

Our latest Utilities updates



India set to embrace nuclear energy - II

- We recently published a report on the emerging nuclear landscape in India titled ‘India set to embrace nuclear energy’ ([link](#)), where we discussed: 1) the global nuclear energy landscape (an installed capacity of ~399GW by 2024-end); 2) India’s nuclear capacity ambitions of 22GW by 2032 and 100GW by 2047, along with two pathways—conventional and Small Modular Reactors (SMR); and 3) NTPC as the bellwether play for nuclear energy, with projects under planning entailing a total capex of INR1.5t, while private operators such as TPWR and Jindal Nuclear could also take advantage of opportunities in the nuclear space.
- In the second part of this series, we delve into: 1) a comparative analysis of capex and tariffs (INR/kWh) for nuclear vs thermal/solar/wind/hybrid energy sources, evaluating their economic viability; 2) the legal and financial complexities associated with nuclear power, which have been key hurdles to increasing investment in the sector; 3) the challenges related to uranium procurement, geopolitical dependencies, and the risks of time and cost overruns; and 4) the potential for private operators such as Adani Power, Reliance Industries, Vedanta Group, TPWR, and Jindal Nuclear to invest in nuclear power.
- Our key conclusions: 1) capex for conventional nuclear is ~INR180m/MW, with tariffs ranging INR7-8/kWh; 2) nuclear is a long-term solution that addresses the issue of base load supply; 3) we believe private capex in nuclear will take the SMR route, with sizeable commercial investment likely a few years away; 4) clarifying nuclear liability regulations will help advance stalled projects, enhance clean energy capacity, and align India with global advancements in SMRs; 5) uranium supply could emerge as a challenge, as over 50% of global uranium supply is processed by just three countries; 6) the World Nuclear Association (2023) projects a 28% rise in uranium demand by 2030; 7) In India, the Civil Liability for Nuclear Damage Act (CLNDA) places primary liability for nuclear accidents on NPCIL, capping it at INR15b, which we believe could be grossly inadequate in the event of a disaster.

Tariff comparison: Nuclear expensive but addresses base load supply issue

- Electricity costs in India vary significantly depending on the energy source, as shown in this tariff comparison (INR per kilowatt-hour). Solar power leads as the most economical option at INR2.5-2.7/KWh, followed by onshore wind at INR3-3.5/KWh. Hybrid ranges from INR3.2 to 3.6/KWh, while FDRE stands at INR4.5-5/KWh. Thermal power costs INR5-6/KWh.
- Conventional nuclear power is currently the most expensive at INR7-8/KWh. While it is more expensive than plain vanilla solar/wind, it does address the issue of renewables’ inability to meet base load supply requirements.

Exhibit 1: Average tariff by source (India)

| Technology | Tariff (INR/kWh) |
|------------------------|------------------|
| Solar | 2.5-2.7 |
| Onshore Wind | 3-3.5 |
| Hybrid | 3.2-3.6 |
| Thermal | 5-6 |
| Nuclear (Conventional) | 7-8 |
| FDRE | 4.5-5 |

Source: MOFSL

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Capex comparison: Conventional nuclear power leads at INR180m/MW

- In India, the average capital expenditure for power generation varies widely by technology. Solar costs the lowest at INR50m/MW, followed by onshore wind at INR65m/MW, hybrid renewable systems at INR55m/MW, thermal at INR120m/MW, and nuclear the highest at INR180m/MW. These costs are key considerations for any power project development.

Exhibit 2: Average capex per MW by technology (India)

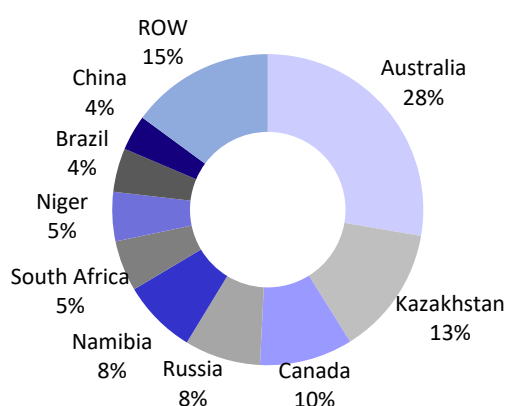
| Technology | INRm/MW |
|------------------------|---------|
| Solar | 50 |
| Onshore Wind | 65 |
| Hybrid | 55 |
| Thermal | 120 |
| Nuclear (Conventional) | 180 |

Source: MOFSL

Over 50% of global uranium supply processed by just three countries

- Uranium exploration, like R&D, is a high-risk, high-reward venture. Successful exploration identifies mineable deposits, which are then processed into nuclear fuel. Recoverable uranium resources are categorized by uranium production costs, with the highest cost bracket being <USD60/kgU (7.9mt as of 2021).
- **Resources costing up to USD130/kgU are considered the most economically viable and, therefore, the most favorable.** Global identified recoverable uranium resources, within the <USD130/kgU cost category, **amounted to 6.1mt in 2021.**
- However, this supply is heavily concentrated, with **three countries possessing more than 50% of the total.** Despite uranium mining taking place in ~20 countries, in 2022, over half of the world's uranium came from just 10 mines in five countries.

Exhibit 3: Identified recoverable (<USD130/kgU) Uranium resources- ~6.1mt (as of 2021)



Source: World Nuclear Association, MOFSL

Exhibit 4: Largest Uranium producing mines in 2022

| Mine Name | Main Owner(s) | Production (tons U) | % of World |
|--------------------------------------|--------------------------|---------------------|------------|
| Cigar Lake, Canada | Cameco/ Orano | 6,928 | 14 |
| Husab, Namibia | Swakop Uranium (CGN) | 3,358 | 7 |
| Inkai, sites 1-3, Kazakhstan | Kazatomprom/ Cameco | 3,201 | 7 |
| Olympic Dam, Australia | BHP Billiton | 2,813 | 6 |
| Karatau (Budenovskoye 2), Kazakhstan | Uranium One/ Kazatomprom | 2,560 | 5 |
| Rössing, Namibia | CNNC | 2,255 | 5 |
| SOMAIR, Niger | Orano | 2,020 | 4 |
| Four Mile, Australia | Quasar | 1,740 | 3 |
| Central Mynkuduk, Kazakhstan | Ortalyk | 1,650 | 3 |
| South Inkai 4, Kazakhstan | Uranium One/ Kazatomprom | 1,600 | 3 |
| Top 10 Total | | 28,125 | 57% |

- Global nuclear power, with a capacity of roughly 400GWe, **requires about 67,500t uranium annually**, which is fulfilled by both primary and secondary sources.
- Current primary global uranium resources (6.1mt) are **projected to last ~90 years with conventional reactor use**, which is a robust reserve compared to other minerals. Further exploration and higher prices are expected to unlock additional resources. Advancements in uranium enrichment and spent fuel reprocessing have **improved fuel efficiency, reducing industry-wide consumption from 175 to 160t/GWe annually**. This is evident in the fact that while nuclear electricity generation increased 3.6-fold between 1980 and 2008, uranium consumption only increased 2.5-fold due to factors like higher fuel burn-up.
- **Secondary uranium supplies currently contribute the equivalent of about 12,000t annually**. Major sources of secondary uranium include the decommissioning of US and Russian nuclear warheads, government and utility stockpiles, and depleted uranium from past enrichment (which can be re-enriched). A small amount also comes from recycled uranium from reprocessing.
- Each **additional GWe of nuclear capacity requires about 150t of uranium annually for routine operation and 300-450t for the initial fuel load**. While reactor efficiency gains slow the growth rate, overall uranium demand continues to rise. The World Nuclear Association's 2023 Nuclear Fuel Report **projects a 28% increase in uranium demand from 2023 to 2030, driven by an 18% rise in reactor capacity. From 2031 to 2040, demand is projected to increase by 51%**. Plant lifetime extensions and the economic viability of older reactors will significantly influence the medium-term market.
- The price of natural uranium has been volatile in recent years. After a period of low prices of around USD30/lbs in 2019, it surged to over USD100/lbs in early 2024 before dropping back below USD80/lbs by the end of the year. The current price, as of Feb'25, is ~USD65/lbs.

Exhibit 5: Uranium SPOT prices (USD/lbs)


Source: Bloomberg, MOFSL

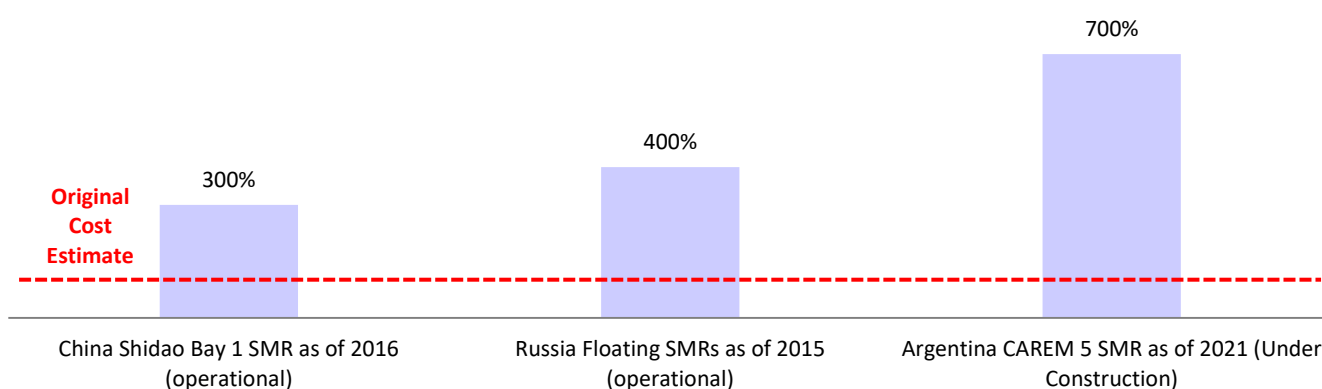
Amendments to CLNDA: a focus on private investment

- As part of the 2025-26 Union Budget, the Finance Minister proposed amendments to the Civil Liability for Nuclear Damage Act (CLNDA), 2010, and the Atomic Energy Act (AEA), 1962, to encourage private investments in India's nuclear energy sector.
- The CLNDA assigns primary liability to the operator (NPCIL), with a cap of INR15b. According to a [media article](#), India's existing nuclear liability laws have discouraged private investment in the sector. This is largely due to concerns regarding Section 17(b) of the CLNDA, which grants operators the [right to recourse](#) against suppliers when a 'nuclear incident has resulted as a consequence of an act of the supplier or his employee, including the supply of equipment or material with patent or latent defects, or sub-standard services'. This provision has been a major deterrent.
- According to Section 7(1)(a) of the Act, any liability beyond the INR15b limit, up to the equivalent of 300m SDRs, will be covered by the Central Government. For claims exceeding this amount, India can access international funds under the Convention on Supplementary Compensation for Nuclear Damage (CSC).
- However, given the scale of funding that may be required in the event of a mishap, we believe the current liability regime may need a complete overhaul. For instance, according to the Board of Audit of Japan, ~¥12.1t (USD82b) has been expended to address the aftermath of the 2011 Fukushima Daiichi nuclear disaster ([Link](#)), which includes expenses related to compensation payments, reactor decommissioning, and decontamination efforts. These expenditures reflect the substantial financial burden incurred over 11 years following the nuclear meltdowns, underscoring the long-term economic and environmental challenges associated with such a disaster.
- According to the [article](#), India's low nuclear liability cap is not the main deterrent to private investment; rather, it is the ambiguity surrounding the law. Uncertainty regarding the application of other laws to suppliers, enforcing recourse, CLNDA's compatibility with the CSC, and potential cap revisions create a challenging environment.
- Amendments will help advance stalled nuclear projects, such as Westinghouse's AP1000 reactors and EDF's Jaitapur plant, which could substantially increase India's clean energy capacity. India's focus on SMRs aligns with global trends, offering modular and cost-effective nuclear solutions. Collaborations with the US and France on nuclear energy will enhance India's technological expertise, diversify its energy portfolio, and reduce reliance on fossil fuels.

SMR development has been complex with recurring time delays

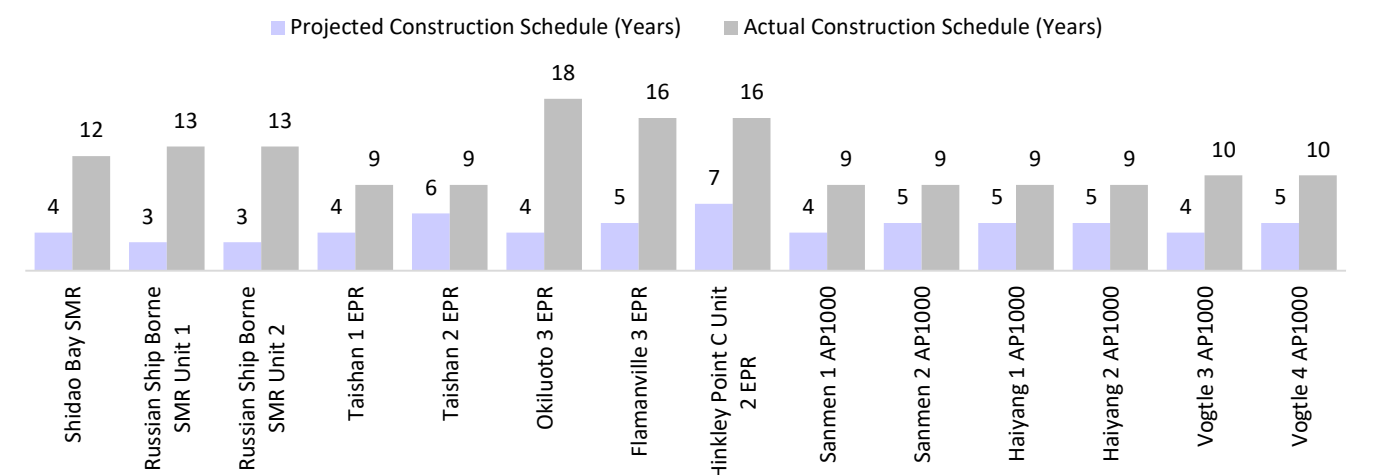
- The future of nuclear power depends on the efficient and timely construction of reactors. Construction delays and cost overruns pose a threat to competitiveness. Unfortunately, the few SMRs that have been built or are under construction suggest a concerning trend: they face the same significant delays and escalating costs that have affected traditional reactor projects.
- Actual construction costs have far exceeded projections. By 2015, Russian SMR costs had tripled initial estimates and likely escalated further by the time of their commissioning in 2019. China's Shidao Bay SMR also tripled its projected cost. Argentina's CAREM 25 reactor saw a 600% cost surge. US projects face similar issues: NuScale's costs doubled, resulting in the cancellation of projects. Both X-Energy and GE-Hitachi have also experienced significant cost increases before construction.

Exhibit 6: SMR cost overruns



Source: IEEFA, MOFSL

- The development process, including design, licensing, scaling, and testing, is complex and historically susceptible to delays and added expenses. Further, the idea that SMR costs will decrease with mass production is debatable. With numerous competing designs (~80), it is unclear if any single design will achieve the necessary scale to drive down costs.
- Additionally, existing SMR projects in Russia, China, and Argentina have consistently faced significant delays, far exceeding initial projections of three to four years. Even newer projects are falling behind schedule, leading to further postponements and a rise in costs.

Exhibit 7: Nuclear construction gap between promise and delivery (years)


Source: IEEFA, MOFSL

- Strategic partnerships between public and private sector companies, including international collaborations, can help share risks and leverage expertise. Transparent cost management, using robust methodologies and lifecycle tracking, ensures accountability. Success hinges on long-term R&D commitment, learning from experiences, and market adaptation. Limiting designs, rigorous testing, and collaborative efforts are key to SMR competitiveness.

NTPC's growing role in India's nuclear energy sector

- According to a [media article](#), NTPC is embarking on a major nuclear expansion, with plans to add 10GW of capacity in the next 10 years. This INR1.5t investment highlights the company's commitment to nuclear energy as a key driver of its long-term sustainable growth.
- In Sep'24, the government approved Anushakti Vidhyut Nigam Ltd. (ASHVINI), a joint venture between NPCIL (51%) and NTPC (49%), to build, own, and operate nuclear power plants in India, in compliance with the Atomic Energy Act.
- Planned projects under ASHVINI include the Chutka (Madhya Pradesh, 2x700 MW) and two new PHWR facilities to boost India's fleet-mode nuclear capacity ([Link](#)). The transfer of the Mahi Banswara Rajasthan Atomic Power Project (MBRAPP), a 4*700MW project using indigenous PHWR technology, from NPCIL to ASHVINI will further boost NTPC's nuclear project pipeline.
- While NTPC may continue to partner with NPCIL for conventional nuclear projects, the company incorporated a wholly-owned subsidiary, NTPC Parmanu Urja Nigam Limited (NPUNL), in Jan'25, with the goal of commercially developing nuclear energy for electricity generation and other uses.
- As NTPC gains experience in managing nuclear projects, NPUNL may emerge as a key vehicle for undertaking nuclear energy projects in the future.

Private sector participation contingent on technological evolution

- Private sector participation in conventional nuclear projects remains constrained due to pending amendments to the Atomic Energy Act and the Civil Liability for Nuclear Damage Act. While the Union Budget has proposed amendments to facilitate private players' involvement, their engagement may

remain limited due to the substantial capital investment required and the long gestation period associated with such projects.

- NPCIL, both independently and through its subsidiaries, is projected to contribute ~50% of the government's target of building 100GW of nuclear energy by 2047. The state-owned entity will primarily leverage its indigenous technologies while remaining open to foreign collaborations, provided such partnerships offer large capacities at competitive costs.
- Private players such as Tata Power, Adani Power, Vedanta, Reliance, and Jindal Nuclear have shown interest in the nuclear space.
- **Tata Power** is exploring diversification into the SMR segment while considering the divestment of USD1b in non-core international assets. The company is actively evaluating opportunities in the nuclear sector, contingent on forthcoming policy directions and amendments to the Atomic Energy Act, which will determine the regulatory framework for private players' participation in SMRs and nuclear reactors.
- **Jindal Group** established Jindal Nuclear Power Private Limited, aiming for 18GW capacity, utilizing advanced technologies like SMRs and BSRs.
- **Vedanta Group** is inviting bids from global firms to develop 5GW of nuclear power capacity in India for captive use ([Link](#)).
- **Reliance Industries** intends to develop nuclear energy in Assam ([Link](#)), aligning with the government's push for private involvement.
- **Adani Power** is planning to develop 30GW of nuclear power capacity ([Link](#)) with the goal of transitioning its entire thermal power portfolio to nuclear energy in the coming years.

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|----------------------------------|--|
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