibility. By doing so, they not only gain access to cutting-edge nuclear technologies and research but also play a role in shaping the future of global nuclear governance and energy innovation.

4. Focus on Safety, Waste Management & Public Trust

- Adopt robust nuclear regulatory frameworks.
- Invest in long-term waste storage solutions, possibly regionally shared repositories.
- Launch transparent public outreach to maintain public trust and support.

5. Integrate with Broader Energy Strategy

- Use nuclear as part of a diversified low-carbon energy mix (renewables + nuclear).
- Explore Small Modular Reactors (SMRs) for flexibility and reduced upfront investment.

Example Countries

- **South Korea:** No major uranium deposits, yet a nuclear powerhouse through imports and domestic technology.
- **Japan:** Dependent on imports, but developed reprocessing and recycling infrastructure.
- **Turkey:** Building nuclear plants via international turnkey projects (e.g., Russia's Rosatom building Akkuyu).

2.0 The Mature Cases from Japan and Korea

Japanese and Korean private nuclear power companies have managed to survive and operate effectively despite their heavy dependence on imported fuel and technology through a combination of strategic government support, international partnerships, robust supply chain management, and a focus on innovation and efficiency. In Japan, companies like Tokyo Electric Power Company (TEPCO) and Kansai Electric have historically relied almost entirely on imported uranium, mainly from countries like Australia, Canada, and Kazakhstan. Post-Fukushima, these companies pivoted toward enhancing nuclear safety and investing in global uranium assets through joint ventures and long-term procurement contracts, ensuring supply security despite the lack of domestic resources. Similarly, in South Korea, Korea Hydro & Nuclear Power (KHNP), a subsidiary of KEPCO, has built a vertically integrated approach by developing close ties with global suppliers and investing in overseas uranium mines while establishing strategic stockpiles. The survival and competitiveness of these firms have also been supported by their governments' firm commitment to nuclear energy as a key part of national energy security strategies, recognizing the geopolitical limitations of resource-poor nations. Moreover, both Japanese and Korean companies have capitalized on their engineering excellence and nuclear expertise to diversify into international markets—providing reactor construction, maintenance, and consulting services across the Middle East, Southeast Asia, and Eastern Europe. This outward focus has not only brought in revenue but also reduced the vulnerability of their business models to domestic policy shifts. By leaning into globalization, fostering resilient procurement networks, and aligning with national energy priorities, these private nuclear players have maintained a competitive edge even while being fully dependent on imports for their critical fuel and components. Here's how they typically do it:

2.1 Uranium Trading Market and Dominant Hedging Options for a Large Or Small Buyer

The uranium trading market is unique compared to other commodities like oil or gold. It's smaller, less liquid, and

tightly regulated — but still has room for strategic plays, especially for countries or companies seeking long-term energy security.

Who Controls the Uranium Market?

1. Major Uranium Producers

They control the primary supply:

- Kazakhstan (Kazatomprom) – World's largest producer (~40% global supply)
- Canada (Cameco) – Major producer with large reserves
- Australia – Huge reserves, strict export control
- Others: Namibia, Uzbekistan, Russia

2. Conversion and Enrichment Facilities

Raw uranium (U_3O_8 or "yellowcake") needs to be converted and enriched. Only a few players dominate this midstream segment:

- Orano (France)
- URENCO (EU)
- Rosatom (Russia)
- ConverDyn (USA)

3. Utilities & Governments

Nuclear utilities (e.g., EDF, TEPCO, Exelon) are the main buyers. They often secure uranium through long-term contracts (5–10+ years), insulating them from spot market volatility.

Governments control trade through:

- Export/Import regulations
- Non-proliferation treaties
- Strategic reserves (like the IAEA LEU Bank)

Is There a Spot or Futures Market?

Yes, but it's limited compared to other commodities.

4. Spot Market

- Traded as U_3O_8, priced in USD per pound.
- Platforms: UxC, TradeTech, and brokers.
- Mostly used for short-term needs or price discovery.

5. Futures Market

- NYMEX/COMEX used to have uranium futures, but low liquidity made them unattractive.
- No dominant futures market today — most uranium is not traded on open exchanges, but through bilateral, long-term contracts.

Hedging Options

For Large Buyers (utilities, governments)

- Long-term supply contracts (main strategy)
- Portfolio diversification (multiple suppliers & jurisdictions)
- Stockpiling/reserves (buy when prices are low)
- Vertical integration (invest in or partner with miners, e.g., China General Nuclear)

For Smaller Buyers or Traders

- Spot market purchases via brokers (e.g., Numerco, Yellow Cake Plc)
- Offtake agreements (smaller scale, but stable)
- Investment vehicles like:
- Uranium Participation Corp (now Sprott Physical Uranium Trust)
- Yellow Cake Plc – holds uranium as a commodity asset

But traditional commodity hedging tools (like put/call options or commodity swaps) are rare or bespoke due to the market's illiquidity and regulatory complexity.

Table 1. Summary of options

Factor	Uranium Market
Liquidity	Low
Price Discovery	Via spot (UxC/TradeTech), mostly opaque
Hedging Tools	Limited (long-term contracts > financial tools)
Dominant Forces	Kazakhstan, Cameco, enrichment oligopoly
Best Play for Buyers	Contracts, partnerships, strategic stockpiling

2.2 Instances of Plant Shutdown due to the Stoppage or Disruption of Imported Uranium

Although reactor fuel stocks are generally managed to avoid outages, there have been notable cases where imported uranium disruptions forced prolonged shutdowns or delays. In India, the two 150 MWe Tarapur boiling-water reactors—dependent on Russian supplied enriched uranium since 2001—were forced offline for roughly six months in 2005–06 after Moscow deferred further shipments under the Nuclear Suppliers Group framework, only resuming deliveries once contracts were renegotiated World Nuclear Association. More broadly, India's overall nuclear fleet saw capacity factors plunge from over 85% in 2001–02 to around 40% in 2008, a

slump directly attributed to chronic uranium shortages before new domestic mills came online World Nuclear Association. Even advanced technology projects have felt the pinch: in December 2022, Bill Gates's TerraPower "Nat-rium" demonstration reactor in Wyoming was delayed by at least two years because its specialized HALEU fuel—sourced only from Russia at the time—became unavailable in the wake of sanctions and export restrictions Data Center Dynamics.

These examples underscore that, despite heavy reliance on multi-year stockpiles and diverse procurement channels, disruptions in uranium imports can still translate into substantial operational setbacks when alternate supplies are not immediately accessible.

2.3 Role of Core Competence

In the nuclear fuel cycle, the surest way to break foreign-enrichment dependence is to combine a home-grown enrichment capability (e.g. high-speed gas centrifuges or next generation laser isotope separation) with reactor designs that can breed and recycle their own fuel—most notably Integral Fast Reactors (IFRs) using on site pyro-processing or molten salt reactors operating on the thorium cycle. By enriching uranium domestically, then feeding it into a reactor that converts fertile isotopes (U 238 or Th 232) into fissile material (Pu 239 or U 233) and reprocessing spent fuel in house, a country can effectively "close" its fuel cycle. Add to that emerging techniques like uranium extraction from seawater and standardized Small Modular Reactor (SMR) fuels, and you create a truly diversified, sovereign supply chain that sidesteps geopolitical bottlenecks in imported fuel.

How might a small country or an independent utility structure its uranium supply strategy efficiently?

For a small country or independent utility aiming to efficiently structure its uranium supply strategy, the key lies in balancing long-term stability with flexibility and risk management. This typically involves securing multi-year supply contracts with established producers to lock in reliable and predictable uranium deliveries, while also maintaining the option to purchase from the spot market to address short-term needs or capitalize on favourable pricing. Diversifying sources—across regions like Kazakhstan, Canada, Australia, and Africa—helps reduce geopolitical risk, and building strategic stockpiles can buffer against global disruptions. Smaller players often benefit from participating in international fuel assurance programs like the IAEA's LEU Bank or engaging in fuel leasing arrangements, which reduce the burden of owning full fuel cycle infrastructure. Additionally, partnering with fuel fabrication vendors or bundling procurement and fabrication services streamlines logistics. Strategic investments in foreign uranium projects, even as minority stakeholders, can offer preferential access to supply while reinforcing diplomatic and trade relationships. Altogether, a lean but diversified approach combining contracts, diplomacy, and reserves creates a robust, secure, and cost-effective uranium supply chain.

Can a nuclear power private company survive without government support?

A private company can survive in the uranium or nuclear fuel market without direct government support, but it's extremely tough, and in most cases, some level of government involvement or alignment is essential, especially for long-term viability.

What Kind of Private Companies?

There are different types of private players in the uranium/nuclear space:

1. Uranium mining/exploration companies – e.g., NexGen, Denison Mines

2. Traders/brokers – e.g., Numerco, Yellow Cake Plc, Sprott Physical Uranium Trust

3. Fuel cycle tech startups – like companies working on SMRs or advanced reactor fuels (e.g., Oklo, TerraPower)

4. Service providers – transport, conversion, enrichment, waste, etc.

The need for Government Support?

Where They Can Be Independent:

- Exploration/mining juniors can raise private capital (especially during a uranium bull market).
- Trading firms can operate based on market conditions, using private funds to hold physical uranium as a commodity.
- Fuel tech companies can attract VC and strategic investors (e.g., Bill Gates backing TerraPower).

Where Government Support Becomes Critical

1. **Licensing & Regulation**

a. Nuclear = heavily regulated.

b. Companies need permits for mining, transportation, enrichment, and storage.

c. No private company can operate without regulatory approval (often backed by government policy frameworks).

2. **Market Access & Long-Term Demand**

- Most uranium is bought by state-influenced utilities.
- Private players struggle to lock in revenue unless governments or large public utilities are on board.

3. **Geopolitical Risk Mitigation**

1. Uranium trading is politically sensitive.
2. Governments often intervene in times of crisis (e.g., sanctions on Russia, export controls).
3. A private company needs to navigate this world — usually with diplomatic or policy backing.

4. **Capital Intensity & Risk**

- Projects are long-term and capital-heavy.
- Banks and investors often require risk-sharing or guarantees from public bodies.

Smart Survival Strategies (Without Direct Subsidies)

A private player can survive if it:

1. Focuses on niche roles (e.g., fuel innovation, modular reactors, trading).
2. Builds strategic alliances with utilities or state-backed companies.
3. Raises private equity or uses public market instruments (e.g., Yellow Cake Plc on LSE).
4. Keeps a low-cost structure and avoids heavy capex unless it has offtake agreements.

Real-World Example

1. Sprott Physical Uranium Trust (SPUT): Privately run fund that buys and holds uranium — no government support, but thrives on market speculation and investor interest.
2. Oklo (USA): Trying to build micro-reactors — privately funded, but must work within DOE regulations and needs fuel from government stockpiles.

Bottom Line

A private company can survive, especially if it's small, agile, and innovative. But to scale, enter nuclear fuel production, or secure long-term contracts, some level of government alignment, approval, or partnership is almost always necessary.

(Note: this is an excerpt of a detailed article. The detailed article will be published in the Journal of Power and Development (https://www.informaticsjournals.co.in/index.php/ijprvd)